INTRODUCING THE GAME DESIGN MATRIX: A STEP-BY-STEP PROCESS FOR CREATING SERIOUS GAMES

THESIS

Aaron J. Pendleton, Captain, USAF

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DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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Aaron J. Pendleton, B.S.

Captain, USAF

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Aaron J. Pendleton, B.S.
Captain, USAF

Committee Membership:

James Okolica, Ph.D.
Chair

Gilbert Peterson, Ph.D.
Member

Mark Reith, Ph.D.
Member

AFIT-ENG-MS-20-M-054

Abstract

The Game Design Matrix (GDM) was developed to make effective game design accessible to novice game designers. Serious Games are a powerful tool for educators seeking to boost the level of student engagement and application in academic environments, but they can be difficult to incorporate into existing courses due to availability and the cost of quality game design. Traditional serious game design is centered around an experienced or aspiring game designer with a particular vision for a game. This places educators in a situation where they recognize the value of serious games, but they cannot effectively create one without a significant investment in their development as a designer. GDM uses a game dynamics focused approach to scaffold novice game designers through the selection of game elements and incorporation of learning objectives to guide designers during the most challenging phase of creating a game. Case study games were designed by novices using GDM, and then tested in live classroom environments to assess the level of efficacy achieved through this new methodology. A qualitative assessment of the step-by-step GDM game design framework through these case study games yielded an effective and engaging series of serious games designed to teach elements of cybersecurity and software engineering graduate courses. The results of the games created by GDM to this point strongly indicate that GDM provides a scaffolding for novice designers to create an effective game. Furthermore, GDM games have been play-test ready in about twenty hours of design time. This is a marked improvement over games designed by novices in the literature review, which took longer to create and were consistently ineffective.

This work is dedicated to my family. Thank you for all you do!

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I would like to express my sincere thanks to my fellow classmates for their support, camaraderie, and talent for making hard work a lot more fun. In a similar manner, this thesis would not have been possible without the help of my advisor, Dr. Okolica. Meeting with him and discussing the potential applications of this research was extremely helpful, but it was his insight into the life of a student and encouragement that it would all be worth it in the end that I found to be particularly inspiring. The faculty of the GCO program consistently surprised me with their student oriented policies and time they took to get to know us. This was deeply appreciated and made my experience at AFIT very positive. Lastly I would like to thank my wife. Her loving support and patience made the irregular hours and late nights of grad school a much happier time.

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INTRODUCING THE GAME DESIGN MATRIX: A STEP-BY-STEP PROCESS FOR CREATING LEARNING OBJECTIVE BASED SERIOUS GAMES

I. Introduction

1.1 Background and Motivation

Serious Games are a powerful tool for educators seeking to boost the level of student engagement and application in academic environments, but they can be difficult to incorporate due to availability. The level of game expertise and knowledge required in order to design a game with playable mechanics and well integrated learning objectives can be overwhelming, and outsourcing a serious game can be both difficult and expensive. Traditional serious game design is often centered around an experienced or aspiring game designer with a particular vision for a game. This places educators in a situation where they recognize the value of serious games, but they cannot effectively create one without a significant investment in their development as a designer. The product of a novice game designer is often a near clone of an existing game with learning elements incorporated at peripheral level [7]. Constructing a serious game from its basic elements takes much longer to design and implement.

The Game Design Matrix (GDM) approaches this problem from two directions in order to make game design more available to novice game designers, specifically those in an education role, with expertise in the subject matter of the game's learning objectives. This brings additional resources to classrooms and education courses which do not have the resources to bring in game design experts. Additionally, GDM seeks to decrease the time it takes to develop games in order to make them more

comparable to other classroom exercises.

1.2 Problem Statement

The United States Air Force Air Education and Training Command (AETC) issued a strategic plan outlining the need for additional games within the Air Force education and training construct [12]. There is currently no game design framework that enables educators to easily and effectively create serious games centered on learning objectives. It has been shown that designing serious games requires both technical acumen and an element of creativity that is difficult to quantify [7]. This makes serious game design a challenge without adequate experience working with the interaction of game elements. Research in games design is not centered around serious games, but many concepts of traditional game design carry over into serious game design. Traditional game design frameworks such as the Mechanics, Dynamics, and Aesthetics (MDA) [1] model discussed in Chapter II advocate for construction of mechanics, followed by dynamics. The adaptation of traditional (non-serious) game design frameworks to serious games leads to serious game design frameworks which do not base designs on a learning objective. As a result learning objectives are often incorporated primarily as adjuncts. Novice game designers have been shown to struggle [7] with incorporating learning objectives when designing the basic structure for a serious game. This results in the addition of learning elements at a later stage in design. GDM presupposes that learning objectives are most directly applicable to game dynamics. Many current game design methodologies such as the Design and Integration of Collaborative Classroom Games (DICCG) [3] model explored in Chapter II do not directly target learning objectives in this manner. This shortcoming in the state of the art prevents educators from designing effective games quickly and effectively.

1.3 Assumptions and Limitations

- Well-designed serious games are an effective tool in the selected applications
- The assessment of GDM is limited by current serious game assessment methods
- The output of a design framework is still extremely reliant on the designer

1.4 Research Objectives

The intent of this research is to develop and assess a serious game design framework that targets multiple objectives.

- Introduce novice designers to the core elements of game design in a framework that is approachable and can be employed by a user with no previous game design experience.
- Create a dynamics driven game design methodology to allow the designer to more accurately model the elements of application in higher-level learning objectives.
- Allow a designer to target specific levels of Bloom's taxonomy in order to match the game design to desired levels of learning outcome
- Decrease the time required for a novice to create an effective game by scaffolding the initial phase of game design.
- Increase baseline efficacy of games designed by novices targeting higher-level learning objectives

The questions to be answered by this research in order to meet the aforementioned objectives are as follows:

- Are the games designed using the Game Design Matrix effective as an education tool?
- Are games designed using the Game Design Matrix playable, and do they include well developed learning objective implementation?
- Do novice game designers benefit from shorter design times when the Game Design Matrix is employed?
- To what extent does GDM improve the overall efficacy of serious games designed by novices?

1.5 Hypothesis

The basic elements of the design of a serious game include mechanics, dynamics, and learning objectives. These elements are the most challenging portion for a novice game designer to select. A step-by-step game design framework which creates a scaffold to guide the novice designer can increase the effectiveness of serious games from a level determined to be insufficient, to a level which can be shown to be effective in a classroom environment.

1.6 Approach

This research takes the basic elements of game design as defined by MDA [1] and develops a step-by-step guide that can be implemented by a novice game designer that is attempting to create a serious game with specific learning objectives. The key steps in this process are identification of desired learning outcome, environmental elements that can effect the design, and the real life applications the game seeks to replicate in order to select game dynamics and mechanics. Several tools are created to improve the consistency of novice game designs including an association of game dynamics to

a level of Bloom's taxonomy, a mapping of game dynamics to game mechanics which can be selected to create the dynamic, and a process diagram for designing serious games. The GDM process is assessed by creating case study serious games that are played in live classroom environments that have learning objectives which match the design specifications of the games.

1.7 Contributions

Targeting higher level learning objectives is notoriously difficult. Education and training developed by the DOD has attempted to use gamification or serious games, but at significant cost. This research targets educators that do not have the budget to outsource the design of a serious game. The contributions of this thesis to the field of serious game design are distinct and novel. The current state-of-the-art recognizes that novice game designers are severely impaired when they attempt to design a serious game due to the complexity of the involved elements and the liberty that most design frameworks give to designers [7]. This methodology increases the guidance and structure of design frameworks to provide a new type of design process which removes several stumbling blocks to inexperienced designers. Specific areas of research furthered by this thesis are defined below.

- Enables novice game designers and accessibility of serious games
- Created inclusive list of serious game dynamics
- Associates game dynamics with levels of Bloom's taxonomy
- Proposes dynamics driven game design for novice game designers
- Proposes activity-model based game design methodology
- Creates scaffolding for game designers including all basic game elements

- Step-by-step game design guide allowing self-contained game design

1.8 Results

Novice game designers who were subject matter experts in the material used as the topic of the game created two case study games designed using pre-determined learning objectives from active classrooms using GDM. These games were played by students, and the data collected shows that the efficacy of the game exceeded the results seen previously in games designed by novices. Each game was observed to be as effective as a lecture and in many cases more effective when classroom engagement and interaction is considered. Each game was considered playable, and while feedback was collected to improve each game in further iterations, the games were all in a state of maturity appropriate for educational play. The design time for each game took approximately 20 hours from conception to the first play test. The overall assessment concluded that each case study game was effective. This is a measurable improvement over the previous research conducted using a state of the art serious game design framework and novice game designers.

1.9 Organization

This thesis is organized as follows:

Chapter II introduces the basic elements of serious games, serious game design, and a background overview of both learning tools and the cyber risk elements needed to construct the case study serious game.

Chapter III presents the methodology of the Game Design Framework in its latest state following an iterative development cycle. Following the completion of each case study game the framework is assessed and updated. This chapter outlines and introduces assessment methods.

Chapter IV lists results of playing the case study games in a classroom environment, the interview results from the designers providing qualitative feedback on the efficacy of the design scaffolding, and the results of the game analysis performed by game design experts.

Chapter V presents a summary of the work and the contributions to the field. It also presents recommendations for those utilizing similar tools or frameworks. Future work areas for this research involve improvements to the presentation media of the guide, upgraded mappings, and other additional assessment efforts.

II. Background and Related Work

2.1 Overview

This chapter provides background information on serious games as an alternative instructional method that can be applied to both lower and higher level education. It reviews fundamental challenges to existing education methods such as classroom engagement and targeting higher-level learning objectives which are pervasive in both lecture and non-lecture based teaching styles. The intent is to show serious games can be an effective method of training and education which can mitigate these challenges and allow for specific lesson objectives.

Serious games are highlighted as a teaching method with flexible implementation. Developed out of traditional games, serious games now comprise a unique field of research. With an understanding of serious games, this chapter explores the state of the art in serious game components, design frameworks, and design methodology. One such methodology is the Mechanics, Dynamics, and Aesthetics (MDA) model [1]. This is used to identify the prerequisite research needed for chapter 3.

Current tools for creating learning objectives are identified. These methods are designed around the specific challenges of education and optimized for a serious game application using Bloom's Taxonomy. It is the role of the instructor/teacher to create learning objectives based on an education based requirement.

Finally, an overview of state of the art serious game assessment methods is introduced to provide foundation for the qualitative analysis of serious game performance in Chapter 4, as well as review methods used previously to assess game design frameworks. Additionally, an introduction to the basic principles of cyber risk analysis and assessment methods is reviewed for use in designing the flagship case study game, Enterprise.

2.2 Alternatives to Traditional Lecture-Based Teaching Methods

Interactive teaching methods can outperform traditional lectures in multiple education disciplines, and non-lecture based teaching methods can be viably employed to increase the overall engagement of a classroom [13]. An examination of interactive teaching methods yields several underdeveloped areas to include flipped classroom and game-based learning.

2.2.1 Flipped Classroom

Bishop [13] lays out the primary goals and unique attributes of the flipped classroom model through a survey of available publications in 2013. He identifies several teaching methods incorporated by the flipped classroom method such as Project and Problem Based Learning (PBL), Cooperative and Collaboration Based Learning, and Peer Assisted Learning. The use of these techniques rather than an in-class lecture focus establishes the cornerstone of the flipped classroom framework. This is typically implemented by assigning guided learning videos to students in order to develop their basic knowledge outside of the classroom, and then challenging them to understand, analyze, and apply that knowledge inside the classroom. Bishop writes with a perceivable passion for the flipped classroom construct and presents a relatively compelling argument for its effectiveness based on the merits of increased engagement and interaction with students. Bishop argues that student-centric activities with teachers acting as facilitators or guides encourages active learning with much higher levels of engagement. However, he does not overcome several easily identified challenges and counter arguments, such as, good teachers create engaging classrooms, which have been noted in similar survey papers such as Karabulut-Ilgu [14].

The lack of long term studies creates further knowledge gaps in the flipped classroom field. Of the Bishop-surveyed studies only one spanned an entire semester of

flipped classroom study. Within the shorter studies there is no measure of the work required of the traditional lecture model students outside of the lecture time. This leaves the possibility that students are spending more time on the flipped classroom material and could negatively impact the efficiency. This leaves open the question of the relevance of the flipped classroom construct to an entire class versus a single assignment. As presented, the research is encouraging, but not concrete. For researchers interested in pursuing the flipped classroom model, there is still a substantial shortage of papers with measurable and repeatable results [13]. Karabulut-Ilgu confirms the lack of development in the field and attributes this to difficulty in creating quantitative methods of analysis. Furthermore, the positive effects of the flipped classroom construct are contingent on the quality of the theoretical framework they are based upon. This is yet another area of flipped classroom development that is in need of additional research and longer term experimentation.

2.2.2 Project and Game-Based Learning

Ho[15], advocates for the classification of Game-Based Learning (GBL) and game style teaching underneath the PBL method. PBL is regarded as activity based learning that engages students by involving them in projects that they can personally relate to or find meaning in [15]. The argument for classifying Serious Games (as a subset of GBL) under the umbrella of PBL and the Flipped Classroom is based on virtue of the consistent, repeatable, and fair nature of games. Serious games are uniquely suited to providing a controlled and managed introduction to the application of newly learned concepts [15].

2.3 Serious Games

This section introduces the concept of a "serious" game and its development into digital games. The effectiveness of serious games is explored both inside of a formal learning environment and as a commercial product.

2.3.1 Origin of Serious Games

The concept of the "Serious Game" was introduced by Clark Abt in 1970 as a method of engaging students who struggled to relate the implications of abstract concepts learned in school with familiar daily situations. He maintains that the balance of analytic thought and emotional engagement of game-play provides an accurate metaphor for real-life scenarios.

Susi [16] identifies the next generation of serious game development beginning with the emergence of the Serious Games Initiative (SGI) in 2002. A shortcoming of Abt's work is the absence of a tangible definition for the scope of what qualifies as a Serious Game. Abt confines the term serious games to games which have "an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement". Many attempts to define Serious Games at a less abstracted level debate whether Serious Games must be computer based and whether they must be fun. Michael and Chen propose that the point of serious games is to get players to learn something, and if possible, have fun in the process. They further clarify that serious games do not have entertainment, enjoyment, or fun as their primary purpose. As such there is very little new material introduced from the original specifications introduced by Abt. With this in mind, Susi reiterates that it is necessary to recognize that games, including serious games, must be inherently engaging. It is this multidimensional aspect of Serious Games that provides value to cyber education applications.

Girard [17] conducts a survey of over 30 publications and 9 studies regarding the effectiveness of serious games in the context of educational value. He surmises that at the date of publication (2013) there was a lack of statistically relevant data to conclusively state serious games are effective in all applications, but many studies show that there are beneficial aspects of serious games that merit further study.

2.3.2 Digital vs Physical Serious Games

There is some measure of discrepancy on the first application of the term "Serious Game" to Digital Game-Based Learning, but many sources attribute it to Ben Sawyer, co-founder of SGI [18]. Breuer [18] continues to attribute the modern definition of Serious Games to be primarily digital, but maintains that the definition first outlined by Abt is still applicable. The essence of Abt's original intent is valid in both board games and digital games. Susi [16] asserts that board games or turn-based digital serious games can move slower and encourage critical thinking at a higher level than faster paced digital games can [16]. The position that fun is not critical to success, engagement is, continues to create a case for serious games with significant levels of engagement. Serious games give educators implicit engagement because simply participating requires some level of interaction. [16].

2.4 Serious Game Design

Serious Game design draws from traditional game design in many applications. An overview of traditional game design yields many frameworks for designing games that engage players, but notably misses the ability to incorporate learning objectives at the earliest stages of planning and development.

2.4.1 MDA Framework

The Mechanics, Dynamics, and Aesthetics (MDA) [1] approach is one of the cornerstones of current game design. It develops a simple and effective framework which defines the three distinct components of games that build off of each other to form the complete experience to the player. The framework examines game design through the lens of the consumer, as well as the developer, in order to allow for proper perspective in the creation of a game that is both fun and well founded. It relies on the concept of iterative development to create a final developed product. The focus of game mechanics are the particular components and their representation within the game construct. Game dynamics bridge the game mechanics and the user experience through the player's interactions with each other and the game itself. Aesthetics are the result of the player's direct and indirect interactions with the game. They are the emotional responses garnered by the game dynamics and mechanics for the purpose of making the game fun, sensational, or addicting. The contribution made by the MDA framework is foundational, but does not provide significant application [1]. Over 1800 publications cite the research done by Hunicke, and this research has

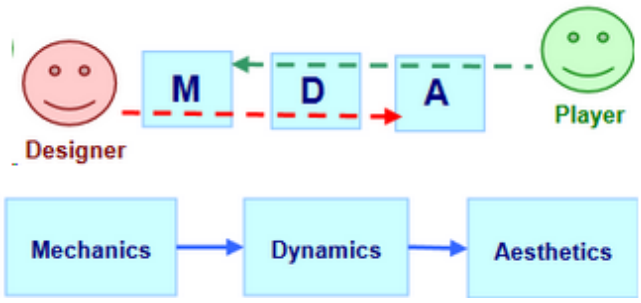


Figure 1. MDA Framework [1].

yielded substantial development in the general acceptance of serious games as a legitimate teaching tool. MDA provides a direct framework to build upon for outlining a

process to design serious games[1].

2.4.2 Additional Serious Game Design Frameworks

Extensions to MDA have been attempted, but there has not been one specific framework which has overshadowed the original methodology. The simple nature of MDA creates a very approachable system that can be easily iterated to produce a refined end product.

2.4.2.1 Design, Dynamics, and Experience Framework

Walk [9] approaches several observed weaknesses in the MDA framework through the Design, Dynamics, and Experience (DDE) framework. Walk assembles several arguments against the MDA framework and concisely summarizes them as primarily situational. MDA neglects to give designers direct influence over Dynamics and Aesthetics, instead claiming they are reliant on the player [9]. Similarly, the player experience is not wholly accounted for in Aesthetics. Players have additional influences from other players, storytelling, and environment. Lastly, MDA does not directly account for serious game development [9]. DDE remedies the perceived weaknesses in the MDA framework with a complex and scrupulously detailed framework which can now account for nearly any game at the cost of simplicity and brevity. The DDE framework is included in Appendix A for comparison. DDE attempts to shorten the iteration time required to create a game at the cost of initial design time. DDE provides little to no evidence of the effectiveness of this time savings, and is not an approachable framework for a novice game designer[9].

2.4.2.2 Learning Mechanic-Game Mechanic (LM-GM)Framework

The LM-GM framework is driven by the concept of supporting the intrinsic experiential learning of games. Arnab [2] postulates that because the experiential element of a game is in the actual game play, in the form of interacting with game mechanics, that learning a learning element can be mapped to a game mechanic. An effort to map elements of mechanics present in educational philosophies to game mechanics is the basis of the LM-GM design framework. The model is intended to allow game designers a great deal of freedom to relate elements of learning mechanics to a game mechanic. The primary intent of the framework is to provide a concise means of relating pedagogical intentions to the game elements themselves. A strength of this framework is the attempt to relate game mechanics to a level of Bloom's taxonomy and a primary learning mechanic.

GAME MECHANICS	THINKING SKILLS	LEARNING MECHANICS	
○ Design/Editing ○ Infinite Game play ○ Ownership ○ Protégé Effect ○ Status ○ Strategy/Planning ○ Tiles/Grids	CREATING	○ Accountability ○ Ownership ○ Planning ○ Responsibility	LOTS to HOTS
○ Action Points ○ Assessment ○ Collaboration ○ Communal Discovery ○ Resource Management ○ Game Turns ○ Pareto Optimal ○ Rewards/Penalties ○ Urgent Optimism	EVALUATING	○ Assessment ○ Collaboration ○ Hypothesis ○ Incentive ○ Motivation ○ Reflect/Discuss	
○ Feedback ○ Meta-game ○ Realism	ANALYSING	○ Analyse ○ Experimentation ○ Feedback ○ Identify ○ Observation ○ Shadowing	
○ Capture/Elimination ○ Competition ○ Cooperation ○ Movement ○ Progression ○ Selecting/Collecting ○ Simulate/Response ○ Time Pressure	APPLYING	○ Action/Task ○ Competition ○ Cooperation ○ Demonstration ○ Imitation ○ Simulation	
○ Appointment ○ Cascading Information ○ Questions And Answers ○ Role-play ○ Tutorial	UNDERSTANDING	○ Objectify ○ Participation ○ Question And Answers ○ Tutorial	
○ Cut scenes/Story ○ Tokens ○ Virality ○ Behavioural Momentum ○ Pavlovian Interactions ○ Goods/Information	RETENTION	○ Discover ○ Explore ○ Generalisation ○ Guidance ○ Instruction ○ Repetition	

Figure 2. LM:GM Framework [2].

2.4.2.3 Design and Integration of Collaborative Classroom Games

Echeverría's [3] framework for the Design and Integration of Collaborative Classroom Games (DICCG) is a game design framework that maps the "Ludic Dimension" which is the elements of the game itself to the "Educational Dimension" composed of education elements built into the design. This is shown in Figure 3. This framework targets a method of designing games based on a level of Bloom's taxonomy introduces a great deal of specificity to developers targeting a desired learning outcome. DICCG translates the Massive Multiplayer Online Game (MMOG) concept into a classroom based tool they name Classroom Multiplayer Presential Game (CMPG). This creates a digital collaborative learning environment which can be used to create games in a consistent environment which students can become accustomed to quickly. DICCG defines the core elements to create a game, but does not provide detailed information on how to create and execute the design elements [3].

2.5 Applications of Serious Games to Cyber Education and Training

Olana [19] describes a brief history of the more notable serious game contributions to cyber education including both traditional games and digital games. The distinctions and advantages between traditional games and digital games is well articulated and defined. Digital games require an intensive up-front investment in order to provide a more consistent and easier to distribute game experience. Similarly, there are significant differences in the intended audience of most games and their subject matter which broadly eliminates overlap in the currently available serious games. Highly technical games such as Elevation of Privilege [20] can be categorized as a form of hybrid game which requires some players to have a preexisting knowledge rather than functioning as an education tool appropriate for all novice players. This enables a measure of education level due to the intense barrier to entry of comprehending the

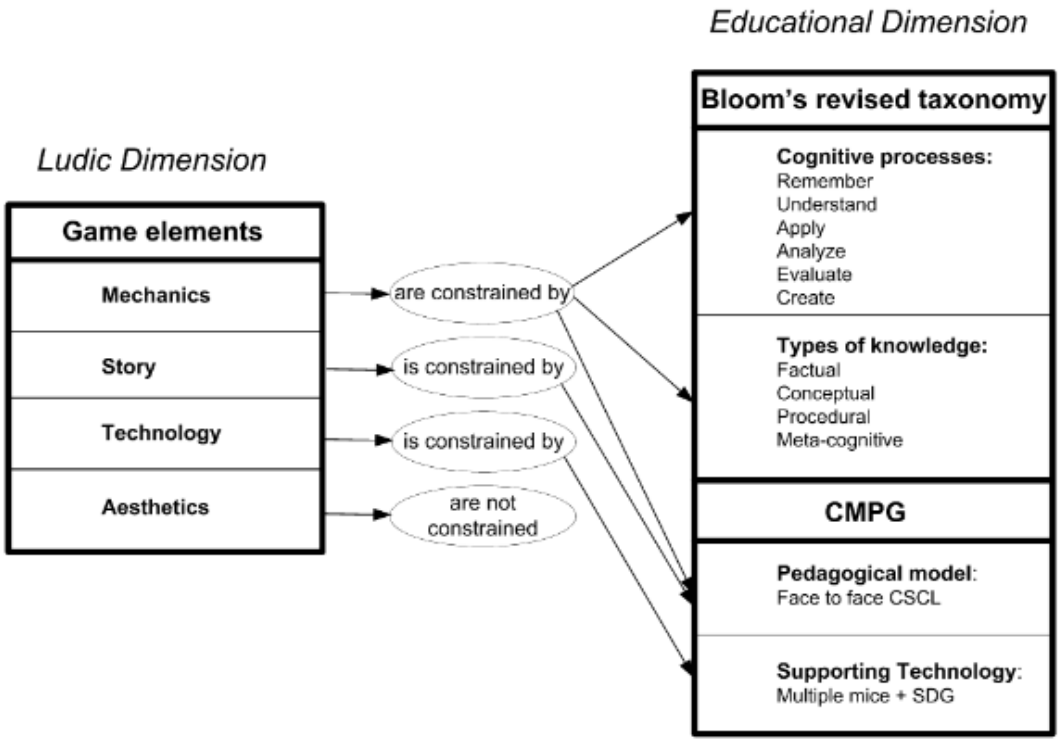


Figure 3. Game Design Process [3].

mechanics at work in the player experience. The game requires certain players to understand and comprehend the game in a manner which displays their knowledge as it is passed from them to the other participants. Conversely, some games provide an overly repetitive experience which is quickly discarded by players as uninteresting and rudimentary due to how quickly they are able to be mastered. As of 2014, Olano assesses the availability of serious games targeted at the basic Information Assurance (IA) skill set to be underdeveloped. SecurityEmpire is introduced to target basic IA education in order to teach students or employees the necessary skills to minimize risk during their daily interactions [19]. The U.S. Naval Postgraduate School developed the digital serious game CyberCIEGE to teach students the basic concepts of building, operating, and defending networks. Despite active play between 2005 and 2015

and hundreds of distributed copies CyberCIEGE has not been formally evaluated for educational effectiveness [21].

2.6 Learning Taxonomies and Learning Objective Development

Benjamin Bloom first proposed the concept of a framework to map the process of learning a subject to specific levels of demonstrated mastery in 1949 [4]. The need for the taxonomy was motivate by an observed simplicity in many assessment methods that favored simple memorization rather than a higher degree of mastery [5]. The original undertaking was the synthesis of several academic disciplines which contributed to the final framework over the course of a 7 year development cycle. Bloom's taxonomy was originally intended to be used as a measurement tool to aid curriculum developers and educators by creating a common language with which to define the specific levels of education measured by a course or assessment. It has since been applied to the development of learning objectives as well.

2.6.1 Introduction to Learning Taxonomies: Bloom's Taxonomy

What will be referred to as the "old version" in Figure 4 is the original Bloom's Taxonomy. It is designed to escalate in intensity as one masters each simpler category before being able to master the next, that is the prerequisite mastery to be able to apply a subject is to have full knowledge and comprehension of it [4].

2.6.2 Advancements in Learning Taxonomies

Krathwohl [4] proposes a revision to the original framework to better provide specification when creating requirements based on each of the six level categories. This provides a meaningful improvement over the original, as both the matrices of keywords used to relate each category and evolution of the applications for the original

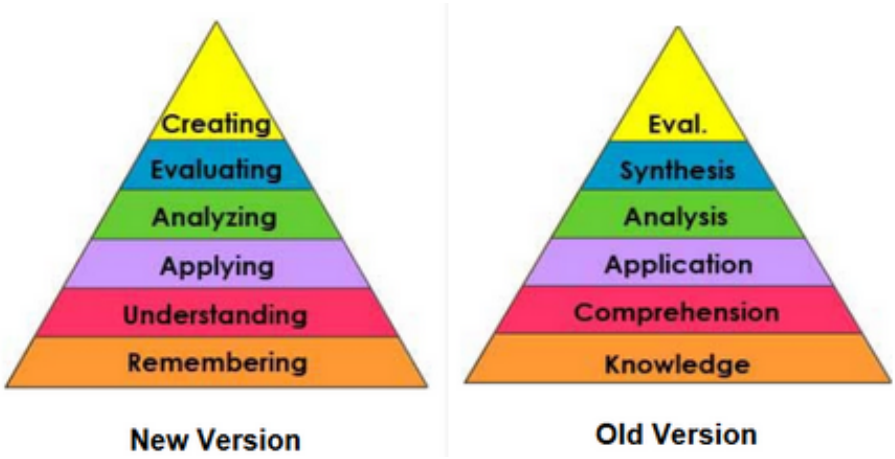


Figure 4. Comparison of old and new Bloom's Learning Taxonomy [4]

taxonomy are beyond the scope of the original intentions. There is very little research comparing the new version to the old version due to the overwhelming acceptance of the new revised version within the academic community. Krathwohl is uniquely qualified to present these revisions without substantial corroborating research because he was a co-author on Bloom's original works, but that is the extent of the article. Krathwohl essentially submits revisions based on the merit of his name and a relatively succinct assessment of known weaknesses. With this in mind, the reader is left to determine the effectiveness of the old version versus the new version in their specific application.

2.6.3 Developing Learning Objectives with Bloom's Taxonomy

Starr [5] advocates for the concept of using Bloom's taxonomy to aide in the development of learning objectives in the same manner it can be used to create learning assessments. As originally intended, Bloom's was a tool to gauge level of mastery in a subject matter. Starr creates a meta-level analysis with which to apply Bloom's Taxonomy within the scope of a lesson objective. This evolution of Bloom's

is a drastic simplification of the original version of the taxonomy, but adds a new dimension of application. Figure 5 shows a breakdown of the levels of mastery taken from the original version divided into work produced and knowledge explained. This allows for the design of a learning objective with the student mastery level in mind. The generation of objectives derived from expected mastery levels is particularly useful for faculty assessing the level of instruction necessary for a course, as well as allowing for development of follow-on courses to properly scope learning objectives. Starr lays out a simple two step method for applying Bloom's Taxonomy to a learning objective: identify topics to be covered, and then for each topic assign an expected level of mastery to be achieved. The strength of the approach created by Starr is its simplicity, but it is far from an applicable framework. In order to strengthen the work begun by Starr, a more substantial framework is necessary. This would allow for significant improvement in the consistency of results based on the construct.

Buchanan [6] breaks down the levels of Bloom's taxonomy as applicable to Serious Games in order to better classify types of games and game mechanics with a particular level of mastery. The levels originally defined by Buchanan have been modified to match the new version of Bloom's. The categories identified by Buchanan in figure 6. are particularly applicable to categorizing game dynamics according to levels of Bloom's Taxonomy.

	Phase within Meta-Level	
Meta-Level	***Produce***	***Explain***
Beginner	Recall	Comprehension
Intermediate	Application	Analysis
Expert	Synthesis	Evaluation

Figure 5. Meta-level structure for Bloom's Taxonomy [5].

Mastery Level	Expectations	Game Types
Remembering	The student can recall and match information	Memorization and association games
Understanding	a learner should be able to interpret, discuss, compare concepts in terms of similarities or differences, or explain the subject in their own words.	Games which involve identifying and reacting to inputs. Dynamic reaction games like First Person Shooters (FPS)
Applying	Solving a problem by using or examining knowledge and understanding in some conceptual manner	In depth strategy games with require association of multiple concepts to properly identify next moves
Analyzing	Learners are expected to make connections beyond the surface level, including anticipation of counterplay	Introduction of simultaneous independent variables with which the player must contend
Creating and Evaluating	These levels "break the 4th wall" of the game	

Figure 6. Buchanan Mastery Level to Game Type [6].

2.6.4 Implementing Educational Taxonomies in Computer Science and Cyber Education Applications

Fuller [22] examines the Krathwohl revision of Bloom's, the SOLO learning taxonomy and several others in order to argue that the mastery tiers of traditional learning taxonomies do not easily compare to computer science and computer engineering due to the extreme focus on production of coding. In order to create code, an "application" level activity, students must first master the evaluation and to some extent: creation. Computer scientist must learn beyond the traditional level of academic mastery. To be successful they must be able to intrinsically devise elegant solutions to problems which have never been solved or have never had the opportunity to see a solution. For this reason, computer science course learning objectives often target very high levels of mastery. This necessitates teaching tools which can reach higher levels of learning than lecture alone.

2.7 Fundamental Elements of Serious Game Design

The primary elements of any game are defined by MDA as the mechanics, dynamics, and aesthetics. This section examines attempts to define and identify game mechanics and dynamics, as well as published lists that designers can utilize when creating games from base elements.

2.7.1 Game Mechanics

A flagship work on defining game mechanics is Lundgren's [23] work introducing terminology for describing game interactions. This definition of a game mechanic is constrained to a part of the rules system that covers one and only one possible kind of interaction that takes place within a game. The concept of a game mechanics existed previously, but this is an early attempt to publish a specfic definition. Järvinen [10]

Table 1. Järvinen Game Mechanics [10]

Accelerating/Decelerating	Bidding	Allocating	Arranging
Attacking/Defending	Conquering	Browsing	Building
Buying/Selling	Catching	Choosing	Composing
Aiming & Shooting	Contracting	Controlling	Conversing
Discarding	Enclosing	Expressing	Herding
Information-seeking	Jumping	Manoeuvring	Motion
Moving	Operating	Performing	Placing
Point-to-point Movement	Powering	Sequencing	Voting
Sprinting/Slowing	Storytelling	Submitting	Substituting
Upgrading/Downgrading	Taking	Trading	Transforming

defines game mechanics as a compound element used by the game to allow the player a means to pursue game objectives. This adds the concept of a sub-mechanic which is a simplified version of an existing mechanic that can be used alone or as part of the game mechanic. Game mechanics are specifically defined as the connection between player-behavior and system-behavior. This concept of system-behavior is equated to game dynamics. A simplification of this is that mechanics are the bridge between the player and the game. It is important to recognize that the earlier work defining and building on game design pattern research [24] is not incompatible with this definition, but this interaction of game mechanics and dynamics is an evolution of the original concept. Järvinen identifies the core mechanics that can be used to define the player-game interactions in every form of game. This is accomplished by listing every possible interface a player can have in an activity (game) and defining them within the context of the other interfaces. The list of game mechanics created by Järvinen is shown in Table 1, and a list of mechanics definitions can be found in Appendix C.

2.7.2 Game Mechanics Controversy

Sicart [25] highlights the importance of defining game mechanics with regard to game rules and the main "challenge" of the game. An analysis of many contemporary definitions yields an inconsistency in what the term game mechanic actually means. Sicart argues that Järvinen alters the definition from a more traditional design element such as that produced by Hunicke into an analytical element. This evolution of the term has developed a very useful assessment tool, but at the cost of a critical design element. Sicart attempts to contain both aspects into one definition. In its simplest form, Sicart defines game mechanics as methods invoked by agents, designed for interaction with the game state. In short, the game mechanics are the base element of the game whereby the game player (agent) interacts with the game. This implicitly requires all actions a player can make in a game to be either a mechanic or the combination of several mechanics. Drawing further from Järvinen, game mechanics consolidate specific actions and defined them as primarily verbs in order to classify different player options as either a mechanic or a higher level system interaction. Sicart shows direct correlation between mechanics (actions) and agent input through examples of digital games. It is far simpler to map agent interactions in the simplistic example of a digital game because of the incredible limitations placed on agent interaction. One significant weakness in this paper is the lack of extrapolation to non-digital games such as board games or sports. Presenting direct examples of a game mechanic in a collaborative setting with interpersonal communication is far more challenging than relating the buttons on a game controller to an action verb. Sicart addresses several other hard questions directly when attempting to differentiate between game mechanics which may not directly progress game play by removing the goal oriented nature of Järvinen's definition of a mechanic from his own. Järvinen takes a hard line on the requirement that mechanics can be composed of mechanics in

the form of primary and core mechanics. Sicart aptly separates the Järvinen primary mechanic concept from his definition but cannot find a better method of defining it. Sicart effectively recognizes that it is an inconsistency and leaves it open to future researchers to find a solution.

2.7.3 Game Dynamics

Järvinen equates the system behavior of a game with the game dynamics as traditionally defined by MDA. Rather than attempt to define common system behaviors, he consolidates all of them as the operation of the game system (the mechanics and components during play). More specifically, the available mechanics are realized as the game dynamics when employed in a varying number and sequence as the player plays the game. No suitable list of published games dynamics has been found prior to Pendleton [11]. A list of game dynamics shown in Table 2 built to pair with the Järvinen was assembled as part of the initial publication of the Game Design Matrix [11].

Table 2. List of Game Dynamics [11]

Modular Environment	Fog of war	Deck/Hand Building
Bluffing	Chance	Cooperation
Competition	Conflict	Collaborating
Level of communication	Information Control	Time Scarcity
Multiple Strategies	Multiple endings	Infinite Gameplay
Player substitution	Player Autonomy	Team Modeling
Real Time Play	Hidden Objectives	Limited Actions
Feedback	Realism	Negotiation
Diplomacy	Player Ethics	Asymmetric abilities
Resource Scarcity	Adversary Tracking	Teams

2.7.4 Translating Game Mechanics and Dynamics to Learning Objectives

Arnab [2] proposes that the pedagogical elements are the more abstract interface of Serious Games as opposed to the concrete player interface presented by the mechanics of the game in the LM-GM framework. As shown in Figure 2, the strength of the Arnab model is the categorization by Bloom's levels of mastery. This gives serious game designers using common game mechanics a direct mapping for the purpose of selecting game mechanics based on the level of learning they present. The weakness of attempting to map thinking skills to a mechanic is that a mechanic requires no specific level of thinking to be operated. Arnab [2] provides no details on implementing the LM:GM framework and does not offer any explanation as to why mechanics were selected instead of the thoughtful operation of mechanics to form a certain system behavior (dynamic). It is possible to associate some of Arnab's learning mechanics with game dynamics, but the definition provided for a learning mechanics is clearly different.

2.8 The Need for Step-By-Step Game Design Process

One of the main problems faced by the field of serious games is the lack of designers who have both game design experience and educational experience [7]. Theodosiou [7] recognizes and attempts to address this problem by identifying key elements of game design which hamper pedagogical experts from being effective game designers. The experiment was conducted with seventy-five undergraduate students who each designed a game using a basic game design framework called the Integrated Game Elements, Narrative and Content (IGENAC) model. This framework offers no step by step guide to designing a game but rather checkpoints to reach along the way. The result of this study found that the designers' most challenging tasks were the

selection of game mechanics and the incorporation of learning content. Future work suggested a strong need for a systematic way of scaffolding teaching the their early steps of game design.

2.9 Assessment Methods

It is necessary to tailor an assessment to the levels of Bloom's taxonomy targeted in the learning objective. Serious games often attempt to reach level three or above. This introduces a challenge when attempting to assess if students have learned as a result of their game-play experience. The consensus has been that serious games are an effective tool for instruction and achieving a desired learning outcome, but it is still understudied mainly due to the complexity involved creating quantitative assessments [26]. To begin assessing higher levels of learning, the dynamic nature of the skills required to demonstrate knowledge must be acknowledged.

2.9.1 Learning Assessment Methods for Higher Levels of Bloom's Taxonomy

The assessment of higher order thinking skills (regarded as level three or higher in Bloom's taxonomy) remains a challenge to those attempting to accurately gauge learning outcomes [27]. The primary method of conducting an assessment of a student's application, analysis, and evaluation is through long response and essay prompts [28]. This allows instructors and teachers to assess how students reach and explain their conclusions [28]. The disadvantage of these methods is that they can be time consuming and rely on a direct logical analysis or hypothetical scenario rather than requiring the student to adapt to an evolving scenario [27].

2.9.2 Serious Game Assessment Methods

Questionnaires and surveys are only capable of consistently showing efficacy when measuring lower levels of Bloom's Taxonomy [26]. This makes assessing serious games with any form of quantitative analysis difficult when they are targeting higher levels of Bloom's taxonomy. This leads to a primarily qualitative method using post-game survey and short response questions to gauge the level of player engagement and learning [26].

The primary method of assessing serious game efficacy in the games surveyed is environment specific questionnaires or surveys [19], [26]. This faces increasingly high levels of scrutiny because surveys and pre/post game assessments are overly qualitative and cannot be easily used to assess the effectiveness of games which target higher levels of Bloom's Taxonomy.

Game analytics is a growing field of assessment in commercial digital games [26]. They draw heavily from non-disruptive embedded tracking (telemetry) in order to preserve an immersive experience while continuing to draw information about game-play. This solves many issues present when attempting to assess a players learning and abilities when employing a digital serious game. Two interactions are highlighted as primary video game assessment strategies: interactions based on a time-state or an event-state. Event state interactions are selected by Serrano-Laguna [29] for the efficiency and flexibility of their implementation. Each player receives an identifier and is assumed to be working towards a learning outcome. These elements paired with a timestamp create an event. It is important to note that these event-state interactions can often be unique to an individual game. This framework is designed and proposed as an Experience API (xAPI) which can be mapped to API statements designed for specific serious game implementations. This is a very strong approach for any video game application because it is one of the more objective methods achievable. This

result cannot be fully replicated in a board game, but captured events could be a more objective method analysis that a questionnaire. Additional research in event-based game analysis would be appropriate if the learning outcomes were more directly tied to a game-state.

2.9.3 Game Design Assessment Methods

The assessment of game design methodologies is lacking and has been primarily reputation based. Many game design methodologies are introduced with minimal assessments or verification of efficacy [1],[9],[2], and the design systems that do have attempts to verify their effectiveness have been primarily examined through a single case study [30]. The following example describes several game design frameworks and how they have been assessed.

2.9.3.1 MDA

The MDA framework has been introduced as a method of strengthening game design and a basic framework to being an iterative construction. The challenge in this presentation is that the effectiveness of MDA is not analyzed with any scientific process, but that it is merely proposed and accepted by the community. MDA was presented at game design workshops as an effective method, and eventually it was preceded by its own reputation and accepted.

2.9.3.2 DDE

DDE uses a more complex framework in an attempt to shorten the iterative design process necessary when using MDA alone. They assert that while iteration is never going to be completely removed from the design process, it is one of the first steps to be shortened when budget or time constraints are realized. These assertions while

reasonable, are not verified in any way. The claims of improvement over MDA made by Walk are not assessed, and there is no case study to determine the viability of the framework [9].

2.9.3.3 LM-GM

LM-GM used a single case study game to verify the efficacy of the framework. It is intended as both a design or an analysis tool. Rather than design a game, an analysis of an existing game is performed assess the framework [2].

2.9.3.4 DICCG

The game design process was tested by creating a single case study. The primary learning objectives of the case study targeted level one and two of Bloom's taxonomy: remembering and understanding. Secondary objectives targeted level three, applying. The case study game was assessed using an undisclosed pre-post test method, which targeted undisclosed levels of mastery. The assertion was that if the effectiveness of the game could be shown, then the effectiveness of the design process would be verified. The experiment showed that students performed better on the post test, and Echeverría concluded that the design method was effective [3].

2.9.3.5 IGENAC

The novice game designer study performed by Theodosiou [7] created over 34 serious games but did not record any player feedback. The primary method used to assess the effectiveness of the game design was the qualitative assessment of each game by a faculty member who was deemed a serious game design expert. Over half of the design games were evaluated as needing major modification in at least two areas. Not a single game incorporated the learning content well enough to score minor or

no modification needed in that category.

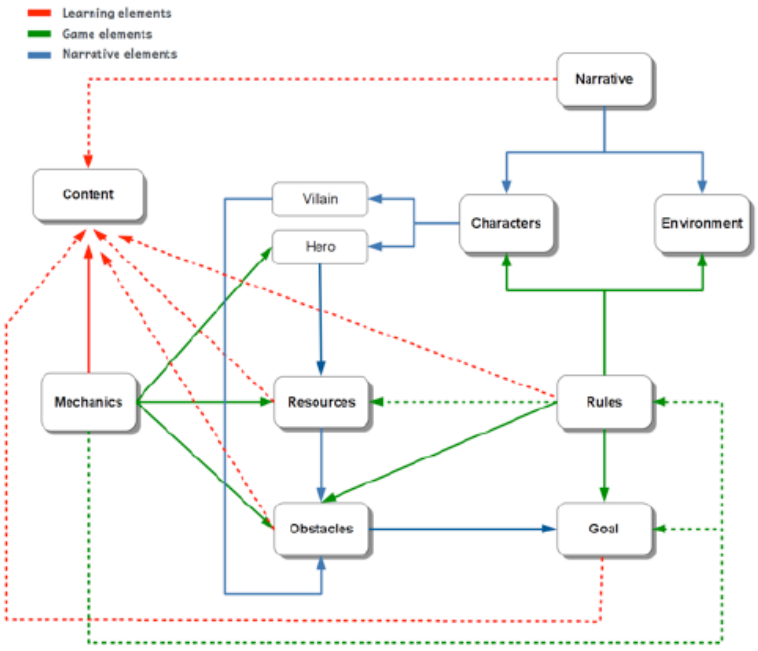


Figure 7. IGENAC Framework [7].

2.10 Technical Background for Case Study Game Design: Cyber Risk Analysis and Assessment

A certain level of pre-requisite information is required in order to create a case study of a serious game. The current defined need for education tools in cyber risk is established in this section, as well as an overview of the basic United States Air Force enterprise network risk assessment implementation. An overview of risk management models [31] was conducted by the designer of the case study game. A summary of that work is presented in this section with the basic information required to understand game elements of the serious game, Enterprise.

2.10.1 Identifying the Need for Risk Management Education

The United States (U.S.) Government Accountability Office (GAO) is a nonpartisan "congressional watchdog" designed to provide objective and reliable information to the government regarding work and spending practices [32]. GAO highlights a shortcoming in most current operational risk assessment frameworks and education programs implemented by the Department of Defense (DoD). The U.S. military and DoD are required to conduct mission assurance through the cybersecurity Risk Management Framework (RMF) developed by the National Institute of Standards and Technology (NIST). Current DoD guidance simply requires certain levels of proficiency certification in order to be qualified to work in a specific function, but this includes no "big picture" DoD system specific training. Additionally, this training does not effectively target higher levels of thinking. This creates a scenario where a technically qualified workforce may not have any experience applying the methodology of RMF to their respective role and function.

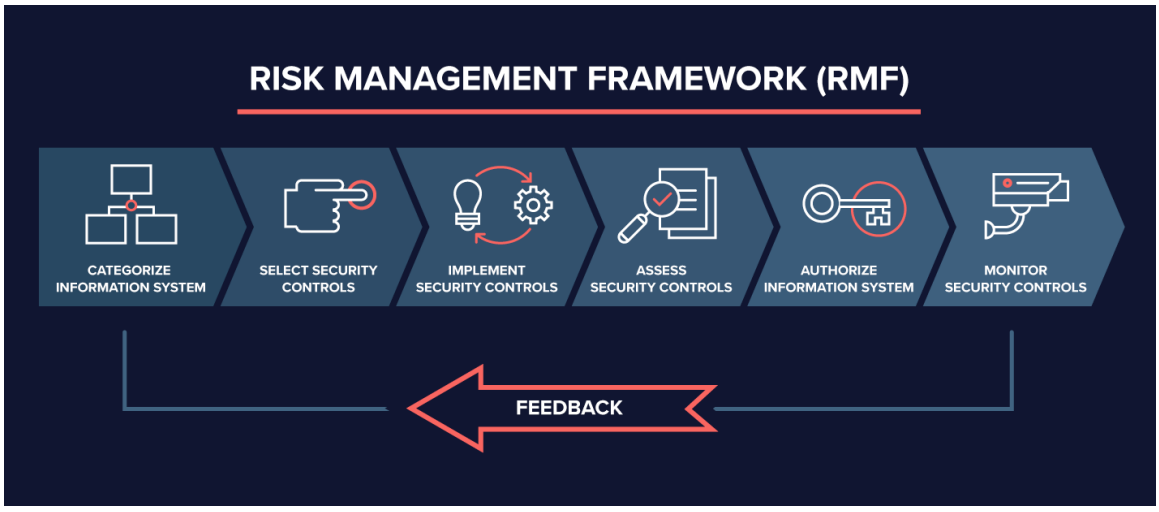


Figure 8. Risk Management Framework [8].

2.10.2 NIST Risk Management Framework

The NIST RMF is a 6 step qualitative analysis method for assessing risk as shown in Figure 8. Common NIST RMF implementation policy requires each government entity to implement several layers of security and defense in depth but does not make specific requirements on how they are to be executed. This leads to drastically different implementations across services and networks. It begins by using a qualitative analysis system to establish a secure baseline. This is accomplished by identifying types of systems within the network and establishing security measures or "controls" which can be implemented to secure that system. Once this process is complete, the network enters a cyclical state of constantly implementing security controls, assessing the controls, monitoring effectiveness, and re-evaluating the terrain to ensure that the controls are still optimal for the state of the network [33]. Training and educating new personnel on a network can take weeks of on the job training before they are familiar with the general components involved in the daily operations of a network. Qualitative frameworks, such as RMF, rely on scanning tools and strict Information Assurance (IA) policy to prevent unauthorized activity. These security measures can be subverted by operators without sufficient experience or understanding of the process as whole. This places the security posture of the network in the hands of the least proficient element [8].

2.10.3 Operational Implementation of RMF in the Air Force

The basic structure implemented in the Air Force is a combination of network operations, maintenance, and basic cybersecurity services onsite. These support organizations must collaborate to provide services which can at times have competing priorities. The role of integrating security into the network which is accredited under RMF falls on the Information System Security Manager (ISSM) to act as the cyber-

security and Information Assurance (IA) expert. This position is typically within the Wing Cybersecurity Office or a similar IA program [34]. The primary role of the ISSM is to oversee the successful implementation of security controls, proper configuration management, and adherence to Security Technical Implementation Guides (STIGs). This is accomplished by coordinating with the Information System Owner (ISO) controlling the network operations, maintenance, incident response, and other mission assurance elements. These elements interdependently work to operate, maintain, and implement security policy on the network. Basic requirements within RMF detail that the baseline approved when the Authorization To Operate (ATO) is to be upheld by the ISO. When this baseline requirement is no longer met, the ATO can be revoked [35].

2.11 Summary

This chapter presented a brief summary of the use of serious games in education and the success they have had when implemented in classrooms as a method of boosting student engagement as well as teaching application concepts which can be more difficult to target in a lecture alone. Several methods of designing serious games are discussed in order to determine the core components of games, level of design difficulty, state of the art of current design frameworks, and to begin introducing the concept of game mechanics and dynamics. Learning taxonomies which have been applied to the development of learning objectives and by extension, serious games, are discussed in order to define a baseline of learning outcomes. The application of Bloom's taxonomy to serious games is evaluated and past efforts to incorporate associations of levels of mastery into serious games are discussed. A deeper look at the elements of serious games reveals a significant level of research put forth into game mechanics, but a very light emphasis on game dynamics. An overview of Jävinen's game mechanics is dis-

cussed to identify the most basic player-game interactions. Furthermore, the methods of assessing previous games and game design frameworks are discussed in order to determine the current standard for serious game analysis and assessment, as well as methods for analyzing the performance of game design frameworks when operated by both experienced and novice designers. The challenges of analyzing game frameworks has not been conclusively solved. The overview of both serious game assessment, and design framework assessment identifies a significant shortcoming in the ability of a designer to effectively determine efficacy.

III. Game Design Matrix Development and Assessment

3.1 Overview

This research investigates the feasibility of creating an effective game design methodology intended to guide educators without game design experience through game design for classrooms use. This will use a step-by-step design method to allow a higher level of consistency and effectiveness at the cost of a small level of novelty and innovation. Additionally, this research seeks to reduce the time required to design a serious game for classroom use to a level approachable for an educator seeking to replace a lecture, in-class lab or activity with a serious game.

This chapter describes the step-by-step game design methodology of the Game Design Matrix (GDM) elements and components. An analysis of serious game design and serious game assessment methods is detailed to create an assessment strategy appropriate for a game design framework. The individual elements of the process and its execution are explained in order to allow designers to quickly create an initial draft of a game which targets their specific objectives and allows for an iterative development cycle. A primary premise of MDA [1] is that games develop effectively when they are able to reach the first iteration of feedback and play-testing quickly. The Game Design Matrix uses these elements of MDA to produce a game framework which allows the designer to select game mechanics and dynamics which are well suited for the game intent but is designed to allow for multiple iterations and substantial revisions as play-testing begins. This allows a guided process through the most difficult part of the game design process and decreases the time required to analyze and select the core components of a game. This method differs from the MDA and LM-GM frameworks by emphasizing the game dynamics selection over the

selection of game mechanics due to the unreliable nature of targeting mechanics to a level of Bloom's taxonomy.

A mapping of game dynamics to level's of mastery is developed and is one of the core elements of game dynamic selection. The second mapping which the Game Design Matrix is built on is a mapping of game dynamics to game mechanics which can be used to create the desired game dynamic. This mapping provides a simplified way for designers to select game mechanics. An assessment strategy is introduced to target each primary interaction between GDM users, game proctors, and game players. The experiment incorporates several elements used by current game design frameworks in order to create one of the most rigorous game design framework assessments present in the current state of the art.

One of the primary contributions of this research is the creation of a mapping from game dynamics to game mechanics and a mapping from game dynamics to a level of Bloom's taxonomy.

3.2 Research Question

This study builds on several game design frameworks to create a step-by-step game design process targeted at novice serious game designers. A gap in the current state of the art shows that novice game designers struggle to properly select game mechanics and incorporate learning objectives in their designs. Similarly, there is a lack of research in the development of game design guides which leads designers through a more structured game design process.

3.2.1 Research Question One

Is it possible to create a step-by-step game design process that effectively guides novice designers through the crucial stage of incorporation learning objectives, select-

ing mechanics, and selecting dynamics?

3.2.2 Research Question Two

Can serious game design be accomplished faster using a highly structured design framework in order to make serious games more feasible in a classroom that does not otherwise have the resources to outsource expert game designers?

3.2.3 Research Assumptions

The primary element required for the efficacy of this research is that serious games can be an effective tool in a classroom. The games in this research specifically target classrooms teaching STEM and computer science based topics.

3.3 Hypothesis

Serious games designed by novices are viable, effective, and can be designed quicker when basic scaffolding is used to integrate learning objectives and game design.

3.4 Approach

This research introduces a step-by-step game design methodology, and then assesses its effectiveness using several techniques previously used to assess game design frameworks.

3.5 Contribution

The current state of the art in game design provides limited substitutes for experience when creating serious games. This work creates a process which can be used to create serious games with a higher level of consistency and in a similar or shorter amount of time than games that are simply devised by a novice game designer.

3.6 Study Setting

All assessment involving human subjects takes place in a classroom environment in accordance with the Institutional Review Board (IRB) waiver obtained for the research found in Appendix J. Additional feedback is obtained through interviews with game designers, institution faculty, and instructors.

3.7 The Game Design Matrix

Shown in Figure 9, and detailed in Section 3.8, GDM is designed to enable educators with established learning objectives and a desired subject matter to identify environmental constraints, model the game off of an activity which can apply the subject matter, and select appropriate game dynamics and mechanics. GDM builds upon the Mechanics, Dynamics, and Aesthetics (MDA) framework to specifically target game dynamics as the first step in order to achieve specific levels of Bloom's taxonomy and better incorporate the desired learning objectives into the core foundation of the game.

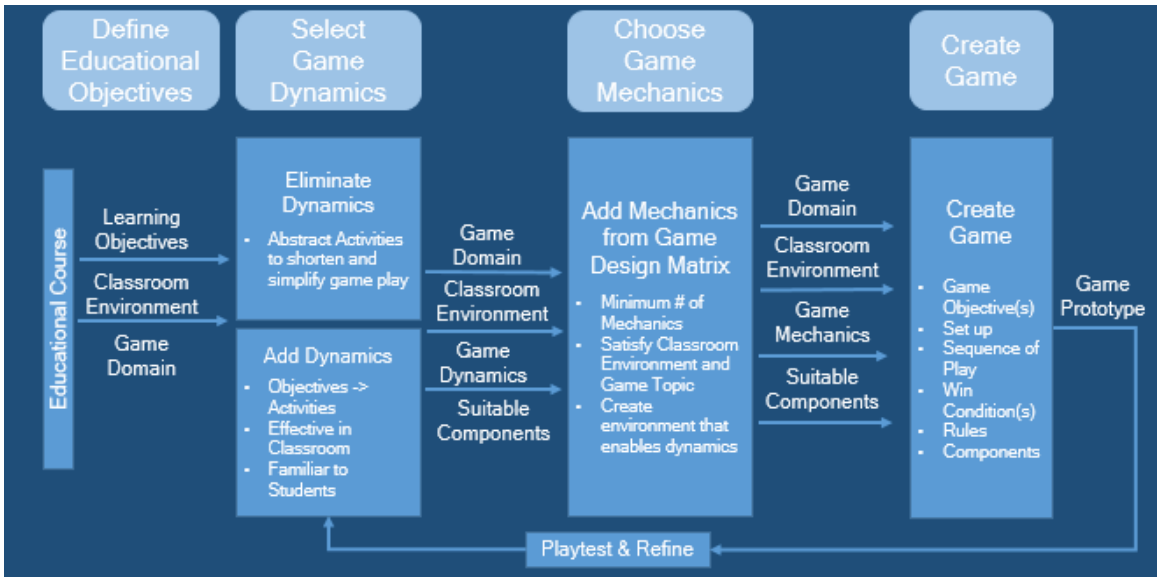


Figure 9. Process of GDM.

Games are powerful tools because the dynamics of a real life process can be modeled. This allows educators to introduce challenging concepts and allow students to fail, adapt, and succeed in a controlled environment. Dynamics can similarly target a specific level of Bloom's taxonomy based on the learning objective requirements. The accuracy of modeling an activity related to the subject matter is the cornerstone of game design. GDM is iterative to allow this modeling to be honed over the course of multiple versions to achieve a higher level of efficacy. The Game Design Matrix maps game dynamics to a Bloom's levels of mastery, and game mechanics. Key factors in the effectiveness of a serious game include constructing a game based on the core elements of the learning material. Well-defined learning objectives correlated to a level of Bloom's Taxonomy define the knowledge a student requires, and the level of critical thinking needed to accomplish it. The design of "Enterprise", a cyber risk serious game, is used as a case study of executing each step of GDM.

3.7.1 Important Definitions

Several different definitions of key elements of GDM are presented in Chapter II. The definitions selected for this research are defined as follows:

3.7.1.1 Game Mechanics

Specific actions, primarily verbs, a player can have during game-play. These are direct options a player has to interact with a game [1], [10].

3.7.1.2 Game Domain

The class material simulated in the game; what the game is supposed to do.

3.7.1.3 Game Dynamics

Player options which can be combined to create higher level system interactions than basic mechanics. These can be considered the system-behavior of a game and are not as reliably created as game mechanics. Game dynamics are a combination of game mechanic interactions [10], [1].

3.7.1.4 Classroom Environment

Where and by whom is the game going to be played (e.g., play time, play space, # of players, player experience, player knowledge, introduction time, camaraderie, budget, etc.)

3.7.1.5 Game Aesthetics

The result of the player's direct and indirect interactions with the game. They are the emotional responses garnered by the game dynamics and mechanics for the purpose of making the game fun, sensational, or addicting [1].

3.7.1.6 Game Components

The pieces of the game which are used to create mechanics and dynamics. Examples include cards, tokens, boards, or digital infrastructure [1].

3.7.1.7 Environmental Constraints

The limitations within an individual classroom or educational program that must be accounted for when designing a game optimized for a particular course.

3.7.1.8 Learning Objectives

Brief statements describing the expectations of what students are anticipated to accomplish over the course of a defined period of education. Within GDM, it is expected that learning objectives are developed with a targeted level of Bloom's Mastery.

3.7.1.9 Learning Outcomes

The end results of a student's skill level after a course or block of education. Typically, a learning outcome is measured against the learning objective using an assessment tool.

3.7.1.10 Novice Game Designer

The term novice is granted to game designers that have limited exposure to game design through either a graduate or undergraduate course or have some experience with games. Each participant in the IGENAC [7] novice game designer study had experience from a serious game design course. The baseline for a novice is a designer that has not created a playable serious game but may have made efforts to educate themselves on design elements or created unsuccessful games in the past.

3.8 Step-By-Step Framework

This section introduces the elements of the guided portion of GDM. These steps are defined and generalized to allow a game designer to begin with a basic concept and finish with a basic game structure.

- Step One: Define Educational Objectives and Classroom Environment
- Step Two: Select Game Dynamics
- Step Three: Choose Game Mechanics
- Step Four: Create Game

3.8.1 Step One: Define Educational Objectives

Serious games are defined by GDM as either learning oriented, or application oriented. Learning oriented games target the bottom two levels of Bloom's taxonomy and focus largely on relaying basic principles and information. Learning games often take the place of or supplement a lecture. They are a tool to mix up the classroom dynamic when students are expected to ingest large amounts of data. Application focused games are designed to use or build off of information students have already been taught. Students practice and work with information too complex to learn reliably from a lecture alone in order to apply concepts in an environment where they can fail, adapt, and succeed. This form of game is application focused at minimum. The primary objective of these games is not to teach lower levels of Bloom's mastery, but higher levels (level three and higher).

The key part of this step is to select a specific activity, process, or concept that can be used as the basis of a game to define the game domain. The level of Bloom's taxonomy that the designer targets largely determines the nature of the game. The

designer must verify that the desired learning objectives and learning outcomes for the players accurately match the selected game domain. The learning objectives are used to target specfic levels of Bloom's taxonomy. The process developed by Starr [5] can be used if the designer is unfamiliar with this concept. In addition to specifying the activity, process or concept to be taught and the learning objectives to be achieved, the educator also needs to provide details about the classroom environment. These details will include the desired play time and time to teach the game as well as the available play space, expected number of players, and player experience. It might also include the budget for game components and how much time is available for them to be produced

3.8.1.1 Case Study: Walk-through of Enterprise Game Design

Enterprise is a serious game designed to teach principles of applying cyber risk management in an operational environment. The learning objectives targeted by Enterprise are:

- To apply principles of mission assurance and cybersecurity risk management in enterprise network operations
- To understand the balance between operations (availability), cybersecurity (confidentiality), and Information Assurance (integrity) in network operations.

This game is designed to accompany a lecture which teaches the fundamentals of each primary contributor to this process in order to augment the presentation of the material with a more application focused activity. This defines a game domain that extends broadly through "daily network operations".

The class environment provides several significant constraints. Play time must be approximately 20 minutes, and support four or five users. The game must be learned

quickly (under 15 minutes), played on a tabletop, and easily reproduced to support classes of 50+. The desired learning outcome targets the selection of dynamics based on level three (application) and level four (analysis) of Bloom's taxonomy. Classifying Enterprise as an application focused game requires identification of an activity or process in the game domain, in this case the cyclical operation of a network. Simple abstractions are very effective when attempting to reduced game learning and play time. In this situation, the different moving pieces involved in a network are all working towards the same goal: keep the network up, operational, accessible, and secure.

3.8.2 Step Two: Select Game Dynamics

In Step One, the game designer selects the core focus of the game. In this step the heart of the game, the dynamics, are chosen. All environmental constraints must addressed in the selected dynamics. This also drives suitable games components (see 3.8.4 for more details). GDM is designed to be adaptable to every classroom situation in some capacity because the mechanism allows for an abstract implementation structured by the end user.

3.8.2.1 Defining Game Dynamics

Game dynamics, as referenced by Järvinen, are system-behaviors and a method of player-game interaction which can be considered more advanced than a game mechanic. They provide the "feel" or "style" of the game. A list of game dynamics is introduced in Table 2 in Chapter II. An example of the practical difference can be demonstrated with the game dynamic Deck/Hand Building. This dynamic is determined to be a more advanced game interaction than a mechanic because it requires employment of multiple game mechanics to accomplish, and also requires analysis of

other cards to be performed correctly. It can invoke high levels of evaluation and analytical thinking beyond simply drawing a card from a pile. A detailed overview of each game dynamic can be found in Appendix B. The designer should select dynamics which have familiarity and extensibility by choosing "real-life" subject matter elements. Similarly, dynamics which do not contribute to the game or level of mastery targeted should be eliminated or abstracted based on the environmental constraints.

3.8.2.2 Choosing Game Dynamics

A designer targets key dynamics in a top-down method to replicate or simulate dynamics present in the game domain, and then select dynamics as needed to round out the player experience. Select from the subset of dynamics in the Game Design Matrix that link to the levels of Bloom's taxonomy. This is the most nebulous step in the GDM process. Educators/designers blend subject matter knowledge and game design experience to select what fits best. This may involve multiple prototypes iterating through the GDM process. A list of game dynamics has been compiled as part of the GDM in Figure 10, and a list of definitions with examples can be found in Appendix B. It is important to recognize that some dynamics have pre-requisite components, and account for it when moving forwards to mechanics selection. Examples include: Modular Game Board, Deck/Hand Building, and Chance.

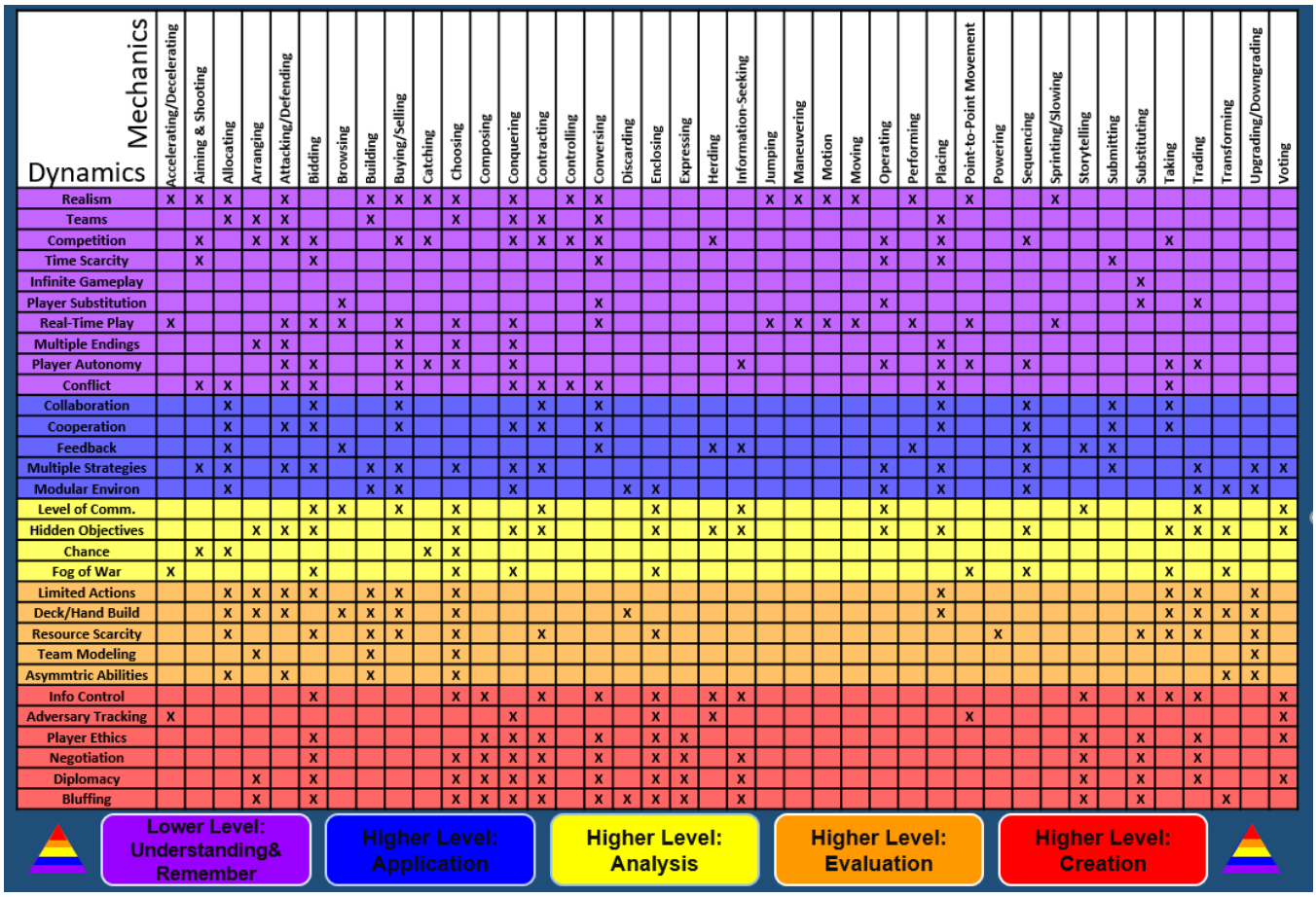


Figure 10. The Game Design Matrix: Mapping Dynamics to Mechanics and a Level of Bloom's Taxonomy.

3.8.2.3 Case Study Example

Enterprise simulates key elements of an enterprise network. This was accomplished by identifying a combination of interactions in what could be considered "routine operations". Elements of a typical United States Air Force communications squadron are used in order to apply the game to the targeted classroom audience. All elements of the network cooperate to conduct mission assurance and operations roles with a collaborative dynamic. This makes collaboration a natural first step when selecting dynamics for a game because it closely mirrors the real activity and is an appropriate

dynamic for the targeted level of mastery in Figure 10. Similarly, it is natural to choose asymmetric abilities in an effort to model each of the unique roles present, as well as chance to model the unpredictability of the external factors. Chance enables the designer to model opportunities for equipment failure, "hacking", or even budget raises/cuts impacting the readiness of the network. The last dynamic selected is resource scarcity. This dynamic creates the primary challenge of implementing proper elements of risk management within a large network. These dynamics are shown in Table 3 and collectively mirror elements of real life risk management principles to create a game environment that can allow for high levels of application, analysis, and potentially evaluation. Players balancing unknown (chance), multiple options which lead to different outcomes (multiple strategies), and several different capabilities that can be used to mitigate risk (asymmetric abilities) inevitably have to make a decision based on an incomplete understanding of the situation.

Table 3. List Enterprise of Game Dynamics [11]

Collaboration	Mirrors the working environment
Chance	Models unpredictable nature of attacks and failures
Asymmetric Abilities	Models the different roles
Multiple Strategies	An abstraction of the possible Courses of Action
Resource Scarcity	Realistic limitations placed on the game to make it more realistic

3.8.3 Step Three: Select Game Mechanics

Game mechanics directly define the player-game interactions. Dynamics can be targeted when designing a game, but mechanics are chosen. Mechanics that are familiar and approachable provide three primary benefits: students learn the game quicker, are able to play the game easier, and spend more cognitive capacity on learning material rather than operating the game. Many modern board games provide so

many mechanics (rules) that the game sometimes feels more like a puzzle to figure out. Older games used one or two mechanics with the expectation that player interaction is the focus rather than a puzzle. Depending on the desired learning objectives and game dynamics, either might fit better. Using mechanics that match the subject matter makes learning easier and playing more natural.

Choose mechanics from the subset of mechanics in the Game Design Matrix that link to the selected dynamics. The mechanics combined effect creates an environment (game dynamics) where players "feel" like they're in a situation where using what they have learned is the path to success The efficacy of the game mechanics selection can be assessed based on the results of play-testing.

3.8.3.1 Case Study Example

The Enterprise game mechanics were selected according to the GDM mapping in Figure 10. The game dynamics implemented in Enterprise can be facilitated by many different mechanics, but Upgrading/Downgrading and Choosing are selected to minimize complexity. This allows for a selection of mechanics based on which elements of the "real life" dynamics are highlighted within the game. These selected mechanics work together in a collaborative environment as unique capabilities can be upgraded/downgraded to meet game requirements. Difficult choices must be made when the limited resources only allow for certain elements to be upgraded. This is an example of how several dynamics can be created using only a few mechanics.

3.8.4 Step Four: Create Game

Many mechanics and dynamics require specific components (e.g. hand/deck building requires cards). Cost, lead time to use, and play space also drive component selection. The designer can examine games that have used similar mechanic/dynamic

selections for examples of good implementation. The goal is to create a playable draft that can be modified based on play tests. Component selection involves considering trade-offs between mechanics, dynamics, and the classroom environment. For instance, a common game board provides a single place for everyone to look and analyze the game state but increases component expense and play space. A modular board increases replayability and the opportunity to explore different scenarios but increases design time. Individual player boards are useful for tracking player-specific upgrades, but they also increase component expense and play space as well as making it harder for individuals to parse the entire game space. Cards provide knowable randomness (e.g., in a pack of playing cards an Ace will appear exactly four times). This provides players with some control in developing strategies. However, the cards needs to be balanced so that one strategy isn't dominant. Balancing cards (as well as other game components) takes a large part of the time that a designer spends refining a game. Clever design enables a single card to do multiple things depending on how it's used. Multi-use cards can function as money, resources, powers, and events. They also make it easier to add additional functionality to the game later. However, using them effectively takes time (e.g., the text on the cards needs to be minimized; the icons need to be limited and consistent between cards). Finally, when designing the rules, there are several key elements to consider

- Game Objectives: The "story" behind the game
- Setup: The beginning state of the game
- Sequence of Play: Are their turns? What do players do?
- Win Conditions: The desired end state(s)
- Components: The elements required to play the game

The strength of the GDM process is the ability to quickly create the draft game with playable mechanics and dynamics to begin iteration and development. This process can be repeated several times to develop the game through revisions as each iteration is evaluated.

3.8.4.1 Case Study Example

The established dynamics and mechanics for Enterprise enabled a targeted development focused on creating the components and aesthetics within known constraints using the framework elements. The result of this process is outlined in Table 4. A playable draft was completed within 15 hours of game conception and a developed classroom ready iteration with 25 hours of total design, testing, and production time.

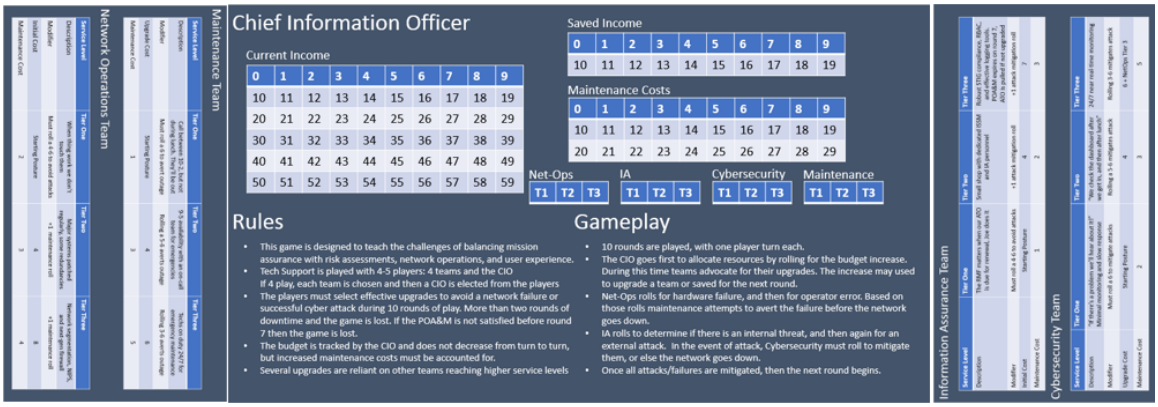


Figure 11. Squadron Commander Dashboard of Enterprise Serious Game.

Table 4. Building Enterprise

Game Objective	Players are Air Force communications squadron branch chiefs working together to prevent network downtime
Setup	Hand out capability cards; shuffle events
Sequence of Play	• Roll dice for player budgets • Players allocate funds to purchase upgrades • Players pay maintenance costs; • Events cards are drawn testing network resiliency • Players mitigate events
Win Condition	Players must complete six rounds and satisfy a POA&M. If the network goes down more than two times then they lose.
Components	board; role, upgrade & event cards; die

Figure 11 shows the basic board and player positions. It allows 4-5 players to take on different roles within the network operations, information assurance, network maintenance, and cybersecurity functions of a large network. The players keep the network operational for six rounds while addressing cyber attacks, hardware failures, user errors, and equipment upgrades. Players collaborate to make purchases/network upgrades, mitigate attacks, fix failures, and ultimately restore services. The game is designed to be played in 10-15 minutes and requires a 5-10 minute introduction time. It is intended for students that already understand basic enterprise operations concepts as taught by the preceding lecture, and does not explain roles or equipment used during play. This allows for significant time savings. Students are expected to immediately begin applying their knowledge to "emergencies" created in the game. A primary objective of the collaboration dynamic is to increase communication amongst the players to provide additional learning through discussion and decision-making interactions.

3.9 Serious Game Design Assessment

The iterative development of the Game Design Matrix allows for data to be gathered at several stages of game design and from several sources. Creating an effective assessment methodology for a game design framework is challenging due to the difficulty of establishing a statistically significant number of games and controlling the level of experience of the designers. This research uses a multi-faceted strategy which combines techniques developed from each of the referenced design frameworks. The primary data collection is through interviews with the game designers, survey results from the instructors implementing the game, and survey results from the students who are playing the game within an established classroom setting. This builds a highly qualitative, but very diverse analysis strategy which is more rigorous than any

single method identified in the related work section. Table 5 is an overview of data collection vectors. The general assessment strategy is threefold: designer, instructor, and player feedback.

Table 5. Data Collection Vectors

	Overview of Techniques & Expectations		
Assessment Method	***Tool***	***Analysis Type***	***Source***
Designer Feedback	Interview	Qualitative	Appendix H
Instructor Feedback	Survey	Qualitative	Appendix I
Student Feedback	Survey	Mixed	Appendix I

3.9.1 Game Designer Feedback Interviews

The primary interaction between game designers and GDM is not easily quantified. A qualitative analysis is performed based on the direct feedback of the GDM users. Designer interviews focus on the specific process of employing GDM to create a game and the natural course of iteration during play-testing. The designers are prompted to articulate specific elements of GDM that presented a challenge or felt incoherent, as well as components of GDM that they felt saved them time and made creating a game easier. Designers are asked how the final product reflects the use of GDM, and speculate on whether the end product was more or less effective due to the design framework. The mechanism for receiving direct designer feedback is through interviews. The interview results are analyzed in Chapter IV.

3.10 Survey Tools for Student and Instructor Feedback

This is a question driven feedback system intended to prompt deliberate thought for each question and allow the subject to contribute valuable information through targeted questions.

3.10.1 Instructor Feedback

The instructor assessment targets the initial impression the instructor has of the game. This is specifically intended as a secondary verification of the incorporation of the learning objectives and the overall coherency of the game. The instructor is given the opportunity to provide feedback through short response as well as through questions answered on a Likert scale. The intent of each question is explained as it is introduced.

1. My impression prior to students playing the game was that it thoroughly covered the learning objectives

Intent: This question is to determine the initial impression the instructor has with the design of the game. It is based on initial impressions allowing for insight into the static analysis of the game by the instructor. This can be analyzed in parallel with question 2 to assess whether an instructors inital impression was accurate.

2. I felt that the game thoroughly covered the learning objectives AFTER observing the students play

Intent: This question seeks to verify the efficacy of the game from the instructor's perspective after they have experienced the game played in their classroom. This question provides substantial evidence on the efficacy of the game.

3. I would consider using serious games for classroom exercises in the future if development time were similar to other exercises and lecture methods

Intent: This question is paired with question 4 in order to determine the level of confidence the instructor has in games within their classroom. This question also seeks to target the significance of design and development time.

4. I would consider using serious games for classroom exercises in the future even if development time took longer than other exercises and

lecture methods

Intent: Same as question 3, but with different specification for design/development time.

5. The game engaged the students

Intent: This question is designed to assess the level of engagement the instructor perceives amongst the students.

6. The game was a beneficial addition to the lesson

Intent: This question continues to determine the level of effectiveness the game brings to the lesson, specifically whether it added value, or simply maintained the same level (or decreased) the learning outcome of the lecture.

7. Please provide additional insight into the strengths/weaknesses of the use of serious games in the classroom, and your thoughts on designing them for future classes if you could use a step-by-step process to create their basic framework (Short Response)

Intent: This question seeks to garner additional feedback from the instructor in a more qualitative/free form manner. The primary data collection is through the Likert scale, but all survey data will be correlated to find specific trends and feedback for confirming or targeting specific elements of the design process for improvement.

3.10.1.1 Instructor Survey Analysis Objectives

The survey questions are designed to be grouped to analyze four specific objectives. These objectives include direct questions as well as indirect questions which are used to analyze background information that can be influencing the survey environment.

- Objective One: Determine the level of engagement the game achieves in the classroom setting (Q5)
- Objective Two: Does the game achieve the targeted higher-level learning ob-

jectives it is designed for (Q1,Q2,Q6)

- Objective Three: Assess the willingness of instructors to use games, and design games for their specific course requirements (Q3,Q4)

3.10.2 Student Feedback Survey and Question Intent

In a similar method, the student feedback survey targets qualitative feedback rather than a direct assessment of student learning. As outlined in Chapter II, the level of mastery assessed in a multiple choice or very short response test is low. In order to elicit a more dynamic level of feedback centered around game design, and the incorporation of learning objectives, the students are presented with pointed questions which allow for analysis beyond simple level of learning. The survey is composed of both a short response, as well as Likert scale questions. The intent of each question is outlined as the questions are introduced.

1. The game complemented the lecture and was a good way to apply the material

Intent: This is a straightforward question designed to elicit the level of effectiveness the game has manifested from the student's perspective. This question is used as an indicator to determine game effectiveness.

2. I better understood challenges and concepts of real-life activities after playing the game

Intent: This question targets the level of application the student perceives reached during playing. It specifically attempts to gauge whether a higher level of learning may have been reached during game-play than the lecture.

3. Playing prompted additional discussion analyzing course material and its role in the game

Intent: This question similarly attempts to gauge the level of learning perceived by

the student, and specifically targets additional attempts to analyze/evaluate elements of the lecture and game to proceed in the most logical way. The results of questions 2 and 3 provide significant insight into the effectiveness of each individual game's desired learning outcome.

4. The time allocated for playing the game was LESS effective than an in class exercise/lab

Intent: This question is a simple tool to assess whether the student felt that the game was a valuable utilization of time. If the games can be shown to be perceived as more valuable than a lecture from a time spent standpoint, then it provides a powerful testimony to the introduction of additional games into the curriculum. This question is specifically worded to avoid a "straight line" survey, and attempts to elicit additional thought from the students rather than just selecting answers based on a single response location.

5. Playing this game felt more engaging than a lecture

Intent: This question attempts to confirm whether the student was engaged by the game, and if it was more engaging than the lecture. This is particularly important because it is considered a strength of serious games, and if it is not more engaging than the lecture then there may be a design flaw.

6. The game was too difficult

Intent: This question targets the level of information the students are introduced to within a limited amount of time. If students as a whole consider the game too complex and an insufficient introduction time was reported, then there is reason to consider that a new data collection may be needed to properly assess the effectiveness of the game or the game may need to be iterated into a simpler version. If students consider the game too complex, and also felt that the introduction was sufficient, then the design elements should be considered. Incorporation of environmental constraints

within the dynamics pairing is particularly targeted in this question.

7. The game dynamics and injects felt realistic

Intent: This question is meant to target the selection/abstraction of dynamics. Some dynamics are critical to keeping the experience grounded in a somewhat realistic process/activity. If that is lost then the selection process may need additional development.

8. The team had to think critically about where to apply resources

Intent: This question seeks to determine both level of thinking the player felt they employed, as well as perceived level of game difficulty.

9. Players had to interact in order to play the game well

Intent: A goal of many games is to create additional conversation about topics found in the lecture, and stimulate learning through group discussion in a natural manner. This question seeks to assess the level of additional interaction present during gameplay

10. Games like this are an effective tool to be incorporated into classrooms in order to teach/apply information in an engaging manner

Intent: This question attempts to gauge the students reception of the game, and if they considered it to be an effective teaching tool. It highlights the higher level of learning and engagement that the game seeks to provide.

11. I would be interested in seeing similar games in future Air Force courses

Intent: Question gauging the overall level of player interest in future games. This question is paired with Q10 to compare game interest inside and outside of Air Force classrooms.

If you have any feedback that was not covered in the brief assessment, please leave it in this short response section. (Short Response)

Intent: To give students the chance to clarify answers to the Likert scale questions, as well as provide any other feedback, anecdotes, or similar information about their experience.

3.10.2.1 Student Survey Analysis Objectives

The survey is broken down into four focus areas. Each of these objectives is designed to use direct and indirect questions to assess the effectiveness of the game.

- Objective One: Assess level of classroom engagement (Q5,Q6,Q7,Q10)
- Objective Two: Assess level of higher level thinking (Q1,Q2,Q3,Q8,Q10)
- Objective Three: Assess level of interaction (Q3,Q9)
- Objective Four: Assess extent students and players desire to see additional games (Q4,Q10,Q11)

3.11 Summary

This chapter described the proposed Game Design Matrix and the assessment strategy for determining the present level of efficacy. The game design framework consists of a step-by-step process which begins with identification of learning objectives, environmental constraints, and a specific subject matter (process or specific element of a real life scenario). This is done by guiding the designer through the critical elements of the design stage which are commonly identified as points of contention with fledgling or novice game designers. The assessment methodology is built on an analysis of five existing game design frameworks. These frameworks each use a specific method to initially verify their effectiveness. GDM is tested against each of these methods to create a rigorous evaluation.

IV. Serious Game Designs and Assessments

4.1 Introduction

This chapter introduces the serious games created to assess the efficacy of the Game Design Matrix and presents an analysis of each stage of the game design, play-testing, and application in the classroom. A series of interviews conducted with the game designers and feedback from both instructors and players was collected using the surveys introduced in Chapter III. The primary objective of this assessment is to determine if the learning objectives, dynamics, and mechanics chosen by the designers using the Game Design Matrix have created an effective and useful game. It is important to recognize that the success or failure of a game does not inherently prove/disprove the efficacy of the Game Design Matrix, but rather it allows for a qualitative assessment to be made based off of several factors which cannot be uniformly accounted for in a scale feasible for a purely quantitative analysis. The results of the games created by GDM to this point strongly indicate that GDM provides a scaffolding for novice designers to create an effective game. Furthermore, GDM games have been play-test ready in about twenty hours of design time. This is a marked improvement over games designed by novices in the literature review, which took longer to create and were consistently ineffective.

4.2 Overview of Enterprise

Enterprise is introduced in Chapter III as the case study example for the employment of the Game Design Matrix. This section provides additional detail about the designer, classroom setting, design, and data collection.

4.2.1 Designer

Enterprise was designed by a Cyberspace Operations master's student who had limited experience designing games and had taken an independent study course focused on concepts of game design. For this assessment, the designer is categorized as a novice.

4.2.2 Classroom Environment

Enterprise was played in a classroom comparable to the setting anticipated in the environmental constraints identification step.

4.2.3 Design

The design of Enterprise focuses on modeling the real-life process of operating an enterprise network in a construct that is familiar to Air Force cyberspace operations personnel. It is constructed using the Game Design Matrix to correlate elements of the network operation with game dynamics that can be recreated in a playable form.

4.2.3.1 Learning Objectives

Enterprise targets the following learning objective outlined in Chapter III: "to apply principles of mission assurance and cybersecurity risk management in enterprise network operations".

4.2.3.2 Game Dynamics

The game dynamics selected to foster the learning objectives are selected to create interactions that simulate real-life possibilities through playing the game.

- Collaboration

- Chance
- Resource Scarcity
- Asymmetric Abilities
- Multiple Strategies

4.2.3.3 Game Mechanics

As outlined in Chapter III, the following game mechanics are selected to create the desired game dynamics.

- Choosing
- Upgrading/Downgrading

4.2.4 Data Collection

Enterprise was played as part of the Cyber 200 professional cyberspace education course. This was coordinated with the Cyber 200 faculty, and several instructors were present to facilitate the game play and post-game data collection survey. Students were briefed before the game on the specific details of collection in compliance with the Institutional Review Board (IRB) waiver agreement found in Appendix J.

4.3 Agile Adventure

Agile Adventure is a serious game which teaches the main concepts of Agile Software Development. This section introduces the game and provides detail about the design, designer, classroom setting, and data collection.

4.3.1 Designer

Agile Adventure was designed by an Assistant Professor in the Systems Engineering Department of the Air Force Institute of Technology. The designer had experience with serious games, but had never designed a serious game. For this assessment, the designer is categorized as a novice.

4.3.2 Classroom Environment

The game is designed to be a learning tool within the SENG 593 Agile Software Systems graduate course. The class typically has between 15 and 25 students in each section and is offered multiple times throughout the academic year. The students have the opportunity to work together in the same classroom with the ability to move work spaces to accommodate multiple team sizes and layouts.

4.3.3 Design

Agile Adventure is a multi-player collaborative game designed to apply complex elements of the agile development cycle. The initial construct was created using the Game Design Matrix and modeled an abstracted version of the Agile Software development method by associating game dynamics with the real-life elements present in the Agile cycle.

4.3.3.1 Learning Objectives

The primary objective is "to teach students about the dynamic aspects of Agile software development, explore technical management decisions, and prepare students for assuming technical leadership roles". Two important skills are emphasized as part of this game: decomposing complex requirements, and self-organizing into appropriate teams to implement solutions to those requirements. These are formalized into the

following four objectives

- Students demonstrate mastery of select Essential Scaled Agile Framework (SAFe) principles and concepts to include Agile teams, Scrum, Kanban boards, Program/Sprint Backlogs, etc.
- Students design optimal team structures and decompose complex requirements to maximize business value in minimal time.
- Students evaluate Agile Release Train (ART) performance in terms of business value, average wait times, and team velocity.
- Students understand associated engineering concepts to include DevOps, DevSecOps, technical debt, model-based systems engineering, architecture, etc.

4.3.3.2 Game Dynamics

Agile Adventure is designed to incorporate and model abstracted elements of a complex real-world process into a game. This requires a similarly complex game atmosphere and employs a large number of dynamics. This is possible through the large degree of flexibility identified in the environmental constraints, and the large amount of time the players are given to learn the game. Game play was anticipated to take several hours based on the complexity of the selected dynamics:

- Modular Game Environment
- Chance
- Cooperation
- Collaboration
- Level of Communication

- Time Scarcity
- Infinite Gameplay
- Player Substitutions
- Team Modeling
- Feedback
- Asymmetric Abilities
- Resource Scarcity
- Teams

4.3.3.3 Game Mechanics

The game mechanics selected to facilitate the game dynamics are numerous but related. Each of the mechanics chosen adds an element to other mechanics which can be observed in the dynamics to mechanics mapping in Figure 10.

- Allocating
- Arranging
- Bidding
- Browsing
- Building
- Choosing
- Contracting

- Controlling
- Conversing
- Information-Seeking
- Maneuvering
- Moving
- Operating
- Placing
- Sequencing
- Substituting
- Taking
- Trading
- Upgrading

4.3.4 Data Collection

Data collection through two vectors: student analysis of the game and game material prior to play, and post-play survey. The initial impression of students is available in appendix L. The survey was conducted immediately following a two-hour play period. Students were introduced to the game, the story to be decomposed, and the abstracted elements used to simulate development during the Agile cycle. Each student was given a survey, and each table of four students received an overview of the terms of the IRB waiver for human subjects research as outlined in Appendix J.

4.4 Player Survey Analysis

The player survey was introduced in Chapter III as the primary feedback mechanism for the students to evaluate their experience during play. The feedback is broken down by each game designed using GDM, and a larger analysis of the implications to GDM are discussed in a later section. The intended evaluation objectives each have a grouping of questions targeted to address them.

- Objective One: Assess level of classroom engagement (Q5,Q6,Q7,Q10)
- Objective Two: Assess level of higher level thinking (Q1,Q2,Q3,Q8,Q10)
- Objective Three: Assess level of interaction (Q3,Q9)
- Objective Four: Assess extent students and players desire to see additional games (Q4,Q10,Q11)

4.4.1 Enterprise

The assessment of Enterprise consisted of data collected from n=49 players. The results are shown as Enterprise Question X (EQX), where X is the question number.

4.4.1.1 Objective One - Level of Classroom Engagement

Five questions target an aspect of the level of engagement achieved by the game within the broader classroom experience.

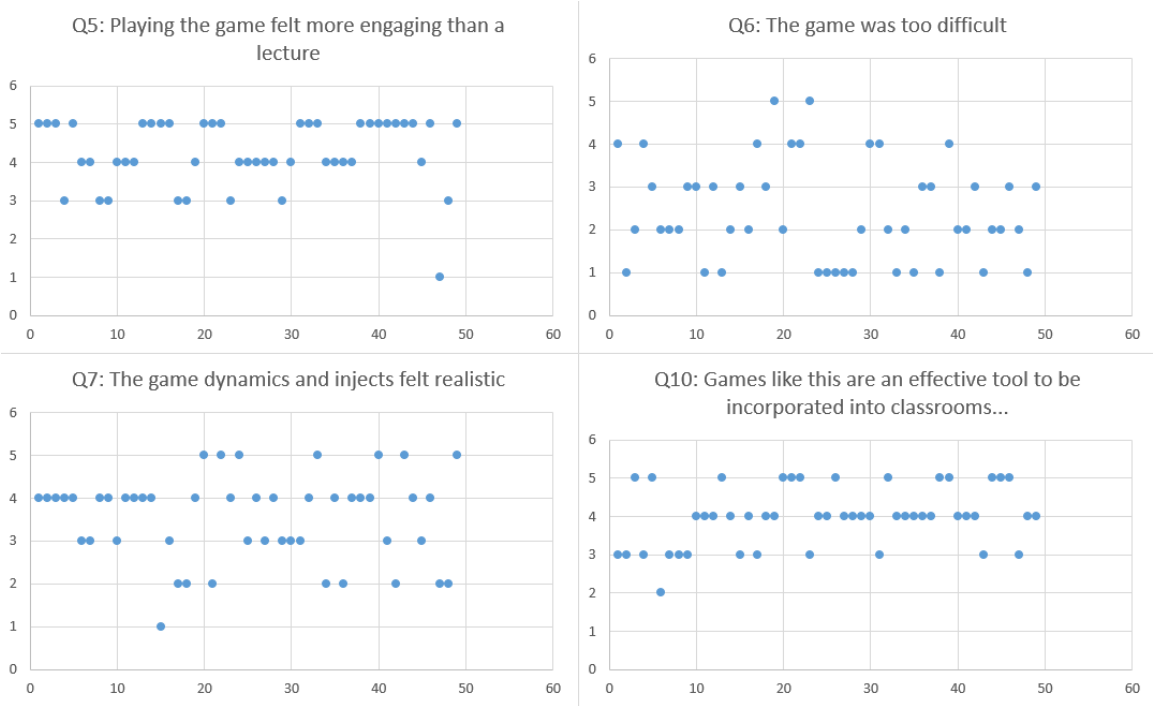


Figure 12. Enterprise Objective One: X = survey response, Y = Score

Table 6. Breakdown of Enterprise Objective One Questions

Measure	EQ5	EQ6	EQ7	EQ10
Mean	4.2	2.4	3.5	4.0
Mode	5	2	4	4
Median	4	2	4	4
Stand. Dev.	0.9	1.6	1.0	0.8

40/49 student responded positively, and only one student negatively to EQ5 when directly asked about the engagement level of the game. This paired with the mode of 5 strongly indicates that Enterprise was successful in engaging students. In an effort to make the qualitative nature of this question more substantial, it was posed relative

to the lecture. It was hypothesized that a correlation might be made between engagement and the players that felt the game was too challenging (EQ6). However, there is no direct pattern between game difficulty and reported effectiveness/engagement. This indicates that the players who were "left behind" during play were not measurably disengaged as play continues. Similarly, EQ7 is paired with EQ5 to evaluate the impact a student's perception of game realism had on the overall engagement. There is no consistent correlation drawn as students which felt the game was less engaging answered EQ7 in several different ways. EQ10 provides background information on overall level of student interest in games. This Enterprise rated highly across player categories of engagement. This is a strong appeal of well designed serious games, but the presence of engagement in a game alone is not confirmation of successful design, but rather a lack of engagement is an indicator of failure.

4.4.1.2 Objective Two - Level of Higher-Level Thinking

Five questions target higher-level learning in an effort to determine if students are forced to think at application level or above. This is a highly qualitative series of questions due to the challenge of targeting this level of Bloom's mastery without a prolonged assessment.

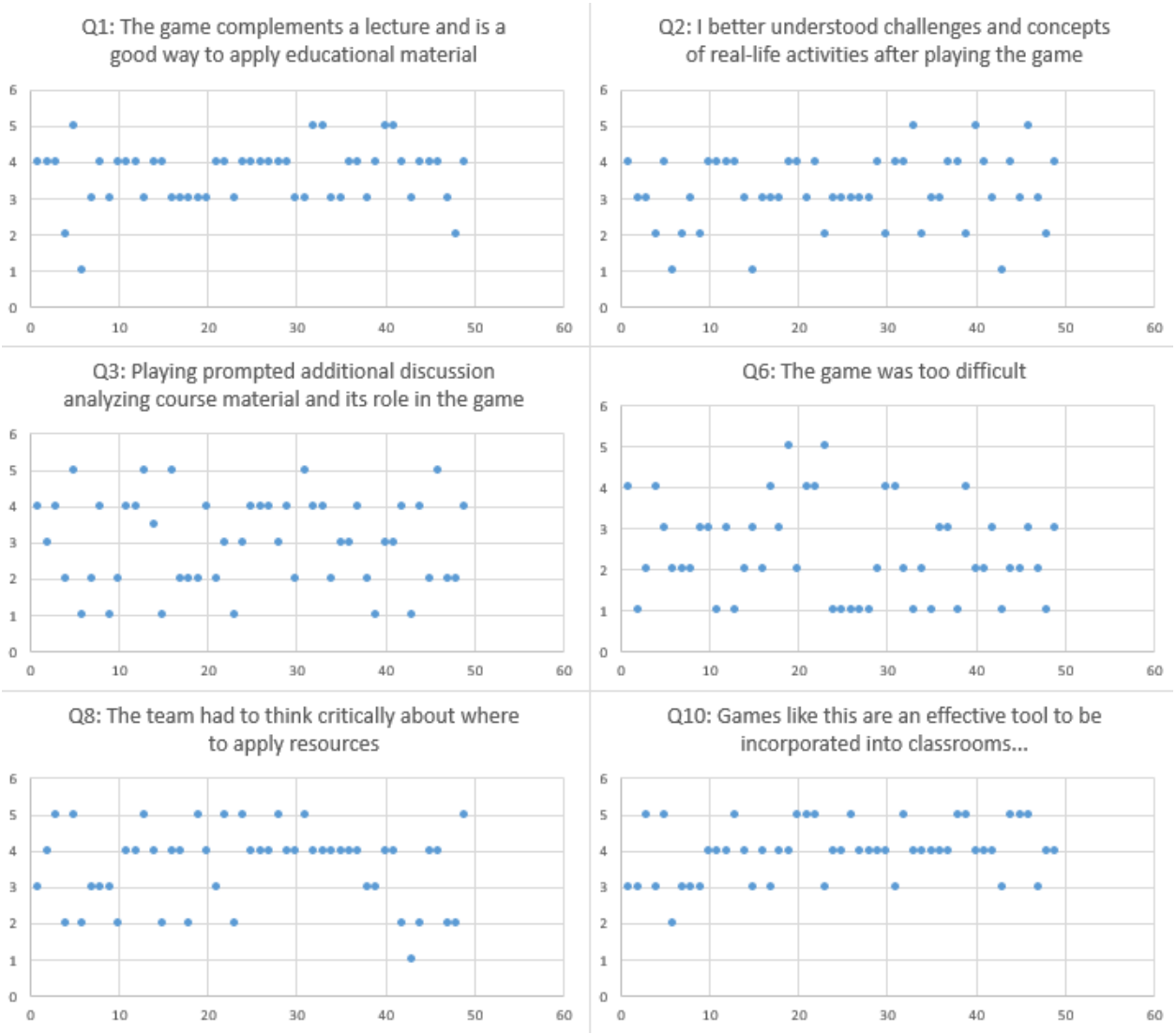


Figure 13. Enterprise Objective Two: X = survey response, Y = Score

Table 7. Breakdown of Enterprise Objective Two Questions

Measure	EQ1	EQ2	EQ3	EQ6	EQ8	EQ10
Mean	3.6	3.2	3.0	2.4	3.6	4.0
Mode	4	3	4	2	4	4
Median	4	3	3	2	4	4
Stand. Dev.	0.8	1.0	1.2	1.6	1.1	0.8

Enterprise outperforms the lecture at a level which trends slightly above mean, but it does not substantially improve all elements surveyed. A weakness in EQ2 is that the question compares knowledge gained from the game to previous knowledge levels rather than a more consistent indicator. EQ6 is an indicator that the player already had significant previous knowledge, and a correlation between lower answers in EQ2 and EQ6 does show that some students already had a baseline of knowledge above the level targeted in the game. EQ1 shows a trend towards higher level learning (application) among most students, but notably included 3 students which did not feel it was effective for them. Thirty percent of students felt it did not surpass the value presented by a lecture. A primary indicator of higher level learning is a student's ability to articulate their understanding, which can be a strength of serious games. EQ3 resulted in a broad spectrum of experiences. EQ8 attempts to determine the level of thinking the players felt they experienced. In this situation the players which indicated they found the game too easy scored the level of critical thinking lower. Overall the majority of players reported the need to use higher-level thinking. EQ10 is a broader question which seeks to answer the higher level question of overall effectiveness. The effectiveness of Enterprise reaching higher-level learning objectives is not an overwhelming improvement over a lecture. At this stage in development the short length of the game and the balancing need additional iteration. Additional game

balancing allows experienced players to remain engaged, while not moving too quickly for newer players. Depth is difficult to achieve in a short game, but it should remain a high priority. This reflects on the overall efficacy of GDM in one of two ways: the dynamics mapping was not mature enough to create the game, or the environmental constraints were severe enough that they negatively impacted the effectiveness of the game design. Significant steps were taken through the development of additional dynamic selection actions to improve the design process, but additional research is needed to assess the impact playtime under twenty minutes has on the stimulation of higher-level learning elements.

4.4.1.3 Objective Three - Level of Interaction

Targeting interaction as a distinct element from engagement allows for an assessment of the level players had to work together beyond operating the basic requirements of the game.

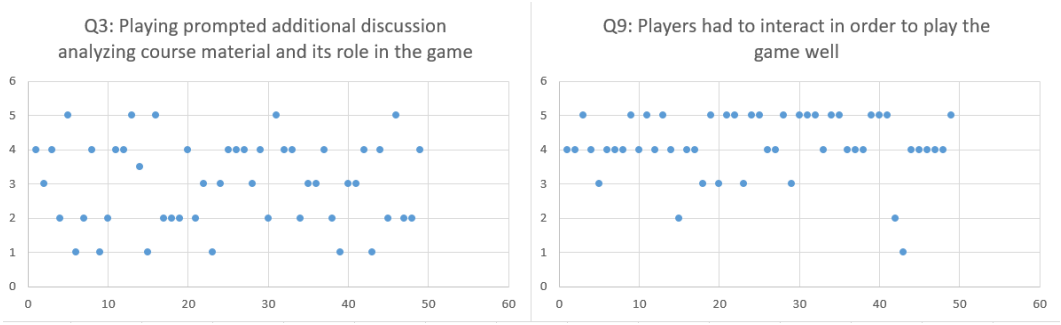


Figure 14. Enterprise Objective Three: X = survey response, Y = Score

Table 8. Breakdown of Enterprise Objective Three Questions

Measure	EQ3	EQ9
Mean	3.0	4.1
Mode	4	4
Median	3	4
Stand. Dev.	1.2	0.9

EQ3 and EQ9 are paired to determine the level of interaction while playing, and the level of interaction that revolved around course material. EQ3 resulted in a broad spectrum of experiences related to interaction. This question can be directly mapped to the responses which reported the game being too hard. It is apparent that when the game difficulty becomes the focus, then the game material is not the focus of the interactions. EQ9 directly asks how much interaction was present in the game, independent of the focus of the interaction. This question strongly indicates that there is a high level of interaction required to play. Paired with EQ3 we see that the focus of the interaction varied greatly, but interaction was a strong element of the game. Initiating subject matter focused interaction can facilitate learning beyond the scope of the game. Creating this element directly impacts the efficacy of game design methods. Enterprise is highly interactive, and this can be considered one of its primary strengths. Many nebulous elements of the learning objectives rely on interactions between players to prompt additional discussion due to the short playtime. Additional development of the game with the intent to focus on encouraging interaction around the learning objectives may result in an increased overall efficacy.

4.4.1.4 Objective Four - Desire for Additional Games

Gauging the overall satisfaction of the players is important when attempting to design games, because a negative perception of games can limit their acceptance and effectiveness.

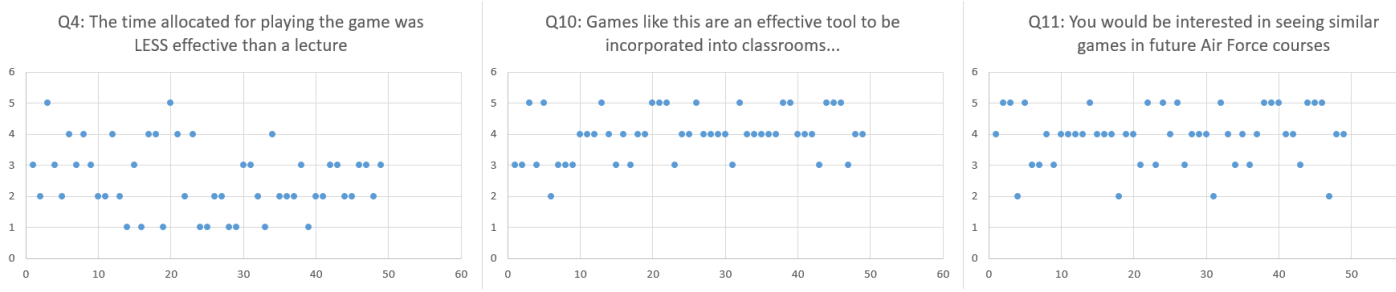


Figure 15. Enterprise Objective Four: X = survey response, Y = Score

Table 9. Breakdown of Enterprise Objective Four Questions

Measure	EQ4	EQ10	EQ11
Mean	2.5	4.0	4.0
Mode	2	4	4
Median	2	4	4
Stand. Dev.	1.1	0.8	0.9

The results of EQ4 trend towards players considering the game more effective than the lecture, but they are not conclusive. Several players did not feel the game outperformed the lecture, but nearly all students felt that game had a place in the classroom. EQ10 is a broad question which seeks to answer overall perception/satisfaction and game effectiveness. EQ11 is designed to specifically gather information regarding the players experience and opinion regarding Air Force education and train-

ing material. The player responses closely mirror the results from EQ10 and indicate that the player experience likely influences their desire to see future games.

4.4.2 Agile Adventure

The assessment of Agile Adventure consisted of data collected from n=22 players. The results are shown as Agile Question X (AQX) where X is the question number.

4.4.2.1 Objective One - Level of Classroom Engagement

Five questions target an aspect of the level of engagement achieved by the game within the broader classroom experience.

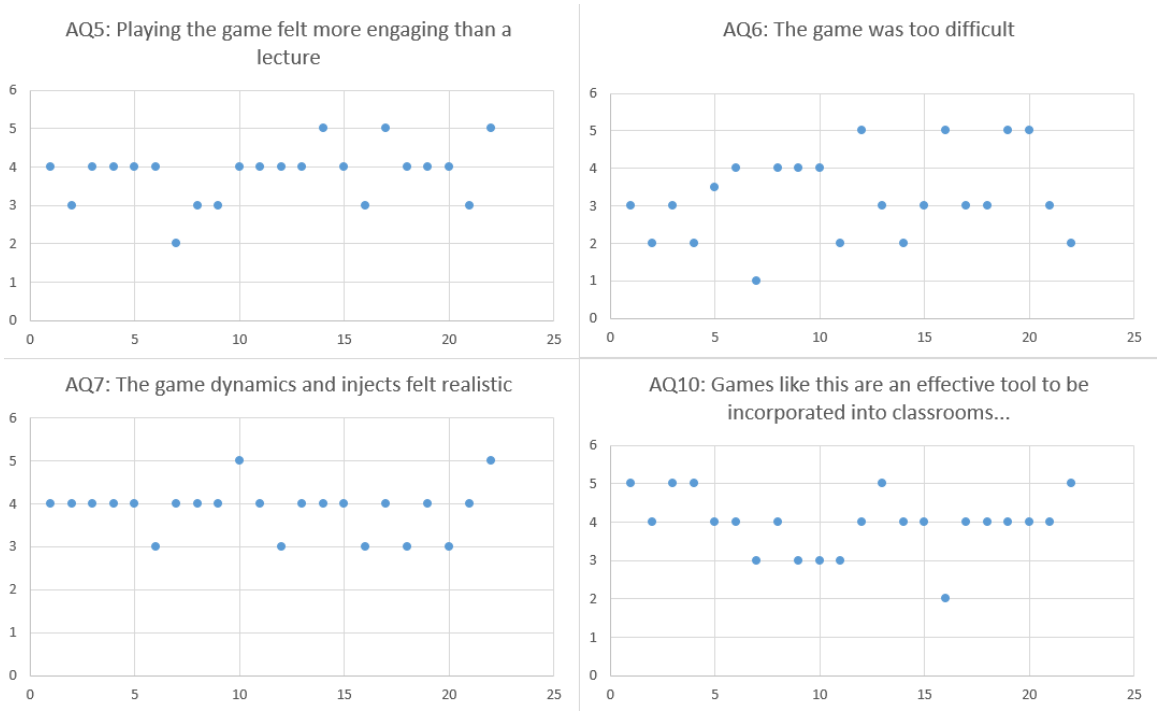


Figure 16. Agile Adventure Objective One: X = survey response, Y = Score

Table 10. Breakdown of Agile Adventure Objective One Questions

Measure	AQ5	AQ6	AQ7	AQ10
Mean	3.8	3.3	3.9	4.0
Mode	4	3	4	4
Median	4	3	4	4
Stand. Dev.	0.7	1.1	0.5	0.8

Agile Adventure scored highly in engagement compared to a lecture. This is a positive sign that the game is well designed but not a clear cut confirmation. The primary measurement of engagement is through AQ5 which gauges player perception specifically. Using a lecture as the baseline provides strong evidence of the effectiveness of the game as a tool to engage students. AQ6 and AQ7 are used to correlate a loss of engagement with player perception of difficulty and realism. AQ6 provides indicators of game balance which can impact engagement. A particular strength of Agile is that many players who rated the game as too difficult still felt it was engaging and effective. AQ7 measures the relation of the game to "real-life". The Game Design Matrix attempts to create a meaningful mapping from real activities to the game. No players rated the game negatively, and the majority considered the relation to be realistic. AQ10 is a general question regarding the game as a whole. The purpose of evaluating it in this objective is to correlate overall satisfaction with level of engagement. Only one player disagreed with the effectiveness of the game, and no significant correlation can be made aside from that player reporting they strongly felt the game was too difficult. Future iterations of the game should attempt to lower the standard deviation of the difficulty feedback by implementing additional measures to guide students through the mechanics, while offering additional challenge to those who quickly master the basic process of Agile.

4.4.2.2 Objective Two - Levels of Higher-Level Thinking

Five questions target higher-level learning in an effort to determine if students were forced to think beyond the level of memorization/understanding.

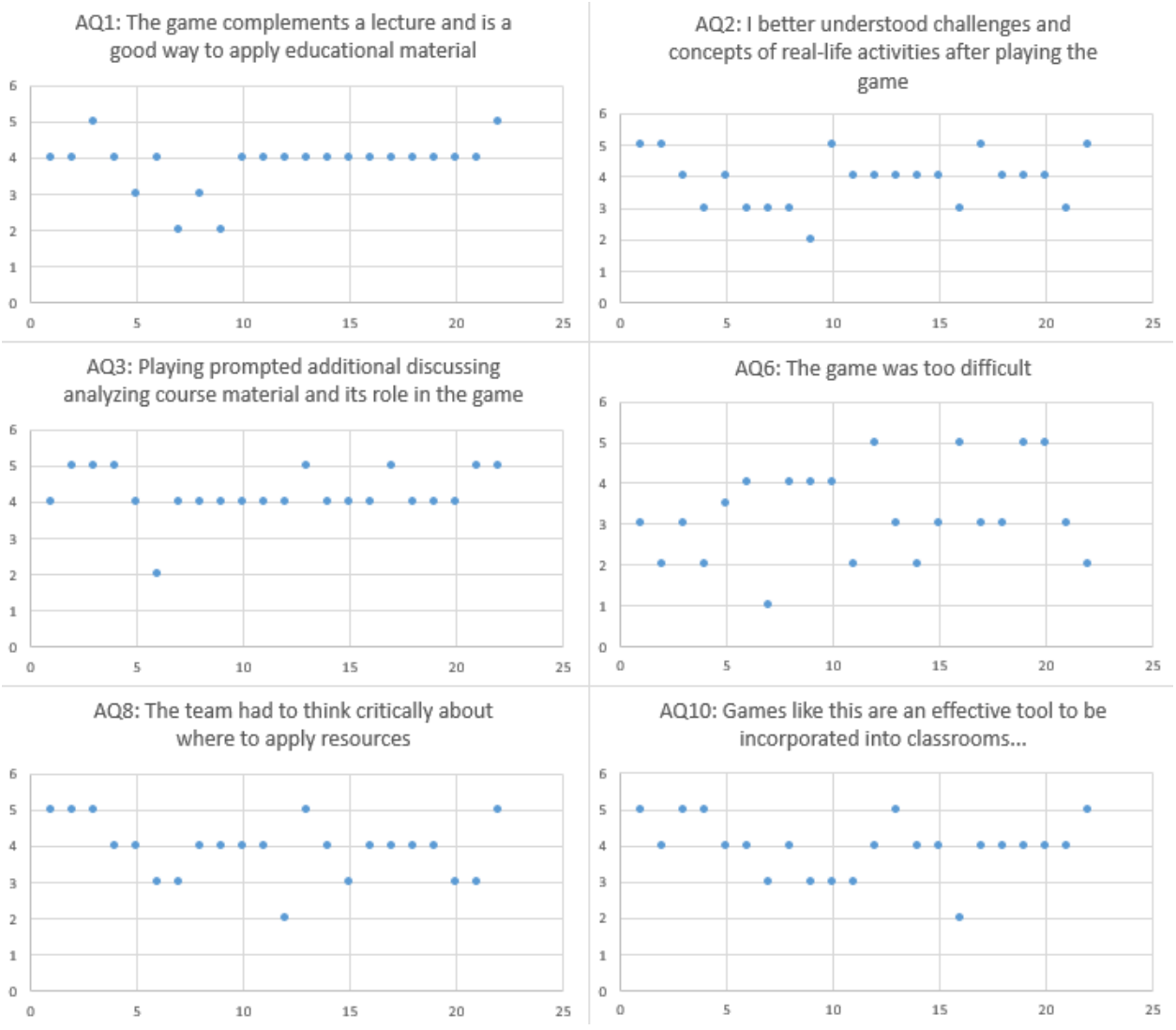


Figure 17. Agile Adventure Objective Two: X = survey response, Y = Score

Table 11. Breakdown of Agile Adventure Objective Two Questions

Measure	AQ1	AQ2	AQ3	AQ6	AQ8	AQ10
Mean	3.8	3.9	4.2	3.3	3.9	4.0
Mode	4	4	4	3	4	4
Median	4	4	4	3	4	4
Stand. Dev.	0.7	0.8	0.8	1.1	0.8	0.8

Agile Adventure scores highly on each learning focused question and scores exceptionally well on AQ3, which is centered on facilitating additional discussion of Agile elements within the game. This is one of the strongest indicators of a successful game. Agile Adventure excels at prompting students to articulate course material to each other. AQ1 measures the extent that students feel the game outperforms or underperforms versus the lecture. AQ2 attempts to determine the level of correlation to real activities the players perceive. There is a strong positive rating indicating that students felt they were learning and relating game-based activities to elements of real life. These are recognized as elements of higher-level learning rather than simply understanding/remembering. AQ3 gauges the level of player interaction and discussion of the course material. Articulate written or verbal interaction is a key element in assessing higher-level learning skills. It remains one of the best indicators of the students's knowledge. AQ6 indicates that some balancing may be required, but it is not significantly hindering game effectiveness. AQ8 is driven by the players perception of how much critical thinking was required to play. Players reported high levels of critical thinking required with the notable exception of a student that strongly rated the game as too difficult. This indicates that they were potentially unable to get past the difficult of the game mechanics. AQ10 is a general question regarding the game as a whole. The purpose of evaluating it in this objective is to correlate overall

satisfaction with level of perceived learning.

4.4.2.3 Objective Three - Level of Interaction

Two questions focus on specific interactions created by the game. Targeting interaction as a distinct element from engagement allows for an assessment of the level players had to work together beyond the basic requirements of the game.

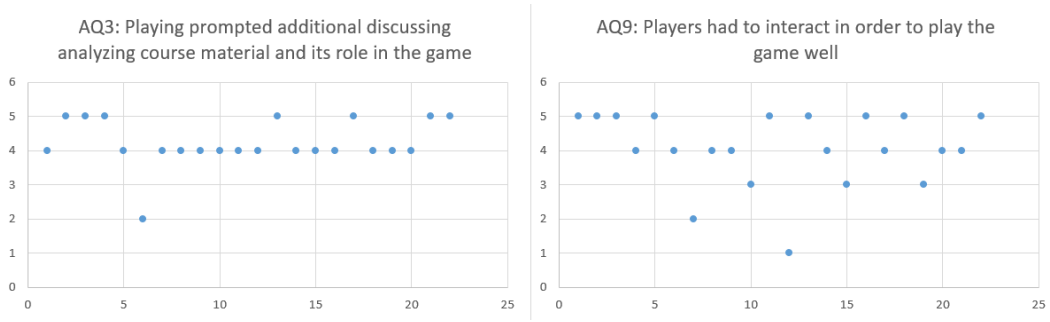


Figure 18. Agile Adventure Objective Three: X = survey response, Y = Score

Table 12. Breakdown of Agile Adventure Objective Three Questions

Measure	AQ3	AQ9
Mean	4.2	4.0
Mode	4	5
Median	4	4
Stand. Dev.	0.8	1.1

The interaction required by Agile Adventure is rated highly in regard to both playing the game and navigating the learning material. This is an indicator of both successful implementation of the desired game mechanics and game dynamics as well as the incorporation of the subject matter. AQ3 specifically targets player interaction

as related to game pedagogical elements whereas AQ9 assesses player interaction at the overall game-play level. This goes beyond the pedagogical elements to include interaction created by game mechanics and dynamics. The responses indicate that some of the players felt interaction was present for the pedagogical discussion but was not required to play the game.

4.4.2.4 Objective Four - Desire for Additional Games

Three questions focus on gauging the overall satisfaction of the players. This is important when attempting to design games because a negative perception of games can limit their acceptance and effectiveness.

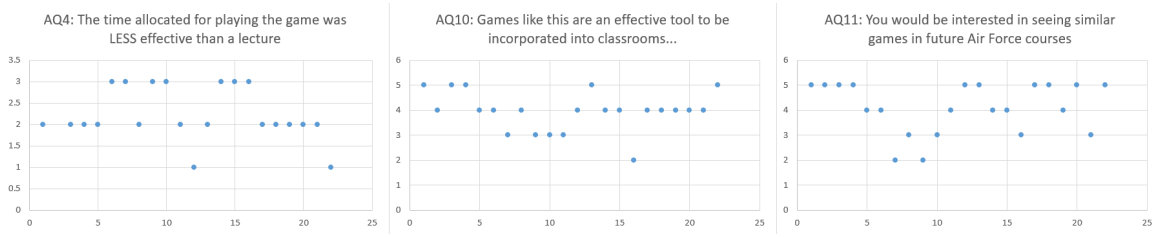


Figure 19. Agile Adventure Objective Four: X = survey response, Y = Score

Table 13. Breakdown of Agile Adventure Objective Four Questions

Measure	AQ4	AQ10	AQ11
Mean	2.2	4.0	4.1
Mode	2	4	5
Median	2	4	4
Stand. Dev.	0.6	0.8	1.0

AQ4 gauges overall effectiveness of the game relative to a lecture. The game scores well when compared to a lecture, and no student rated it as less effective than

the lecture. AQ10 measures the efficacy of games in the classroom from the player perspective. Players responded positively with only one negative response. AQ11 collects the players feedback on their experience and how it relates to future Air Force education specifically. The feedback is primarily positive with both negative responses coming from player that have trended negative across each question domain. This appears to indicate that the player either did not connect with this game, or they do not connect with games in general. Additional trend analysis with the same player set is needed to analyze this further.

4.5 Instructor Survey Analysis

The data gathered from Agile Adventure is through interviews alone rather than the instructor survey, since the Agile Adventure designer who used the GDM process is also the primary instructor. Enterprise was facilitated by four instructors with no direct role in the design. They provided feedback that is presented and initially analyzed in this section. The primary objectives of this survey is to gauge the instructor's feedback on three primary objective areas.

- Objective One: Determine the level of engagement the game achieves in the classroom setting (Q5)
- Objective Two: Does the game achieve the targeted higher-level learning objectives it is designed for (Q1,Q2,Q6)
- Objective Three: Assess the willingness of instructors to use games, and design games for their specific course requirements (Q3,Q4)

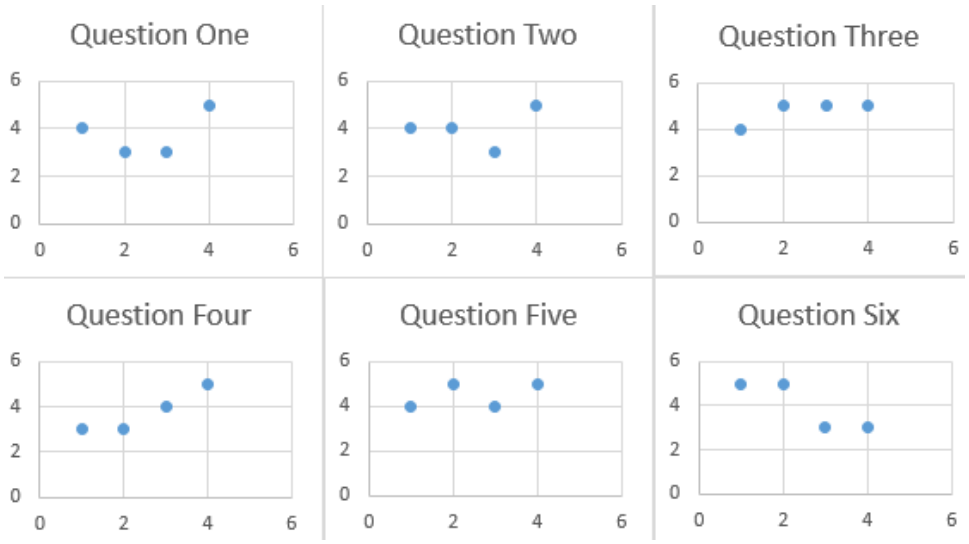


Figure 20. Enterprise Instructor Questions: X = survey response, Y = Score

Table 14. Breakdown of Instructor Questions

Measure	Q1	Q2	Q3	Q4	Q5	Q6
Mean	3.75	4	4.75	3.75	4.5	4
Mode	3	4	5	3	4,5	3,5
Median	3.5	4	5	3.5	4.5	4
Standard Deviation	0.83	0.71	0.43	0.83	0.5	1

4.5.1 Objective One - Level of Player Engagement

Q5 directly asks if "The game engaged the students" and the instructors responded very positively.

4.5.2 Objective Two - Level of Higher-Level Learning

Q1 asks "My impression prior to students playing the game was that it thoroughly covered the learning objectives" in an effort to gauge the initial impression of the in-

structors, but before students have played the game in the class. Many were hesitant to make specific claims prior to seeing the game played, but the overall feedback was good.

Q2 is a followup to Q1 which asks "I felt that the game thoroughly covered the learning objectives AFTER observing the students play". One instructor increased their rating, and two indicated that they felt they could not accurately answer the question until the students had submitted their surveys and a better assessment of performance had been conducted.

Q6 is a general question "The game was a beneficial addition to the lesson". Two instructors rated the game highly, and two instructors withheld rating it highly until they could further analyze the students' experience.

The instructors' assessment of the learning outcome improved slightly after observing game play. The results indicate that the instructors felt the game was effective.

4.5.3 Objective Three - Interest in Future Use of Serious Games

Q3 asks instructors about design time for future serious game applications "I would consider using serious games for classroom exercises in the future if development time were similar to other exercises and lecture methods". This question targets an element of GDM which attempts to shorten the design time of games. Feedback from instructors is important when attempting to determine an accurate target for the tolerable game design time. Instructors were very positive about designing and then continuing to develop games if they took a similar amount of time as normal exercises or labs.

Q4 is a follow up question to Q3 "I would consider using serious games for classroom exercises in the future even if development time took longer than other exercises and lecture methods". It received favorable, but less enthusiastic responses than Q3. No instructor reported being disinterested, but it is a significant hindrance as time is lost in game design.

4.6 Agile Player Analysis

The player analysis focused on introduction to the basic elements of the Agile Adventure. Students were given the opportunity to provide feedback on elements of the game they found good, bad, or ugly. The game was well received and students considered it an appropriate application of agile in the form of a game. Many students reported that they felt they had progressed far enough in the agile software development course that the game was no longer rigorous and recommended playing earlier in the course. It is interesting to observe that the player survey data reflects that many of these students later felt that they did learn from the game. Some students felt the game instructions needed additional clarity, and that feedback is applied in the next iteration cycle of Agile Adventure.

4.7 Designer Feedback and Analysis

The designer feedback from Enterprise was directly from the designer - creator of GDM. This process was the first case study and the results were directly reflected in the second iteration of GDM. The primary method of receiving feedback for Agile Adventure is through the use of in-person and email correspondence interviews. This is a qualitative method of assessment which occurred throughout the iterative development of GDM, and as a result it is challenging to present quantifiable evidence of an effective design process. The feedback and its effect on the development of GDM

is discussed for each game, and the modifications made are outlined accordingly.

4.7.1 Enterprise

The designer of Enterprise worked with the Cyberspace 200 cadre to create a game for the Risk Management Framework instruction block. This is the initial proof of concept using the first version of GDM.

4.7.1.1 Game Design

The design of Enterprise was dominated by environmental constraints placed on the game by the highly structured Cyberspace 200 course. This led to a constraint focused dynamics selection process in the refactoring of GDM in version two of the design process.

4.7.1.2 Game Design Time

Enterprise was designed and drafted in approximately twenty hours with the first play test occurring with a group of master's students with significant experience in the field of cybersecurity and cyber risk management. After a refactor based on feedback on the game play and subject matter it was played with the Cyber 200 cadre for additional fine tuning. The third iteration was the version played in class.

4.7.2 Agile Adventure

Agile Adventure starkly contrasted the environment of Enterprise and was built into a course designed to teach Agile software development by the course instructor.

4.7.2.1 Game Design

The low number of environmental constraints gave the game designer a high level of flexibility when choosing the game dynamics, and the second iteration of GDM was specifically focused on using the environmental constraints to isolate and eliminate dynamics which were not appropriate, rather than focus on dynamics which could foster the best game climate. The methodology the designer appended to the dynamics selection process is described further in Appendix L including the specific excerpt: "I specifically drew from my modeling experience to craft this game. I took the full Scaled Agile Framework (SAFe) and abstracted away details that I felt were not critical to my course learning objectives. The concepts and components that remained were then compared with game dynamics/mechanics for potential matching". This concept was clearly missing from GDMv2 and is addressed in the Chapter III methodology of GDM through the development of the dynamic-process modeling addition to the dynamics isolation step. This is the most significant addition made to GDM over the course of the initial game design case studies.

4.7.2.2 Game Design Time

Agile Adventure was designed and the first playable version was created within approximately twenty working hours of initial conception. It is important to recognize that this is a playable rough draft, that was then iterated multiple times before the version played in the class was complete. A play test was conducted with faculty and developers in the department with experience in the field, and the game was refactored based on feedback regarding both design elements and subject matter. The game was iterated following the play test, and small adjustments were made over the course of preparing new components.

4.7.2.3 Additional Notes

The designer of Agile Adventure is particularly interested in guided development of the game through different branches. This may take the form of a classroom version similar to the current iteration targeted at different levels of education, as well as versions which focus on different elements of the Agile process. This is detailed further in future work.

4.8 Meta-Analysis of Game Design Matrix

Combining the student player feedback, instructor feedback, and designer feedback provides assessment details from the perspective of each human interaction with elements of both GDM and the games created using GDM. The efficacy of each game and the implications made on the efficacy of GDM are discussed in this section.

4.8.1 Enterprise: Designed using first iteration of GDM

Cross referencing instructor and player feedback with designer interview data yields an overall picture of the efficacy of Enterprise. This section outlines the lessons learning and level of effectiveness from each objective covered earlier in the chapter.

4.8.1.1 Overall Game Efficacy

Enterprise is not a flawless game, but it is a game designed within significant constraints. The feedback from the first in-class testing indicates it is at a level where the game is as effective as a lecture for teaching the material, and it has the additional engagement and interaction of a game. This may be improved with additional development as game balancing improvements are made to allow students to focus on the learning material, but additional research is necessary to validate this hypothesis. In the future it is recommended to add questions which assess the level of

game experience the players have, as well as their level of experience with the subject matter.

4.8.2 Agile Adventure: Designed using second iteration of GDM

Agile Adventure is a simpler game to analyze due to limited feedback domains. Cross referencing the student player information with the designer feedback allows for significant insight into the direct impact design choices had on the game. Agile Adventure had much more flexibility on its implementation which left more room for analysis of game dynamic selection.

4.8.2.1 Overall Game Efficacy

The player feedback from Agile Adventure shows that it is an effective game with well incorporated design and learning elements. The primary designer focused on a "real-life" dynamic modeling of a process that they desired to replicate in a game. The modified design methodology used by the creator of Agile Adventure to augment the second iteration of GDM, GDMv2, chose dynamics based on the subject matter with the intent to simulate the process of agile software design. GDMv3 takes this concept and molds the dynamics selection process around abstracting real-life dynamics into the game. Situations with strict environmental constraints may still create effective games, but they will be hindered by the lack of implementation flexibility. This produced a strong and accurate application for the selected learning objectives. The avenue for future Agile Adventure development is improvement on game balance. The specific feedback generated has been collected by the designer and will be used for future iterations of the game. Future research will analyze the level of effectiveness this process has on creating a standardized user experience.

4.8.3 Game Design Matrix Version Three

The design of each game analyzed in the previous section was used as a case study to continue development of GDM. The current iteration presented in Chapter III is the product of feedback from each collection source reviewed in this chapter. The extension of the environmental constraints identification portion of dynamics selection was the product of Enterprise's design and testing. Several steps were taken during the design of Agile Adventure to continue developing dynamics selection to include an active designer-driven dynamics modeling and association step. This process of identifying elements of "real-life" and abstracting away unnecessary pieces to focus on the desired learning material has become the cornerstone of GDM. GDMv3 has a smaller emphasis on the mapping of game dynamics to levels of Bloom's taxonomy due to the considerable challenges presented by measuring the effectiveness of the level of learning present in a game. As game assessment develops, it will be possible to further integrate that element into GDM. At this stage in assessment, it can be stated with a high degree of confidence that games designed to reach higher-levels of learning can achieve them, but it is difficult to isolate specific levels at specifics points in the game. This is explored further in future work.

4.8.4 Current State of GDM

The development of GDM follows an iterative cycle following each round of game design feedback. The strength of this method is its ability to adapt quickly as new ideas are introduced by designers, and the expectation that the process will not yield the same product depending on who implements it. This gives the designers significant latitude to operate the process within their specific use case as a tool to improve the final game design product. GDM is not designed to create novel game mechanics or dynamics, but to constrain novice designers to commonly recognized and effective

game elements. This provides consistency and structure that is not present in other game design methodologies. The loss of some novelty in exchange for more consistent designs is deemed an acceptable trade-off for a framework targeting designers that are less likely to produce a complete game on their initial design efforts. As designers become more experienced, the use of GDM may be less necessary. Intermediate to advanced game designers may benefit from the flexibility and freedom offered by other game design methodologies.

The results of the games created by GDM to this point strongly indicate that GDM provides a scaffolding for novice designers to create an effective game. Furthermore, GDM games have been play-test ready in about twenty hours of design time. This is a marked improvement over games designed by novices in the literature review, which took longer to create and were consistently ineffective.

4.9 Summary

This chapter described the experiments conducted on the games designed using GDM, feedback from the designers, and an analysis of the efficacy of each game. The creation of two games, Enterprise and Agile Adventure, is discussed and analyzed following data collection from play in an active classroom setting, the experiences of the class instructors, and interviews with the game designers. This information is used to make modifications to the GDM dynamics selection process in order to allow for a process driven game design which models the real-life subject matter application. Through the implementation of GDM, an improvement in both game effectiveness and decreased design time are observed in games designed by novice game designers.

V. Conclusion

5.1 Introduction

The sparse selection of serious games can be partially attributed to the high barrier to entry for a designer to effectively create a playable serious game. The Game Design Matrix enables novice designers to create effective serious games using a scaffolding to construct a game based on learning objective optimized dynamics. This dynamics driven methodology is assessed through case study games designed using GDM and tested in a live classroom. Each game is designed by a novice and shown to be effective as a teaching tool. GDM offers educators a new viable option when considering serious games for their classroom.

5.2 Hypothesis and Research Objectives

The premise of this research is the feasibility of enabling novice game designers to increase their efficacy by creating a game design scaffolding. This is accomplished through the construction of a guide capable of combining the primary elements of a serious game, game dynamics, game mechanics, and learning objectives. A step-by-step design framework is created and assessed to determine the viability of this hypothesis.

5.2.1 Summarize Argument

The argument against building a game design framework targeted at novices is centered around several works showing they have been unable to reliably create effective games. The intent of this research is to increase the tools available to instructors and teachers who are interested in employing serious games but do not have games suitable for their requirements available. The Game Design Matrix is designed to

enable these teachers by providing a step-by-step game design guide. A secondary objective of this design methodology is to decrease the design time required in order to offset the time required to add material to an existing class. The development of several game design elements were necessary to form the Game Design Matrix including a comprehensive list of game dynamics, association of game dynamics to a level of learning, mapping of game dynamics to mechanics that can be used to create them, and a game design assessment strategy.

5.3 Results

Novice game designers who were subject matter experts in the material used as the topic of the game created two case study games designed using pre-determined learning objectives from active classrooms using GDM. These games were played by students, and the data collected shows that the efficacy of the game exceeded the results seen previously in games designed by novices. Each game was observed to be as effective as a lecture and in many cases more effective when classroom engagement and interaction is considered. Each game was considered playable, and while feedback was collected to improve each game in further iterations, the games were all in a state of maturity appropriate for educational play. The design time for each game took approximately 20 hours from conception to the first play test. The overall assessment concluded that each case study game was effective. This is a measurable improvement over the previous research conducted using a state of the art serious game design framework and novice game designers.

5.4 Effectiveness and Quality of Research

The iterative development strategy used to create the Game Design Matrix is intended to make GDM flexible and adaptable to feedback from each stage of assess-

ment. The level of effectiveness of the feedback received directly affects the quality of the final product.

5.4.1 Research Constraints

The primary limitation in conducting research is recruiting educators to create games using GDM. The secondary limitation is the time constraints on the assessment period. The games assessed in Chapter 4 provide significant qualitative feedback used to assess the state of GDM, but there is not an available method of quantitative assessment. The limited number of volunteer game designers also prevents a statistically significant number of games designed. This prevents a high confidence level assessment confirming the efficacy of the design framework.

5.4.2 Strengths of Assessment

The multi-iteration design model used to create and develop GDM allows for a designed evolution as the experiences of each novice designer contribute to the framework. Creating multiple games as case studies and assessing them within a predetermined environment allows for analysis of GDM in a live classroom. The players surveyed are volunteers and actual students playing the game as part of a course. This method of assessment provides a full spectrum of players, from players which do not regularly play games, to players who have significant game experience.

5.4.3 Speculation

Several students in the Enterprise player survey reported that the game was too difficult, and that they did not learn as much as a lecture. Based on some of the write in comments these players had very little familiarity with games, but no significant conclusions could be drawn because level of experience with games was not well

assessed in the player survey.

5.5 Contribution

- Enables Novice Game Designers
- Proposed Inclusive Game Dynamics List
- Associates Game Dynamics to Level of Bloom's Taxonomy
- Proposes Dynamics Driven Game Design for Novice Designers
- Proposes Activity-Model Based Game Design Methodology
- Creates Scaffolding for Game Designers Including all Basic Game Elements

Novice game designers have been shown to create ineffective games when using state of the art design frameworks. The primary contribution of GDM to the field of serious game research is by enabling novice game designers to make effective games which target high level learning objectives. It is important to differentiate from existing design frameworks based on MDA because GDM is developed as a step-by-step guide. The framework fills in many areas designed to be left open to the designer in other frameworks. This gives the designer less opportunity for creativity, but creates a consistent and repeatable design process. Each element in GDM which fills in a step of the game design process can be identified as a contribution to the field in at least one form. Comprehensive game design research has not been targeted at novice game designers at the level of GDM in previous work.

5.6 Future Work

This section outlines areas where insufficient research necessitated difficult choices by the author, and elements of GDM which would benefit from additional develop-

ment.

5.6.1 Serious Game Dynamics

The list of game dynamics created for GDM was built as an element which can be modified or substituted easily in order to keep GDM at the state of the art. The dynamics chosen for GDM were based off of an assessment of game dynamics commonly used, but there is not a sufficiently researched list of dynamics currently available.

5.6.2 Serious Game Assessment

This problem is twofold: there is a need for better serious game assessment methods that can target specific levels of learning and the element of the game that drives it, as well as a method of using games to assess the level of knowledge or learning that a student displays through game-play.

5.6.3 Serious Games as an Assessment

The basis of GDM is targeting learning objectives and including elements designed to facilitate them at the most basic levels of composition. This can be greatly strengthened or extended to include serious games as assessments with additional research into mapping player performance to learning.

5.6.4 Creating Digital Game Design Tool

The current version of the GDM whitepaper found in appendix K is designed to be a guide for game designers to select elements of basic games. The downsides to this method is the intimidating size of the whitepaper. Representing the elements of games within a browser platform would allow for a smoother design process and streamlined

introduction of game dynamics and game mechanics. Building a mechanism to save and iterate game designs with the ability to compare two designs would similarly enable a novice designer to make basic adjustments easier.

5.6.5 Creating Game Design Models

A primary avenue of research to extend the basic design scaffolding built by GDM is through the creation of game design models. This can be paired with the digital adaptation of GDM to give designers examples and models of existing games. These games offer specific applications broken down by learning objectives, game mechanics, game dynamics, and game components as a template for novice designers to employ in their own specific game design. This takes the basic game framework designed using GDM to the next level of creation by giving the designer similar games to use as a basis for selection of both components and subject matter inclusion.

5.7 Conclusion

The Game Design Matrix has been employed by novice game designers to create case study games which have been effective in a classroom environment. Future development of game dynamics mapping methods to both game mechanics and learning objectives will improve and bolster the effectiveness of GDM. The effectiveness of the initial case study games demonstrates the capacity of GDM to create effective games within graduate level courses, but additional research will be needed to show that this effectiveness extends to digital games and other forms of teaching games.

Appendix A. Complete DDE Framework

Figure 21. The complete DDE framework [9].

Appendix B. Game Dynamics

Modular Game Board: Elements of the play space which can be manipulated by the players to introduce strategic elements to the game beyond the initial design. Examples: Settlers of Catan expansion packs can allow for shuffling the numerical designators for certain commodity tiles

Fog of war Creating elements of uncertainty by obscuring partner or adversary resources or movements. Example: Card games where a player's hand is only known to themselves, video games where there is only vision within a certain range of the player's resources.

Deck/Hand Building Enabling players to select pieces/cards from a larger group in order to facilitate a more specific strategy within a set amount of "in-play" cards. Example: Dominion and Hearthstone require players to establish which cards are played in the game from a larger pool

Bluffing Allows players to force an adversary into a decision point based off of estimation or statistical analysis of a situation rather than known factors alone. Generally regarded as allowing a weaker player to corner a stronger positioned player into a high-risk high-reward situation. Often requires other dynamics such as fog of war. Example: A player betting high with a weak hand to influence other players into folding.

Chance Incorporates an element of randomness into players decision making. Typically accomplished through introducing specific components such as a random number generator or dice. Example: Rolling die to determine attack power in Risk

Cooperation Allowing players to work together towards a common goal, even if temporary. Example: Two players in Settlers of Catan working together to starve the leading player of a resource.

Competition Creating an objective oriented dynamic which forces players to vie

with each other, or their past performance, in order to complete the required tasks. Example: Multiplayer games that have a "winner"

Conflict Allowing players to actively impede or degrade their adversaries. Example: combat or warfare games.

Collaborating Games with player cooperation that is maintained throughout the experience. Requires defined group objectives. Example: Pandemic.

Level of Communication Limiting the ability players have to communicate with each other, particularly teammates, allows for increased levels of critical thinking and analysis. Example: Spades, Pictionary or Euchre.

Information Control Giving a particular role or player the agency to release information adds an additional strategic element to a situation, which can increase the level of critical thinking and analysis. Example: Viewing party affiliation in Secret Hitler.

Time Scarcity Creating an environment which is reliant on performing under pressure can increase the difficulty of a seemingly simple task. Example: Games with timed turns such as Scrabble or Codenames.

Multiple Strategies Creating separate methods of winning in order to diversify gameplay. Increases the level of analysis required for players attempting to determine a viable path to success. Examples: Shooting the moon in Hearts, or going nil in Spades.

Multiple endings Multiple mechanisms to trigger the end of a game. Increases the level of analysis required for players attempting to determine a viable path to success. Example: Throwing a frisbee through the center hole in Can-Jam

Infinite Gameplay Creating a game which does not have a defined ending. Works best when combined with many other dynamics such as multiple strategies, asymmetric abilities, and hidden objectives. Example: "Grinding" games such as Path of

Exile

Player substitution Allowing players to rotate in and out of positions or even the game in order to add flexibility. Example: Many casino games, such as 21 or Craps.

Player autonomy Giving players substantial ability to make their own decisions, play the game in their own order, and opt in or out of content. Example: Open world video games such as Skyrim.

Team Modeling Allowing players to select roles and traits for their character or position in order to optimize for the objective. Example: DnD, League of Legends, and most team sports.

Real Time Play Games where players cannot pause or halt play in order to make a carefully thought-out decision, or where players might have to make a decision/react at any time. Example: First Person Shooters, Spoons. Hidden Objectives Games where players are unaware of all expectations. This can be an obscured questline, time-delayed random mission card, or an adversary objective that is hidden in the fog of war.

Limited Actions Constraining player ability by forcing them to operate with a set or randomly defined actions list. Example: Dominion, Risk, or the Civ game series.

Feedback Creating a mechanism for players to receive updates on actions/effectiveness. Example: hit markers in FPS game.

Realism Adding lifelike effects to make the game more engaging or interactive. Example: limited stamina/heavy breathing noises in digital games where player characters can sprint.

Negotiation Giving players the ability to barter or engage in trade. Example: Settlers of Catan

Diplomacy Builds off of negotiation, but at a higher and more sustained level. Requires players to maintain relations with other players or player agents in order to

further their efforts. Example: Stellaris, Axis and Allies

Player Ethics Requiring players to make decisions within the context of the moral value of their agents that may have implications at a later time. Often paired with negotiation, bluffing, or diplomacy. Example: Stellaris

Asymmetric abilities Giving players different classes/items/skills/etc in order to provide varied experiences. This must be appropriately balanced, but can favor particular matchups. Pairs well with deck/hand building. Example: Hearthstone

Resource Scarcity Forcing players to compete for necessary items/objectives. Pairs well with cooperation, competition, or collaboration. Example: Settlers of Catan

Adversary Tracking Requires players to pinpoint adversary agent positions or actions through memory or similar mechanisms. Pairs well with fog of war. Example: League of Legends

Teams Requires players to account for the unknown of a teammate. Pairs will with cooperation, collaboration, competition, or team modeling. Example: Spades, FPS games

Appendix C. Game Mechanics

Accelerating / Decelerating Definition: The players are allowed to change the speed of the game element (often component-of-self) they are manoeuvring.Examples: Mario Kart, SSX.Notes: Often a sub-mechanic to Manoeuvring.

Aiming & Shooting Definition: Taking an aim towards a target and trying to hit it with a component (ball, dart, ammunition, etc.).Examples: Throwing darts, kicking a football, shooting bubbles in Puzzle Bobble, shooting with firearms in Halo.

Allocating Definition: Allocating component(s) in possession as quantifiable resource. Examples: Upping the ante in Poker, allocating resources to building hotels in Monopoly.

Arranging Definition: Arranging the order, assembly, or location of game elements, typically components, into sets. Examples: Arranging jewels of Bejeweled into sequences of three, combining Tetris blocks, arranging a Magic the Gathering deck.

Attacking / Defending Definition: Attacking opponent component(s) or defending one's own from them.Examples: Shooting in Max Payne, fighting in the Tekken series or Halo. Taking cover in Gears of War. Notes: Various sub-mechanics (techniques, actions) are possible for combat, such as shielding actions as a defending mechanic.

Bidding Definition: Making an offer on a game component or an area of game environment which is possessed by the game system or another player. Examples: Bidding for paintings in Modern Art the card game.

Browsing Definition: Browsing or moving through possible choices or instances of game elements. Only exists as a sub-mechanic (to, e.g., choosing or manoeuvring). Examples: Browsing inventory in various digital games, manoeuvring around the grid looking for diamond configurations in Bejeweled.

Building Definition: Assembling constructions to the game environment, often

with the help of components and patterns that emerge from components' combinations. Examples: Building a city in SimCity, interior design in The Sims, building channels in board game Ta Yu. Notes: Combination of Placing and Arranging.

Buying / Selling Definition: Buying or selling component, environment location, or information from or to the game system or another player. Examples: Buying real estate in Monopoly, buying accessories in Nintendogs, buying furniture in The Sims.

Catching Definition: Catching a game component, thus gaining possession of it, or returning it to play. Often leads to a Controlling mechanic. Examples: Catching a baseball or basketball, hitting the ball back to play in Breakout.

Choosing Definition: The player is presented with making a choice between a number of options. Examples: Playing Rock-Paper-Scissors, choosing weapons and items for a mission in Tom Clancy's Rainbow Six series, choosing a player role if there are different ones available (e.g, character classes and abilities in role-playing games, etc.).

Composing Definition: The players are afforded means to create images and sounds. Examples: Sound effects in Rez, 'Viewtiful' mechanics in Viewtiful Joe, drawing in Pictionary.

Conquering Definition: Conquering a game environment, thus gaining possession of it. Examples: Conquering a planet via exploration of space in Galactic Civilizations, stealing possession of ball in soccer/basketball/football

Contracting Definition: A contract by two or more players is made through an agreement that is acknowledged by the game system. I.e. informal cooperation is formalised into a mechanic that makes the contract known to the game system.Examples: Assembling a team in sports games, becoming the Shogun player's samurai in the card game Honor of the Samurai.

Controlling Definition: Keeping possession of a component and/or handling/-

controlling it. Examples: Keeping possession of the ball and dribbling with it in basketball or football, playing Croquet, keeping possession of the baton in a relay race in athletics, etc.

Conversing Definition: Players are able to enter into dialogue with game system or other players, and this dialogue has formal consequences to the game state (unlike casual table-talk). Examples: Engaging into conversation with non-player characters, chatting in MMORPGS etc.

Discarding Definition: Discarding a component or using one to displace another. Examples: Discarding cards in a card game such as Gin Rummy or Uno, displacing opponent's token in Checkers.

Enclosing Definition: Enclosing part of the game environment and/or components in order to gain its control. Examples: Enclosing an area in Qix, completing a castle in Carcassonne, Catching butterflies in Loop.

Expressing Definition: Expressing oneself verbally with the means that the game system and technology affords. Examples: Verbally performing a character in a table-top/live action RPG, or expressing oneself by written language in MMORPGS, explaining a word in Alias, singing in Singstar etc.

Herding Definition: Means to control indirectly a component's movement in the game environment and guide it to a certain location.Examples: Herding cattle in Sheep or Harvest Moon, encouraging Yorda character in Ico to jump etc. Notes: The indirect nature of herding means that in some cases its effect is achieved by another mechanic, and there is no particular herding mechanic (in the fashion that there is in Ico). This is the case in Sheep where the sheep components behave in relation to the shepherd's movement, i.e. the manoeuvring mechanic with which the player controls her character takes the function of herding.

Information-seeking Definition: Gathering information or making inquiries about

surroundings, challenges, or other players. Examples: Scanning in Metroid Prime, asking the Game Master hints/elaborations in a table-top RPG, establishing diplomatic relations in Civilization, contacting team-mates.

Jumping Definition: The players are allowed to jump in order to gain best possible result. Examples: Basketball, pole vault, rope jumping.Notes: In e.g. Basketball and Volleyball, this mechanic makes using the Aiming & shooting mechanic much more effective.

Manoeuvring Definition: Manoeuvring a game element in a game environment, including possible chances to jump, fly, etc.Examples: Steering component(s)-of-self or character(s)-of-self through game environments, e.g. downhill in Alpine skiing or along a road in Cycling, or in digital environments, such as the game environments of Pac-Man, Super Mario Bros, SSX, Super Monkey Ball etc.Notes: Often this mechanic has Speeding / Braking sub-mechanics, or the design of the game environment forces/enables change in speed (the labyrinth in Labyrinth Wooden Maze game, the levels in Super Monkey Ball, mountains in snowboarding games etc.).

Motion Definition: The players' bodily stances (postures, gestures, etc.) produce input to the game system or benefit in dealing with its challenges. Examples: Playing Eyetoy games, jumping rope, dancing games, playing Twister.

Moving Definition: Players are allowed to physically move within the game environment. Examples: Football, Basketball, Paintball, most outdoor games.Note: Often combines with Sprinting / Slowingsubmechanic.

Operating Definition: Taking an action where an object belonging to the game system (a component, environment) is operated. Usually the operation executes a game system procedure that produces information or change in other game element. Examples: Rolling dice, spinning a wheel of fortune, opening a door in an adventure game.

Performing Definition: Display of physical skill or physical performance, including simulations of physical performance, which is evaluated by the game system.Examples: Gymnastics, Ice skating, Snowboarding, LARPs, digital skateboarding and snowboarding games.

Placing Definition: Placing a component or a marker on the game environment.Examples: Laying tiles in Carcassonne, playing Dominoes, jigsaw puzzles, drawing a symbol in Tic-Tac-Toe, placing directions in Chu-chu Rocket or waypoint markers in strategy games. Notes: In the case of games like Carcassonne or Ta Yu, this mechanic is used in constructing the game environment, i.e. components transform into another game elements via game dynamics.

Point-to-point Movement Definition: Moving a component or oneself in sequences or turns, e.g., from point to point. Examples: Moving a piece in Chess or Monopoly, moving troops in Starcraft or Heroes of Might & Magic etc.Notes: Possibly includes a submechanic that gives the direction or length of movement. It could also be an operation mechanic in the form of a die roll.

Powering Definition: Players are allowed to use maximum physical power to gain the best result. Examples: Boxing, Wrestling, Weightlifting, Athletics Notes: Strength is a submechanic in many games that use Attacking / Defending mechanics as their primary player actions, emphasizing their effect.

Sequencing Definition: Producing input to the game system in a sequence within a time limit or specific tempo. Examples: Playing Hopscotch, matching the note sequences in Frequency or beats in Dance Dance Revolution, 'Quick-Timer Events' in Shenmue or Dragon's Lair.

Sprinting / Slowing Definition: The players are allowed to change their speed of movement in order to gain best possible result. Examples: 100 meter sprint, Swimming, Cycling, Athletics, getting rid of chasing opponents and creating better

scoring situations in Football/Basketball/Soccer. Notes: Often a submechanic for Moving. For instance, the mechanics of Long jump in athletics is a combination of Moving + Sprinting + Jumping + Strength+Motion mechanics.

Storytelling Definition: Telling or creating a story with the means that the game system affords (and within its rules). Examples: Continuing a story in Once Upon a Time card game, pitching in GameGame.

Submitting Definition: Submitting information (in a format specified in the rules) for evaluation by the game system or other players. Examples: Answering a question in a trivia game or a quiz, submitting a code in Mastermind.

Substituting Definition: Substituting an element in possession, and in play, with another. Examples: Substituting a player into pitch in football or basketball, Sports fantasy leagues, substituting a superhero on a mission with another in Marvel Heroes.

Taking Definition: Taking a game element or a number of them (components, environment locations, information) into possession.Examples: Drawing a card from the deck or another player in various card games, picking up a fish tile in Pingwin, looting items into an inventory in digital role-playing games, collecting items in Animal Crossing, collecting cards by purchasing sets in Magic The Gathering or Pokemon, accumulating cards into hand in Uno, building a game design in GameGame. Notes: Often combined with Choosing game mechanic.

Trading Definition: Exchanging a game element (component, environment-of-self, or information) with another player or the game system. Examples: Changing cards in Poker, or in card game Go Fish.

Transforming Definition: The players are given an ability to transform the flow of time or space to better their chances of overcoming a challenge, or to find out an outcome of their actions. Examples: 'Bullet time' in Max Payne, speed boost in Mario Kart etc., speeding up time in digital strategy games, such as The Sims.

Upgrading / Downgrading Definition: Changing the attributes of a game element, including player role or player contract. Examples: Transforming a pawn into a queen in Chess, gaining a level in character ability in RPGs.

Voting Definition: Casting a vote for one candidate out of a set of game elements. Examples: Naming and voting a resident for eviction in Big Brother television show, voting for the suspect in Werewolf/Mafia parlour game. Notes: Combination of Choosing and Submitting.

Appendix D. Enterprise Rules

Enterprise: An Operational Cyber Risk Game

Instructions

I. INTRODUCTION

Enterprise is a multi-player game designed for Cyber 200 as part of research in serious game design and cyber education at the Air Force Institute of Technology (AFIT). The goal of the game is to teach students about the dynamic aspects of cyber risk management, cyber operations decisions, and prepare students for technical leadership roles. Two important skills are emphasized as part of this game: identifying the collaboration and interdependence of an enterprise network, and understanding basic elements of mission assurance and risk management principles.

II. LEARNING OBJECTIVES

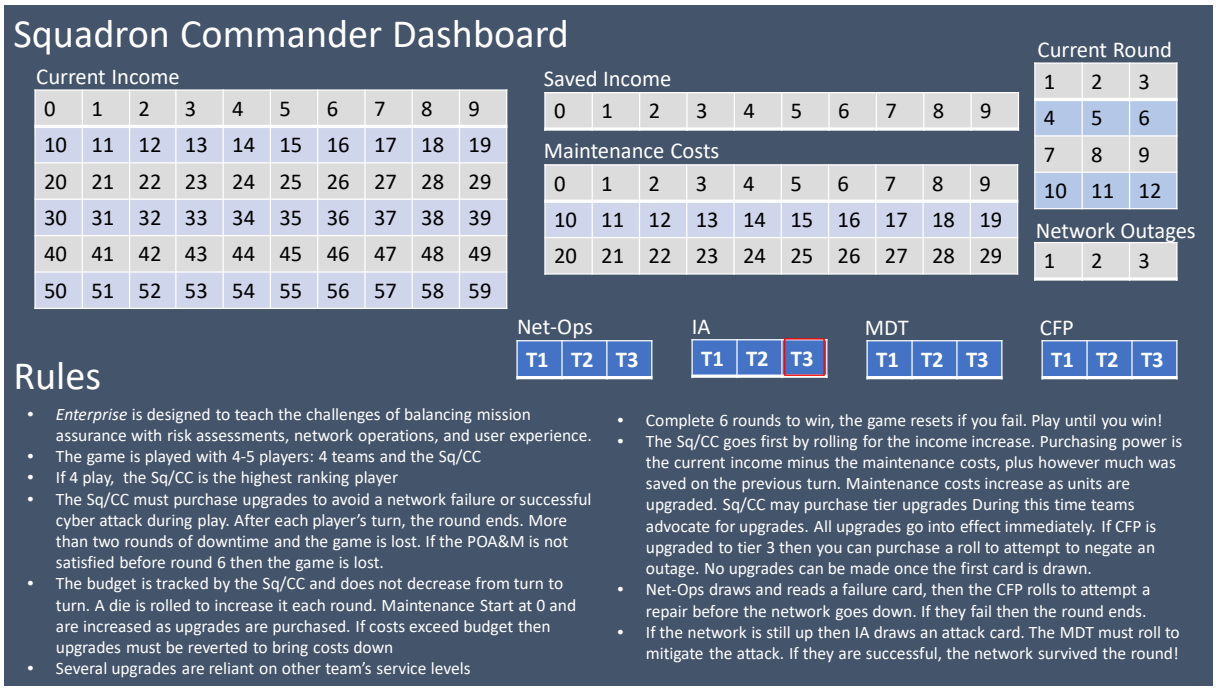
A. Teach students to apply principles of mission assurance and cybersecurity risk management in enterprise network operations.
B. Introduce students to the challenges of balancing network operations with security.

III. EQUIPMENT DESCRIPTION

A. Squadron Commander Dashboard: The primary tool for tracking and assessing progress from round to round, as well as upgrading service level of player roles.
B. Player Role Cards: These cards are dealt to each player and outline the levels of service for each playable role (Network Operations, Mission Defense Team, Communications Focal Point, and Information Operations). These roles are defined by current capabilities, which are outlined on the card, and then their role in mitigating an attack or a failure.

Figure 1. Example Attack and Failure Cards

C. Attack Cards: These cards are drawn once per round and describe an event which occurs during that round. If the network is to be kept "up" then the MDT and IA players must successfully roll to mitigate the attack following the details on the card and their current service level.
D. Failure Cards: These cards are also drawn once per round and describe an event which occurs during the round. They can represent either a software or hardware failure, and they must be addressed by the Network Ops and CFP players in order to keep the network from going down. The failure cards work with similar mechanics to the attack cards.
E. 6-Sided Die: Round will require one least two six-sided die rolls.
F. White Board Marker: Used to mark status on the SQ/CC dashboard.



IV. RULES

This section describes general game play. Play time is organized into games of approximately 20-minutes. The objective is to complete 6 rounds. Any round where there is a failure does not contribute to the 6-round objective. If the network outage counter reaches 3, the current round tracker resets to 0. The game can be continued if time allows.

A. Setup

The game supports 4-5 players. Each player must have an assigned role card. If 4 are playing then a player is designated to act as the Sq/CC and must track progress and make upgrade decisions on the dashboard.

B. Scenario

Each player is now a component of the leadership within a fledgling communication squadron. They have recently struggled with some serious funding issues, and many shops are not providing the services at a level required by their network accredidation. The players must collaborate to best spend their income in order to prevent network downtime. This can be caused by either cyber attacks that are not properly mitigated by the Mission Defense Team, or through hardware/software failures that cannot be caught fast enough by the Communications Focal Point.

C. How to Play a Round

Budget Increases: The round begins when the Sq/CC rolls the die to determine the budget increase. These increases are cumulative (first round is 0 + roll, second round is first roll + second roll, and continuing). The budget may now be allocated towards upgrades. All upgrades go into effect immediately, and are marked on the dashboard. If none are available, or the upgrades do not use the entire budget, then income may be saved until the next round.

Maintenance Costs: Once upgrades are purchased, the increase in maintenance costs must be marked on the dashboard. The costs of the upgrades are also cumulative (Tier 1 = 0, Tier 2 = X, Tier 3 = Y, then at Tier 3 the maintenance costs are 0 + X + Y). If maintenance costs exceed saved income and budget then an upgrade must be reverted to bring down costs.

Net-Ops Turn: The player draws a failure card and then follows the instructions. The CFP will have the chance to roll according to the current net-ops and CFP service levels. If the roll is successful then the failure is mitigated and the network doesn't go down. If they fail, then the network outage is reflected on the dashboard outage counter and you restart the round (you get to roll for new income and purchasing).

CFP Turn: The player works with net-ops to mitigate the failure card by rolling the die.

IA Turn: IA has to track a PO&AM which must be accomplished on or before round 6. This POA&M is to complete IA tier 3. Otherwise, the role is similar to net-ops. The player draws an attack card and then follows the instructions. The MDT will have the chance to roll in order to mitigate the attack similar to the failure card. If they are successful then the current round tracker is advanced by 1, and a new round begins. If they fail then the network outages tracker is increased by 1, and they restart the round (including getting another budget increase and purchasing phase).

MDT Turn: The player works with IA to mitigate the attack cards by rolling the die.

F. Conclusion

Play continues until round 6 is completed. The game is lost if the outage counter reaches 3. The POA&M must be completed on or before round 6. The intent of the game is to teach the challenges of addressing unknown failures and events with a limited budget. Many elements of the game are interdependent in the same way that they rely on each other in real life. This effort to "model" a real-life process in a dynamic and engaging way is the purpose of serious games.

VII. FREQUENTLY ASKED QUESTIONS

A. **How do I know what the maintenance costs are?** Each player's role card shows the cost of their service level upgrades, and the maintenance costs. These are cumulative, and counted on the dashboard. If all tiers are upgraded fully, then the maintenance costs will be the sum of all of those costs (26 points).
B. **Which service should I upgrade first?** The intent of the game is to balance the risk of which upgrade to make first. Depending on income rolls, and the unpredictable nature of the event cards, many courses of action can be justified.
C. **What does +1 to success range mean?** If the card requires a 3 or better, then you now only have to roll a 2 or better. If you have both +1 modifiers then you would only need to roll a 1 or better to mitigate the attack (guaranteed success on a 3 or better event card).
D. **Can I get negate network outages?** If the tier 3 service level for the CFP is purchased, then you have the opportunity to roll for "a new life". You can purchase a die for 5 income points each, and if you roll a 4 or better then an existing outage can be negated.

Appendix E. Enterprise Game Components

Squadron Commander Dashboard

Current Income

0	1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18	19
20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47	48	49
50	51	52	53	54	55	56	57	58	59

Saved Income

0	1	2	3	4	5	6	7	8	9

Maintenance Costs

0	1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18	19
20	21	22	23	24	25	26	27	28	29

Current Round

1	2	3
4	5	6
7	8	9
10	11	12

Network Outages

1	2	3

Net-Ops			IA			MDT			CFP		
T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**

Rules

- *Enterprise* is designed to teach the challenges of balancing mission assurance with risk assessments, network operations, and user experience.
- The game is played with 4-5 players: 4 teams and the Sq/CC
- If 4 play, the Sq/CC is the highest ranking player
- The Sq/CC must purchase upgrades to avoid a network failure or successful cyber attack during play. After each player's turn, the round ends. More than two rounds of downtime and the game is lost. If the POA&M is not satisfied before round 6 then the game is lost.
- The budget is tracked by the Sq/CC and does not decrease from turn to turn. A die is rolled to increase it each round. Maintenance Start at 0 and are increased as upgrades are purchased. If costs exceed budget then upgrades must be reverted to bring costs down
- Several upgrades are reliant on other team's service levels
- Complete 6 rounds to win, the game resets if you fail. Play until you win!
- The Sq/CC goes first by rolling for the income increase. Purchasing power is the current income minus the maintenance costs, plus however much was saved on the previous turn. Maintenance costs increase as units are upgraded. Sq/CC may purchase tier upgrades During this time teams advocate for upgrades. All upgrades go into effect immediately. If CFP is upgraded to tier 3 then you can purchase a roll to attempt to negate an outage. No upgrades can be made once the first card is drawn.
- Net-Ops draws and reads a failure card, then the CFP rolls to attempt a repair before the network goes down. If they fail then the round ends.
- If the network is still up then IA draws an attack card. The MDT must roll to mitigate the attack. If they are successful, the network survived the round!

Communications Focal Point (CFP)

Current Service Level | T1 | T2 | T3

Service Level	Tier One	Tier Two	Tier Three
Description	Call between 10-2, but not during lunch. They'll be out	9-5 availability with an on-call team for emergencies	Techs on duty 24/7 for emergency maintenance
Modifier	Must roll value shown on failure card	+1 to success range on first failure card mitigation roll	Can purchase a chance to negate network outage. Each roll costs 5 saved income. Roll 4 or better to succeed!
Upgrade Cost	Starting Posture	3	5 + T2
Maintenance Cost	0	3	5 + T2

Network Operations Team (Net-Ops)

Current Service Level | T1 | T2 | T3

Service Level	Tier One	Tier Two	Tier Three
Description	When thing work we don't touch them	Major systems patched regularly, some redundancies	Network segmentation, NIPS, and next-gen firewall
Modifier	CFP gets 1 roll to fix failure	CFP gets 2 rolls to fix failures	CFP gets 3 rolls to fix failures
Initial Cost	Starting Posture	5	8 + T2
Maintenance Cost	0	2	3 + T2

Information Assurance Team

Current Service Level **T1** **T2** **T3**

Service Level	Tier One	Tier Two	Tier Three
Description	The RMF matters when our ATO is due for renewal.	Small shop with dedicated ISSM and IA personnel	Robust STIG compliance, RBAC, and effective logging tools. POA&M for logging expires on round 7, ATO is pulled if not upgraded to Tier 3 in time
Modifier	MDT gets 1 roll to mitigate attack	MDT gets 2 rolls to mitigate attack	MDT gets 3 rolls to mitigate attack
Initial Cost	Starting Posture	4	7 + T2
Maintenance Cost	0	2	3

Mission Defense Team

Current Service Level **T1** **T2** **T3**

Service Level	Tier One	Tier Two	Tier Three
Description	“If there’s a problem we’ll hear about it!” Minimal monitoring and slow response	“We check the dashboard after we get in, and then after lunch”	24/7 near real-time monitoring
Modifier	Must roll value shown on attack card	+1 to success range on first attack card mitigation roll	+1 to success range on all attack/failure mitigation rolls
Upgrade Cost	Starting Posture	4	6 + T2 + NetOps T3
Maintenance Cost	0	3	5 + T2

ATTACK!	ATTACK!	ATTACK!	ATTACK!	ATTACK!
ATTACK!	ATTACK!	ATTACK!	ATTACK!	ATTACK!

Insider Threat!

Bob was fired yesterday, but his supervisor hasn't told accounts management about it yet. Roll a 3 or higher to prevent him from wreaking havoc on you network.

Insider Threat!

Several environmentally aware employees are turning off all of the workstations at night before they can be patched. Roll a 3 or better to stop them before they pose a real threat

Insider Threat!

Julio has been embezzling money, but didn't realize the backups had a protected copy of the records he has been modifying. Roll a 3 or better to stop him from wiping out months of backups.

Script Kiddie!

Jordan started off bug hunting, but now he wants to see what he can do to a real network. Roll a 3 or higher to beat a high schooler running exploits from his dad's old work laptop.

Script Kiddie!

King Nigel the 3rd hails from the foreign internet. He's hoping to strike it big in a phishing campaign he is running against email addresses he found on your website. Roll a 2 or higher to keep your employees from trying to reconnect with their long lost royal uncle.

Script Kiddie!

Petya is down on his luck and wants to bring some others down with him. He found a copy of some ransomware that he's spreading to anyone that hasn't patched Windows recently. Roll a 3 or higher to stop the encrypted carnage.

Hacktivists!

Your base leadership has been in the news lately about some of their personal political views. Some fringe groups don't appreciate that and have decided to shut you down. Roll a 3 or better to avoid disaster

Hacktivists!

News just broke that one of your contractors has been using child labor in some of their international factories. "Think of the Children" is an activist group that wants everyone to know you supported unethical activities. Roll a 4 or better to stop their attack

Advanced Persistent Threat!

Ask the MDT which attack vector is exploited in over 90% of successful hacks.
If answer == "phishing": roll a 3 or better to mitigate an incoming email phishing campaign.
Else: roll a 5 or better.

Advanced Persistent Threat!

A large emerging economy needs some new R&D data on a project they're interested in. Your people do good work, and it has caught their eye. Roll a 5 or better to get them to move on to another target

ATTACK!

ATTACK!

ATTACK!

ATTACK!

ATTACK!

FAILURE!

FAILURE!

FAILURE!

FAILURE!

FAILURE!

Hardware Failures!

Your ISP decided not to run redundant gateway routers during an upgrade this week. Roll a 3 or better if you want it to survive

Uneducated Users Strike Again!

Sarah needs some files from her NIPR box while she's TDY. She gives the local admin password to a coworker who then browses the internet while they're transferring. Roll a 3 or better to keep him from stumbling into a worm while using admin credentials

Operational Errors!

The Domain Controller was had a maintenance window to be updated this weekend, but it didn't come back up. Roll a 4 or better to have them fixed by Monday morning

Uneducated Users Strike Again!

Due to a typo, ACAS is now scanning external IP space and filling the external router's ARP table. Roll a 3 or better to keep the network from grinding to a halt

Hardware Failures!

CE has a set of new contractors, and they found your buried fiber line with a backhoe this morning. Roll a 5 or better to find out if you have a failover

Insider Threat!

Bob was fired yesterday, but his supervisor hasn't told accounts management about it yet. Roll a 3 or higher to prevent him from wreaking havoc on you network.

Insider Threat!

Phoebe was offered $1,000,000 to bring her TS hard drive home, clone it, and take it back. Roll a 5 or better to detect the massive data spillage

Social Engineering!

Joey wants to watch the world burn. He got his hands on some classified material and sent it to every unclass inbox on base. Roll a 4 or better to delete it from the exchange server before users pull it down

Script Kiddie!

Ask MDT which format extensions are most commonly used in malicious file downloads

If answer == "Microsoft office": roll a 3 or better to mitigate a click happy user
Else: roll a 5 or better

Industrial Espionage!

A private contractor developed a new process for automating data analysis under one of your R&D directorates. Their competitor plans to leverage its position as your database provider to illegally gain access. Roll a 4 or better to detect their attempts

FAILURE!

FAILURE!

FAILURE!

FAILURE!

FAILURE!

FAILURE!

FAILURE!

FAILURE!

FAILURE!

FAILURE!

Uneducated Users Strike Again!

George has been doing some "research" on his NIPR computer. He's downloaded several files and run the macros using his domain credentials. Roll a 3 or higher to stop the spread of malware.

Operational Errors!

Jason wants to get into the crypto currency game. He has all of the base's idle CPUs working in the mines of Ethereum. Roll a 4 or better to catch him before productivity plummets

Uneducated Users Strike Again!

Jamie just realized that she could use Outlook archives from the share folder and sent out a memo to all 500 department coworkers letting them know they should too. Roll a 4 or higher if you want to be able to use your storage servers today.

Hardware Failures!

The battery UPS hasn't been tested in a few years, but there haven't been power outages since anyone can remember. Unfortunately you need it right now. Roll a 3 or higher and it'll pop on.

Hardware Failures!

It's the warmest summer in over 15 years, and the building AC is on the fritz. Ask the Sq/CC which he values higher: the comfort of people or equipment?
If answer == equipment: Roll a 3 or higher to keep your server room from becoming a sauna.

Else: Roll a 4 or higher

Uneducated Users Strike Again!

Kalel "spilled" some sensitive information to the base mailing list. Roll a 4 or better to delete the email from the exchange server before it can propagate

Operational Errors!

The new firewall has some fun and interesting options that make it hard to replicate the rules from your old one. Unfortunately, your DC is on a VM cluster that isn't completely whitelisted properly. Roll a 4 or higher to avert disaster

Operational Errors!

Crystal was supposed renew the SSL certs last month, but unfortunately the Win10 migration has her distracted. Roll a 3 or higher to keep your highly alert users from avoiding all Air Force sites today

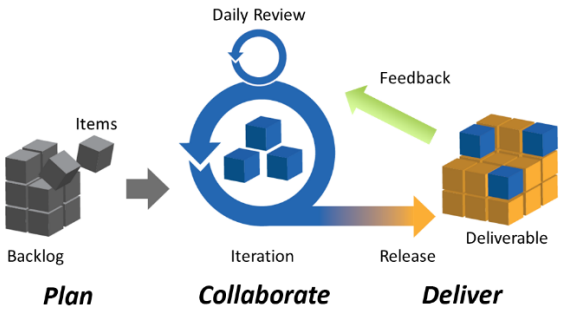
Operational Errors!

The VoIP system is being upgraded tonight, but a routine restart shuts down the update server halfway through. Roll a 4 or better if you want it to start back from where it left off

Hardware Failures!

That Server 2003 box running your DNS server has been end of life for 11 years, it's slated for replacement in 2 weeks. Roll a 3 or better to make it until then

Appendix F. Agile Adventure Instructors Guide and Rules



Agile Adventure: A Systems Development Game

Instructions (Basic Edition)

I. INTRODUCTION

Agile Adventure is a multi-player card-based game associated with SENG 593 Agile Software Systems at the Air Force Institute of Technology (AFIT). The goal of the game is to teach students about the dynamic aspects of Agile software development, explore technical management decisions and prepare students for assuming technical leadership roles. Two important skills are emphasized as part of this game: decomposing complex requirements in order to manage workflow, and self-organizing into appropriate teams to implement solutions to those requirements.

II. LEARNING OBJECTIVES

A. Students demonstrate mastery of select Essential Scaled Agile Framework (SAFe) principles and concepts to include Agile teams, Scrum, Kanban boards, Program/Sprint Backlogs, etc.
B. Students design optimal team structures and decompose complex requirements to maximize business value in minimal time.
C. Students evaluate Agile Release Train (ART) performance in terms of business value, average wait times and team velocity.
D. Students understand associated engineering concepts to include DevOps, DevSecOps, technical debt, model-based systems engineering, architecture, etc.

III. EQUIPMENT DESCRIPTION

A. Role Cards: Describes development capabilities as roles and associated characteristics within an ART and are illustrated in Figure 1. Agile Teams include a minimum of a Scrum Master and Product Owner, and may be supplemented with various development and supporting members. Such members provide characteristics further described in the next section. Such characteristics may be adjusted by Event Cards to increase/decrease skill levels (Apprentice, Journeyman, Craftsman). All cards begin at the Apprentice level.

   Subject Matter Expert (SME) Role Cards are unique in that the represented expertise must be declared at the beginning of each Program Increment (PI) and remain so until the next PI. They cannot be used as a wildcard for any other Role Card.

   Customer Role Cards allow an Agile Team to Analyze one additional User Story per Sprint day.

An Operations Team Member Role Card and Automation Event Card are necessary components to achieve a DevOps environment and reduces the technical debt accumulation rate. DevOps can be upgraded to DevSecOps with the inclusion of a Security Expert Role Card.

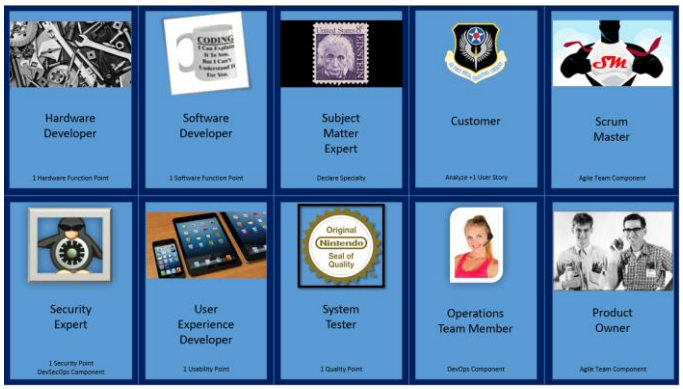


Figure 1. Role Cards

B. Event Cards: Describe development events that may accelerate or hinder progress and are illustrated in Figure 2.
C. User Stories: Describe small pieces of desired functionality written in the user's language. User Story, Feature and Non-Functional Requirement Cards are illustrated in Figure 3.
D. Feature Cards: Describe functional requirements derived from User Stories.
E. Non-Functional Requirement Cards: Describe system attributes and constraints or restrictions.
F. 6-Sided Die: Each self-organized team will require one six-sided die.
G. White Board, Scratch Paper, Writing Utensils: Captures User Stories, Features, NFRs and Architecture sketches during and across play sessions.

Figure 2.

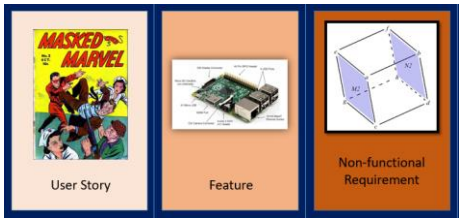


Figure 3.

IV. ABSTRACT REQUIREMENT/CAPACITY/SOLUTION POINT SYSTEM

This point system describes the type and magnitude of a) requirement complexity, b) team capacity to craft solutions, and c) solution maturity. It provides a mechanism to relate these three aspects of the system development effort. The system is adjustable to add (or reduce) characteristics, but the basic edition includes the following:

A. Functionality – describes hardware/software services providing business value.
B. Usability – describes ease and intuitive nature of system use.
C. Security – describes system confidentiality, integrity and availability.
D. Quality – describes satisfaction of customer needs and freedom from defects.

Each User Story, NFR and Feature is described in terms of these points and any additional expertise necessary to address these requirements. Each Role Card provides one or more of these points as team capacity each Sprint day. Sufficient team capacity needs to be generated before these requirements can be transitioned between Kanban board stages. Excess capacity points are added to workflow items as it transitions through the Kanban board.

For example, a single Software Developer generates one Functionality point per Sprint day. After four Sprint days, a requirement of 4 points would be satisfied. Alternatively, two Software Developers may generate two Functionality points per Sprint day and satisfy this requirement in two days. In yet another example, four Software Developers may generate sufficient Functionality points to satisfy this requirement in one Sprint day.

In another example, two Software Developers (1 point each per Sprint day) tackles a 3 Function point requirement over two Sprint days. The work produced is rated 4 Function points because excess capacity is added to the workflow. In both examples, the other characteristics of Usability, Security and Quality work in a similar manner.

V. RULES

This section describes general game play. Play time is organized into 20-minute periods (real time), where each class session plays one or more periods. This game may be played campaign style where the same scenario continued from previous class sessions.

A. Setup

Identify who will be playing the key roles of Release Train Engineer (RTE), System Architect (optional), Product Manager (optional) and Customer. Shuffle the Role Cards into one pile and the Event Cards into another. Gather the User Story, Feature and NFR Cards into their respective piles.

B. Scenario

The Customer (typically external to the class) and RTE (typically the instructor) describe the base scenario to the class and answer initial questions. Every effort should be made to provide the class with a clear understanding of the deliverable as possible at this point to include initial user stories and constraints. The RTE leads a discussion to prompt students to generate ideas on user interfaces, architecture, new user stories and constraints. The System Architect records the architectural ideas and the Product Manager collects and organizes user stories into the Program Backlog. If these roles are not filled, then these tasks fall to the RTE.

Each User Story, Feature and NFR is represented by a numbered card. The associated descriptions and point values are recorded on the white board or scratch paper and indexed by the appropriate numbers on the cards.

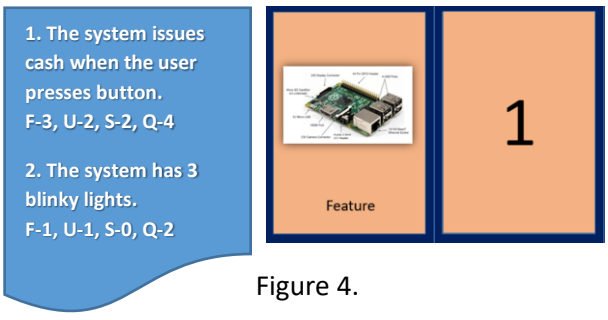


Figure 4.

C. Agile Teams

Students blindly choose a random Role Card and self-organize into teams based on their initial understanding of the architecture and Program Backlog. The RTE leads a discussion on Sprints and Program Increments followed by Scrum Masters reaching consensus of length on each. The RTE ensures that each team has sufficient Event Cards for Sprint execution.

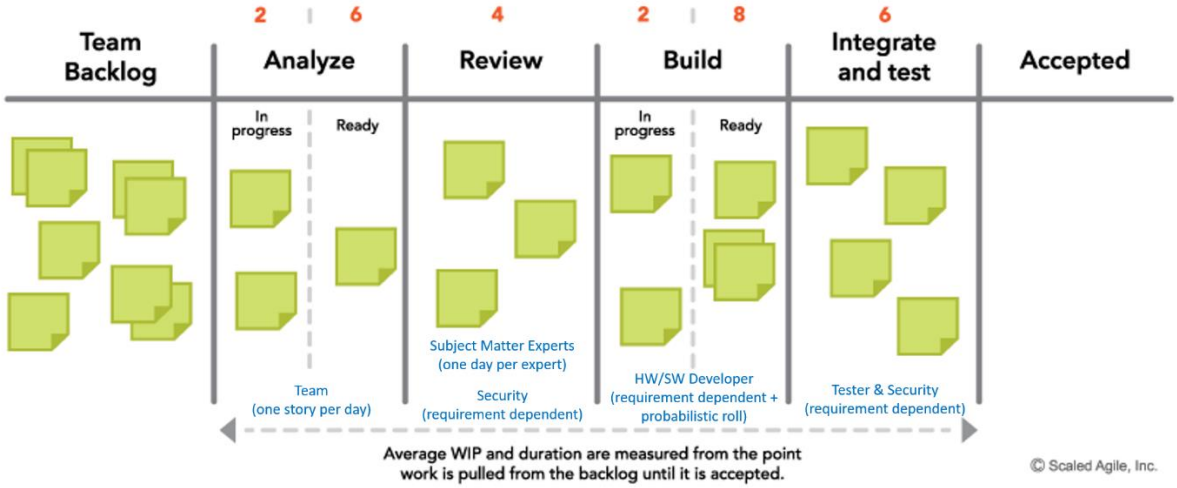
D. Program Increment Planning

The goal of the PI is to reach a minimally viable product (MVP) to show to the Customer. The RTE facilitates a discussion which includes all players. Based on this discussion, each Agile team selects User Stories from the Program Backlog and adds them to their Sprint Backlog by physical passing the card.

E. Sprint Execution

The goal of a Sprint is to build components that satisfy User Stories, Features and NFRs while dealing with random events. The entire Sprint must be completed within 20 minutes regardless of how many days are defined.

1. **Event Cards:** At the beginning of each sprint, each team will first reveal two Event Cards and make appropriate adjustments based on card directions.
2. **Process Daily Workflow:** For each day of the Sprint, execute workflow in each area below based on available expertise within your Agile team and the current state of the Kanban board.
    a. ***Analysis:*** Analyze a subset of the Sprint Backlog at Daily Standup meeting; decompose User Stories into Features
    b. ***Review:*** Review a subset of items from Analysis
    c. ***Build:*** Develop a subset of items from Review; additionally requires a die roll to transition to the next phase
    d. ***Integrate/Test:*** Evaluate a subset of items from Build



3. **Requirement Decomposition:** Agile Teams are encouraged to decompose complex (parent) requirements into simpler and more manageable (child) requirements as described in Figure 5. The summation of child requirement characteristics must be equal to or exceed those of the parent requirement. If a child requirement is still too complex, it may be returned to the Product or Team backlog.

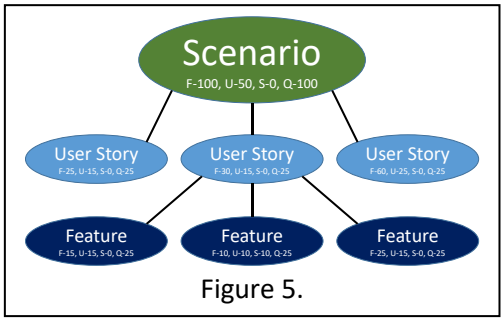


Figure 5.

4. **Build Roll:** Success if player rolls threshold or higher while meeting all constraints (Threshold = Requirement points – Team points + 4)

Probability Table
<= 1: guaranteed success; capes dominate
2 or higher: 5/6 chance
3 or higher: 2/3 chance
4 or higher: 1/2 chance; reqs == capes
5 or higher: 1/3 chance
6 or higher: 1/6 chance
> 6: guaranteed failure; reqs dominate

5. **Bonuses:** If an Agile Team collects all of the components for a DevOps environment, they receive a +1 Usability point and may analyze an additional User Story per Sprint day. If an Agile Team collects all of the components for a DevSecOps environment, they receive a +1 Security point.
6. **Retrospection:** After all days in the Sprint have concluded, determine the total number of accepted Features and team Velocity. Discuss how the team might adjust in order to improve.
7. **Adjustments:** Between Sprints (outside of a class session), students may reform teams in any way with the exceptions a) the same number of teams/backlogs must exist, and b) the Scrum Master and Product Owner must remain attached to those teams. Between PI, these exceptions are lifted.

F. Conclusion

Play continues until a minimally viable product (MVP) is presented to the customer. The MVP is created by integrating Features to satisfy one or more User Stories at the end of each PI. The MVP must also receive an Interim Authority to Operate (IATO) determined by a whether or not the total Security points is greater than or equal to 1/3 of the total Function points from aggregate completed User Stories.

The goal is to satisfy the number of User Stories within a prescribed time and achieve an IATO.

Each student may optionally track total number of Features completed and/or average velocity over the teams they participated.

Multiple campaigns may be played, each resulting in a new MVP. However, for each released MVP, the number of maintenance features increases by one per sprint and must be remain less than 20% of backlog.

VI. EXAMPLE SCENARIOS

A. Team “Awesome” has a backlog of three user stories. During Analysis, the team assesses the following estimated FUSQ points. The team decides that Story #1 is something feasible to tackle, but the others are quite complex and may need to be decomposed.
   a. Story #1: F – 2 pts, U – 2 pts, S – 1 pts, Q – 3 pts
   b. Story #2: F – 4 pts, U – 2 pts, S – 1 pts, Q – 5 pts
   c. Story #3: F – 8 pts, U – 4 pts, S – 1 pts, Q – 10 pts

B. To accomplish Story #1, the Agile Team might consist of a Journeyman Software Developer, a two User Experience Developers, an Apprentice Security Expert and a Craftsman System Tester. This allows Story #1 to transition the Kanban board at a rate of one stage per Sprint day.
C. Since a Journeyman Software Developer rates 2 Software Function Points and the requirement calls for 2 such points, the threshold die roll is 4 (Req – Capability + 4) or higher (1/2 chance).
D. You might consider accomplishing Story #2 with the same team, but it may take longer with a reduced chance of success. This team would require an extra Sprint day in both Build and Test, as well as a threshold die roll of 6 or higher (1/6 chance).
E. Alternatively, you could Level Up! (Event Card) to a Craftsman Software Developer and acquire Automation! (Event Card – doubles quality points) for a threshold die roll of 5 or higher (1/3 chance) with a rate of one stage per Sprint day.

VII. FREQUENTLY ASKED QUESTIONS

A. **Why is the point system important despite not being a SAFe component?** The point system is necessary to abstractly express the type and magnitude of complexity of a User Story, Feature or NFR. It forces players to craft a cross-functional team in order to build an appropriate solution.
B. **Won't the point system confuse SAFe students?** The concepts comprising the point system remain relevant to nearly all system engineering efforts. Although not explicitly part of SAFe, students should at least consider these engineering dimensions.
C. **Why does the Build phase require a die roll?** Requirement decomposition provides an estimate of how long it will take developers to craft a solution. Estimates can be wrong and so the probability roll was necessary to add an element of chance to represent estimate mistakes. Note that in some cases, a requirement can end up being much harder to implement than initially assessed.
D. **Why does the relationship between Scenario, User Stories and Features deviates from SAFe?** The goal behind decomposing requirements in Figure 5 was to simplify requirements elicitation.

VIII. ACKNOWLEDGEMENTS

Creator: Dr. Mark Reith
Contributors: Lt Christopher Voltz, Lt Albert Taglieri, Capt Clayton Wilson

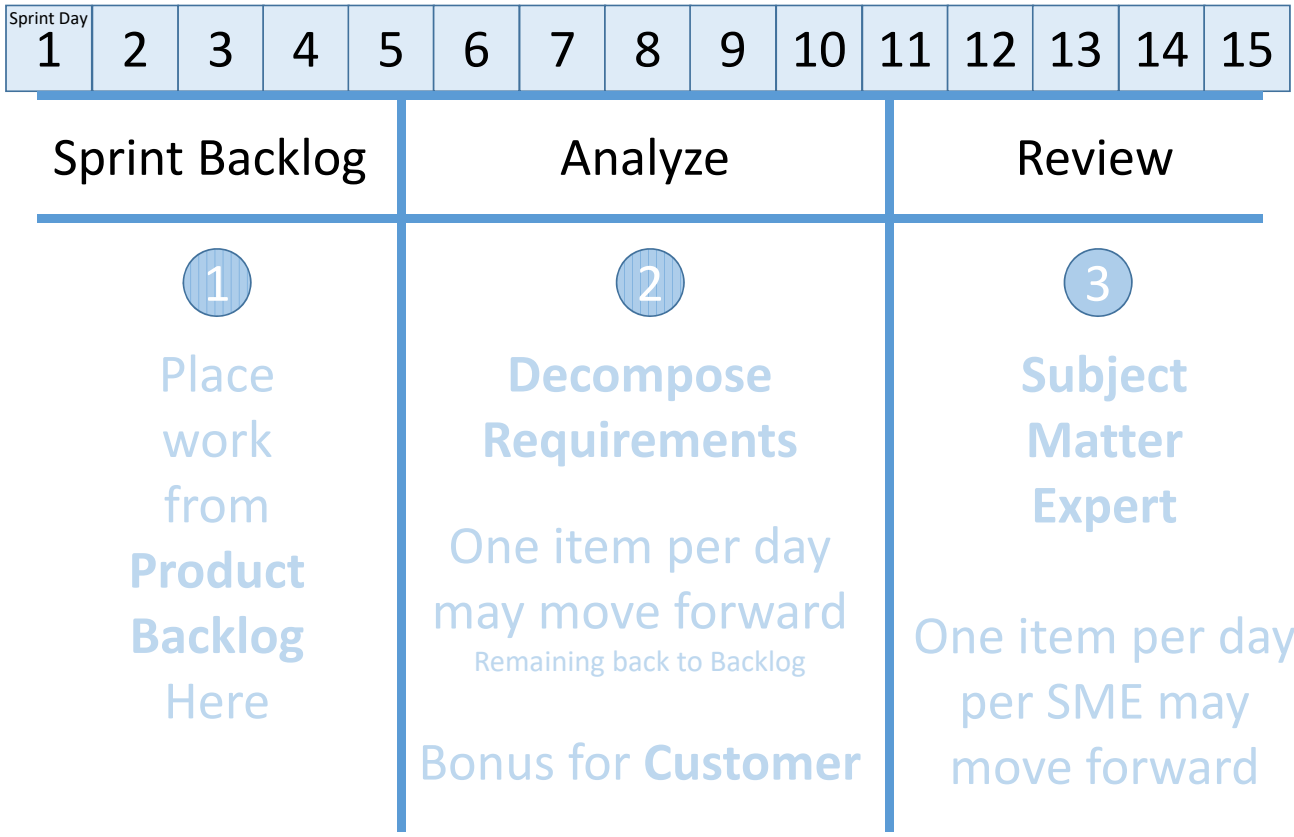
IX. CORRECTIONS & ENHANCEMENT IDEAS

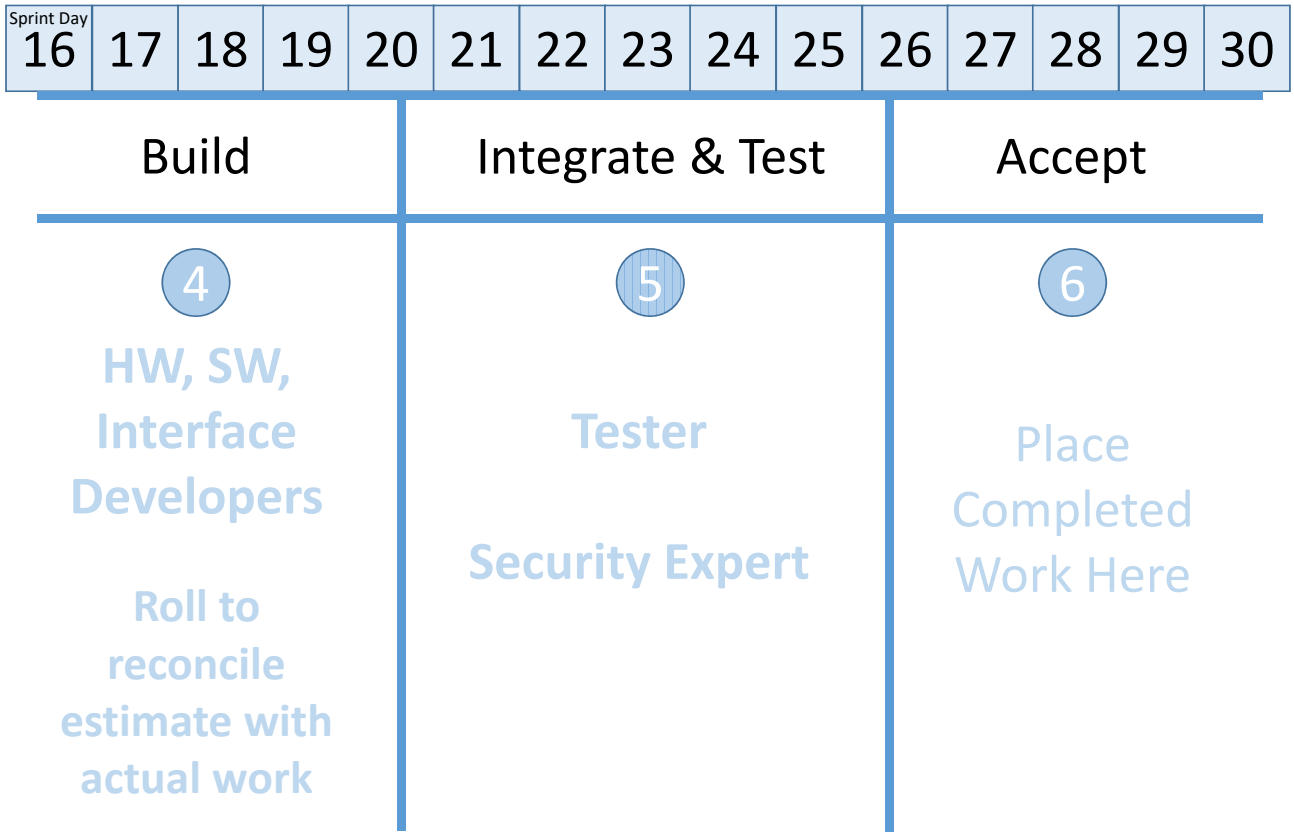
X. GLOSSARY (Knaster, 2019)

A. Agile Release Team (ART) – long-lived team of Agile teams, which, along with other stakeholders, develops and delivers solutions incrementally.
B. Agile Team – a cross functional group of 5 to 11 people who have the responsibility to define, build and test some element of solution value, and includes Dev Team, Scrum Master and Product Owner.
C. Average Wait Time – average queue length (Program Backlog) divided by average processing rate.
D. Customer – the ultimate buyer of every solution.
E. DevOps – a mindset, culture and set of technical practices; typically includes automation and Operational roles on development team.

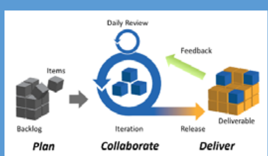
F. **DevSecOps –** similar to DevOps; it includes security experts into the development team.
G. **Feature –** a service that fulfills a stakeholder need.
H. **Kanban Board –** a tool and method used to visualize, manage and analyze the prioritization and flow of workflow.
I. **Minimally Viable Product (MVP) –** prototypes to release in the market for product testing and eliciting customer feedback.
J. **Model Based Systems Engineering (MBSE) –** the practice of developing a set of related systems models that help define, design and document a system under development.
K. **Non-Functional Requirements –** system attributes such as security, reliability, performance, etc. They serve as constraints or restrictions on the design of the system across different backlogs.
L. **Product Manager –** has content authority for the program backlog; helps develop program vision and roadmap.
M. **Product Owner –** member of Agile team responsible for defining stories and prioritizing the team backlog to streamline execution. For this game, this role manages the Kanban.
N. **Program Backlog –** holding area for upcoming features and enabler features.
O. **Program Increment (PI) –** a timebox during which an ART delivers incremental value in the form of working, tested software and systems; typically 8-12 weeks long.
P. **Release Train Engineer (RTE) –** servant leader and coach for the ART; facilitates ART events and manage risk.
Q. **Scrum Master –** servant leader and coach for an Agile Team; foster collaboration and process improvement. For this game, this role adjusts PI and Sprint lengths, provides lateral communication among peer Agile Teams, and ensures no cutting corners on the process.
R. **Sprint –** defined timebox for an Agile Team
S. **System Architect –** defines a shared technical and architectural vision for the solution under development.
T. **Team Backlog –** user and enabler stories that originate from the Program Backlog or derived locally.
U. **Technical Debt –** pending maintenance actions required during sustainment.
V. **Stories –** short description of a small piece of desired functionality written in the user's language.
W. **Velocity –** team metric describing the number of features completed per Sprint day; taken as the average over multiple Sprints.

Appendix G. Agile Adventure Game Components


Sprint Day
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Sprint Backlog
Analyze
Review
1
2
3
Place work from **Product Backlog** Here
Decompose Requirements
One item per day may move forward
Remaining back to Backlog
Bonus for **Customer**
Subject Matter Expert
One item per day per SME may move forward

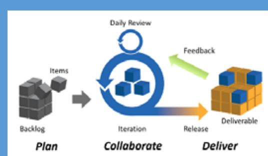

Sprint Day
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
Build
Integrate & Test
Accept
4
5
6
HW, SW, Interface Developers
Roll to reconcile estimate with actual work
Tester
Security Expert
Place Completed Work Here

Agile Adventure:
An Agile Systems
Development Game



Role
Card

Agile Adventure:
An Agile Systems
Development Game



Role
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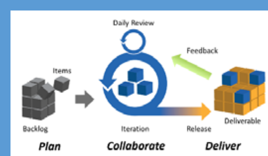

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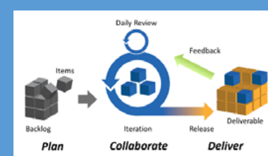

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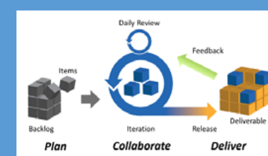
Development Game



Role
Card

Agile Adventure:
An Agile Systems
Development Game

Role
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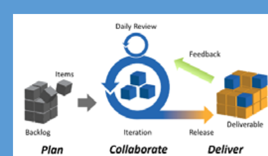


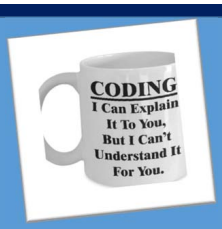
Role
Card

Agile Adventure:
An Agile Systems
Development Game

Role
Card

Hardware Developer

1 Hardware Function Point



Software Developer

1 Software Function Point

Subject Matter Expert

Declare Specialty

Customer

Analyze +1 User Story

Scrum Master

Agile Team Component

Security Expert

1 Security Point
DevSecOps Component

User Experience Developer

1 Usability Point

System Tester

1 Quality Point

Operations Team Member

DevOps Component

Product Owner

Agile Team Component

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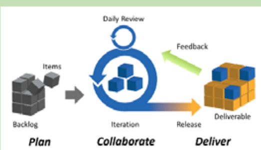

Event Card

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An Agile Systems
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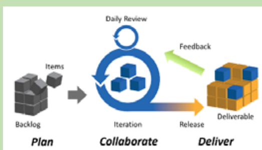

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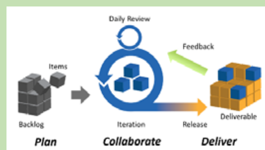

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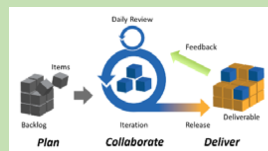

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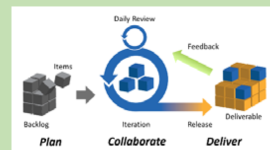

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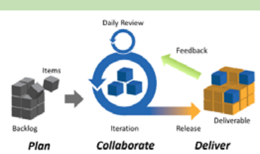

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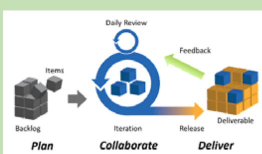

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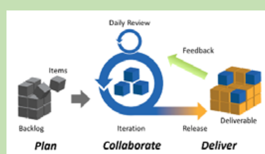

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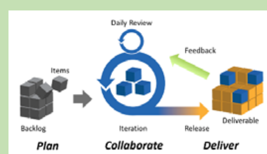

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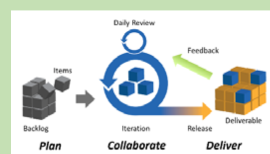


Event Card

Level up!
The proficiency of one team member gained one level.

Automation!
Double the quality points generated by your team.

DevOps Component

Certification!
Add one security point to any role for rest of the game.

Additional duty!
Lose one member of your team for one sprint.

New GUI toy!
Add one usability point to any role for rest of the game.

Wrong tool!
Double the point estimates for three features.

Wandering eye!
Your critical Agile Team member wants to work on another team.

Budget Cuts!
Lose a member of your team for the rest of the game.

Personalities!
Your SME has a PhD in Stubbornness. Review takes +2 days to complete.

Leadership!
You provide top cover for your team. You get 2 rolls per day for this sprint.

Hidden Feature!
Bugs are just hidden features. Features require +1 Quality points.

Major Changes!
Customer changes their mind. Move ¾ of your backlog/WIP to product backlog.
Customer: ½ instead (min 1)

Major Changes!
Customer changes their mind. Move ½ of your backlog/WIP to product backlog.
Customer: ¼ instead (min 1)

Insanity!
Customer goes insane. Move ½ of your finished stories to product backlog.
Customer: ¼ instead (min 1)

Technical Debt!
Working on the wrong baseline. Move all WIP to sprint backlog.

Customer Visit!
Double the number of user stories analyzed per day for current sprint.

Minor Changes!
Customer changes their mind. Move ¼ of your backlog/WIP to product backlog.
Customer: 1 instead

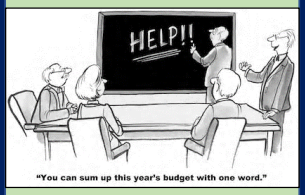
Minor Changes!
Customer changes their mind. Move ¼ of your backlog/WIP to product backlog.
Customer: 1 instead

No Big Deal!
Customer changes their mind. Move 1 of your backlog/WIP to product backlog.

Data Call!
You didn't provide any metrics to leadership. Lose 3 sprint days.

Static Closeout!
Performance reports are due. Lose two Agile Team members for five days.

Security Alert!
IATO now requires +3 Security points.



Funding Shortfall
No funds for maintenance fees. Lose any Automation you might have.

New Fiscal Year!
Your contractors are sidelined. Lose three Agile Team members for 3 days.

Hack-a-thon!
Help from hacker community. IATO now requires -3 Security points.

Higher Priority!
The boss needs a replacement exec and wants your best developer.

Bold/Reckless?
Customer wants to use immature tech. Double your testing requirements.

Hurry Up!
Customer needs to showcase MVP or cut funding. Need by end of PI.

Misplaced CAC!
One Agile Team member loses two days of work while replacing CAC.

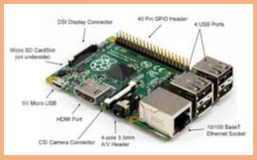
CC Call!
Mandatory fun! 3/4 of Agile Team out of office for one day.

 User Story	 User Story	 User Story	 User Story	 User Story
 User Story	 User Story	 User Story	 User Story	 User Story

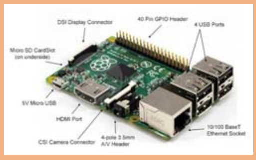
1	2	3	4	5
6	7	8	9	10

11	12	13	14	15
16	17	18	19	20

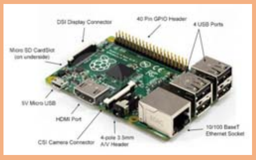
Feature



Feature



Feature



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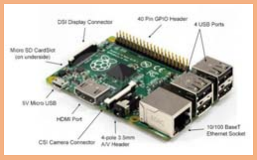

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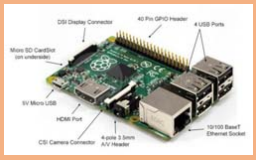

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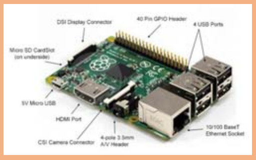


Feature

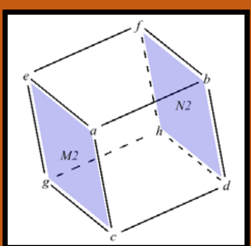
Feature

1	2	3	4	5
6	7	8	9	10

11	12	13	14	15
16	17	18	19	20

21	22	23	24	25
26	27	28	29	30

31	32	33	34	35
36	37	38	39	40



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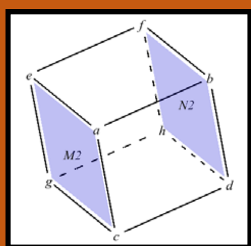

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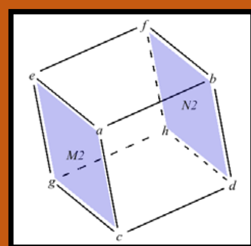

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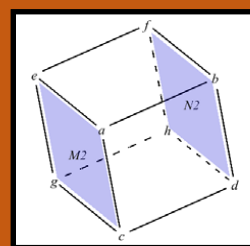

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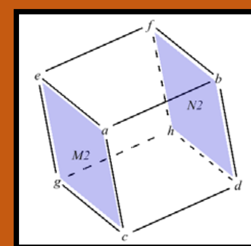

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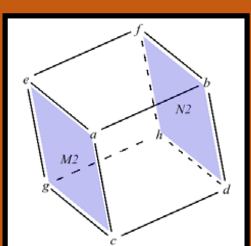

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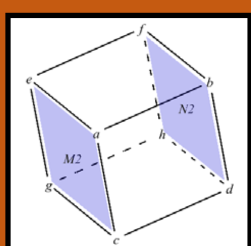

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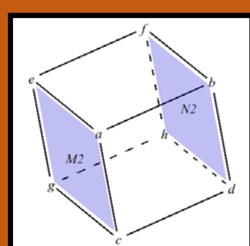

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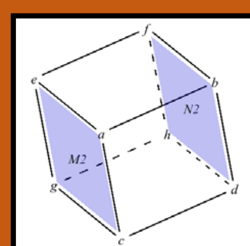
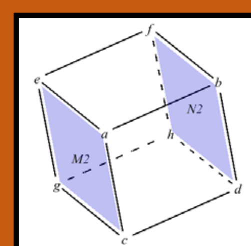


Non-functional Requirement



Non-functional Requirement

1	2	3	4	5
6	7	8	9	10

Appendix H. Interview Results

Interview Discussing Implementation of the Game Design Matrix in a Graduate Agile Software Design Course - 20190919

Observations on GDM process: The overall process included necessary steps in a logical sequence, but something seemed to be missing between Assessing Bloom's Taxonomy and Selecting Game Dynamics. The primary indicator of a problem involved too many dynamic or mechanic choices after applying environmental and learning objective constraints. I'll characterize this missing step as Crafting Learning Experiences. It answers two basic questions. First, what do you want the student to do? Second, what do you want the instructor to do? Once I answered these questions, choosing the game dynamics and mechanics were much easier because they provided choices on "how" I wanted the student and instructor to perform. This suggests a discussion on top down vs. bottom up engineering might be fruitful. For example, my last course instance described structure, and to a lesser extent behavior, of an Agile Release Train. Describing structure is trivial, but describing the dynamic behavior that shapes structure is much more abstract. One of the motivations for my game is to provide my students with a set of experiences that explain why Agile teams are effective in order to provide a richer and more lasting learning outcome. I specifically drew from my modeling experience to craft this game. I took the full Scaled Agile Framework (SAFe) and abstracted away details that I felt were not critical to my course learning objectives. The concepts and components that remained were then compared with game dynamics/mechanics for potential matching. Whereas the current version of GDM describes a top-down approach, I might describe this abstraction process as bottom-up.

Branching Options: Once the base game was established, I could then begin to consider "branching" options by making different abstraction decisions and applying various dynamics and mechanics which may highlight different aspects of SAFe or increase the difficulty or complexity as students reach higher levels of mastery. Game branching could easily occur across several sessions within the same course instance.

Development Time: The design of the game, the creation of the components/cards/storylines, and aesthetic elements took approximately twenty hours thus far. At this time it is a playable draft that is ready for basic testing and could be implemented in the classroom. I have made additional efforts to increase the quality of the aesthetics because I am anticipating using this in my curriculum in the future. It might be worth noting that there is also value in the development of the game over several iterations. The time cost of designing the game could be amortized over several courses by iterating development.

Appendix I. Survey Results

EQ1	EQ2	EQ3	EQ4	EQ5	EQ6	EQ7	EQ8	EQ9	EQ10	EQ11
4	4	4	3	5	4	4	3	4	3	4
4	3	3	2	5	1	4	4	4	3	5
4	3	4	5	5	2	4	5	5	5	5
2	2	2	3	3	4	4	2	4	3	2
5	4	5	2	5	3	4	5	3	5	5
1	1	1	4	4	2	3	2	4	2	3
3	2	2	3	4	2	3	3	4	3	3
4	3	4	4	3	2	4	3	4	3	4
3	2	1	3	3	3	4	3	5	3	3
4	4	2	2	4	3	3	2	4	4	4
4	4	4	2	4	1	4	4	5	4	4
4	4	4	4	4	3	4	4	4	4	4
3	4	5	2	5	1	4	5	5	5	4
4	3	3.5	1	5	2	4	4	4	4	5
4	1	1	3	5	3	1	2	2	3	4
3	3	5	1	5	2	3	4	4	4	4
3	3	2	4	3	4	2	4	4	3	4
3	3	2	4	3	3	2	2	3	4	2
3	4	2	1	4	5	4	5	5	4	4
3	4	4	5	5	2	5	4	3	5	4
4	3	2	4	5	4	2	3	5	5	3
4	4	3	2	5	4	5	5	5	5	5
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4	3	2	2	4	2	3	4	4	5	5
4	5	5	3	5	3	4	4	4	5	5

3	3	2	3	1	2	2	2	4	3	2
2	2	2	2	3	1	2	2	4	4	4
4	4	4	3	5	3	5	5	5	4	4
Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
3.6327	**3.1837**	**3.0306**	**2.5306**	**4.2449**	**2.4082**	**3.5306**	**3.5714**	**4.1429**	**3.9796**	**3.9388**
S/D	S/D	S/D	S/D	S/D	S/D	S/D	S/D	S/D	S/D	S/D
0.8	**0.983**	**1.222**	**1.09**	**0.87**	**1.159**	**0.992**	**1.069**	**0.9035**	**0.769**	**0.89**
Median	Median	Median	Median	Median	Median	Median	Median	Median	Median	Median
4	3	3	2	4	2	4	4	4	4	4
Mode	Mode	Mode	Mode	Mode	Mode	Mode	Mode	Mode	Mode	Mode
4	3	4	2	5	2	4	4	4	4	4

AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11
4	5	4	2	4	3	4	5	5	5	5
4	5	5		3	2	4	5	5	4	5
5	4	5	2	4	3	4	5	5	5	5
4	3	5	2	4	2	4	4	4	5	5
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4	5	5	2	5	3	4	4	4	4	5
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4	4	4	2	4	5	4	4	3	4	4
4	4	4	2	4	5	3	3	4	4	5
4	3	5	2	3	3	4	3	4	4	3
5	5	5	1	5	2	5	5	5	5	5
Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
3.8182	**3.8636**	**4.2273**	**2.2381**	**3.8182**	**3.25**	**3.8636**	**3.9091**	**4.0455**	**3.9545**	**4.0909**
S/D	**S/D**	**S/D**	**S/D**	**S/D**	**S/D**	**S/D**	**S/D**	**S/D**	**S/D**	**S/D**
0.716	**0.814**	**0.67**	**0.61**	**0.716**	**1.126**	**0.547**	**0.793**	**1.065**	**0.767**	**0.996**
Median	Median	Median	Median	Median	Median	Median	Median	Median	Median	Median
4	4	4	2	4	3	4	4	4	4	4
Mode	Mode	Mode	Mode	Mode	Mode	Mode	Mode	Mode	Mode	Mode
4	4	4	2	4	3	4	4	5	4	5

Appendix J. Internal Review Board Waiver

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (AETC)

HRPP Exempt Determination Form

For AFIT HRPP Use Only	
Protocol Number:	REN2019027R Okolica
Protocol Title:	Serious Game Design

EDO Determination

Does this submission meet an Exempt Criteria? *Select the appropriate exemption category. Categories are defined in Exemption Request Package and on Page 2 of this form.*

☒ Yes

Which exempt category applies? **32 CFR 219.104(d)(1)**

Is a limited IRB Review required to determine adequate provisions are in place to protect the privacy of subjects and maintain confidentiality of data? ☐ **Yes** ☒ No

If a limited IRB review is required, IRB Member determined that *either*:

☐ Sufficient measures were taken to protect privacy and confidentiality.

- OR -

☐ Insufficient measures were taken to protect privacy and confidentiality.

☐ No

☐ The human subject research does not meet any exempt criteria. Referred to AFRL IRB Chair for IRB review.

- OR -

☐ The research uses an In Vitro diagnostic device with specimens that are NOT individually identifiable. Referred to AFRL IRB Chair to determine compliance with applicable FDA regulations.

AFIT EDO / IRB Member Submission Analysis

EDO Reviewer Comments

This protocol is exempt because the PI is collecting data in a classroom environment as part of a regular ongoing class. No PII will be collected and subjects will be responding to lesson information in the classroom. No signed record of informed consent will be collected as this would be the only document linking the subject to the research project.

AFIT EDO Signature

	8/28/2019
Exempt Determination Official	**Date**

Note: To sign this form electronically, please save it as a PDF and follow these instructions.

HRPP Exempt Determination Form

Exempt Categories

32 CFR 219.104(d)(1) Exempt Category 1

Research, conducted in established or commonly accepted educational settings that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

32 CFR 219.104(d)(2) Exempt Category 2

Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:

(i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;
(ii) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or
(iii) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review. Complete Section 6.

32 CFR 219.104(d)(3)(i) Exempt Category 3

Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the below criteria are met. Please provide sufficient detail in section 4.1 to ensure the criteria has been met. Please refer to the Investigator Guidance on this topic.

(A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;
(B) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or
(C) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review. Complete Section 6.

Note: Benign behavioral interventions are brief in duration, harmless, painless, not physically invasive, not likely to have a significant adverse lasting impact on the subjects, and the investigator has no reason to think the subjects will find the interventions offensive or embarrassing. If the research involves deceiving the subjects regarding the nature or purposes of the research, this exemption is not applicable unless the subject authorizes the deception through a prospective agreement to participate in research in circumstances in which the subject is informed that he or she will be unaware of or misled regarding the nature or purposes of the research.

32 CFR 219.104(d)(4) Exempt Category 4
Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:
(i) The identifiable private information or identifiable biospecimens are publicly available; (ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects; (iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b); (HIPAA Regulations)
Note: HIPAA applies and includes either an authorization or waiver of authorization. It does not include bio specimens, only protected health information (PHI).
Note: This does not include primary collection from subjects for the proposed research. It allows both retrospective and prospective secondary use.
32 CFR 219.104(d)(5) Exempt Category 5
Research and demonstration projects that are conducted or supported by a Federal department or agency, or otherwise subject to the approval of department or agency heads (or the approval of the heads of bureaus or other subordinate agencies that have been delegated authority to conduct the research and demonstration projects), and that are designed to study, evaluate, improve, or otherwise examine public benefit or service programs, including procedures for obtaining benefits or services under those programs, possible changes in or alternatives to those programs or procedures, or possible changes in methods or levels of payment for benefits or services under those programs.
Note: These must be posted on a federal website.
32 CFR 219.104(d)(6) Exempt Category 6
Taste and food quality evaluation and consumer acceptance studies, (i) If wholesome foods without additives are consumed or (ii) If a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

Benign Behavioral Interventions

Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the following criteria is met:
(A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;
(B) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or
(C) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an **IRB conducts a limited IRB review of privacy and confidentiality** to make a determination of exemption. *This determination is based on adequate provisions to protect privacy of subjects and to maintain the confidentiality of the data, based on the July 26, 2017 DHHS (Department of Health and Human Services) and local policies. Data Security Review will likely be required.*

What is a benign behavioral intervention?

- Behavioral interventions must be brief in duration (a few minutes or hours). Although there is no specific amount of time that is defined as brief, OHRP guidance suggests the intervention must be brief in nature, even if subsequent data collection takes longer.
- Interventions may not be harmful, painful or distressing. Risk to subjects is low.
- Interventions must be unlikely to have significant emotional discomfort or adverse lasting impact
- Study content and procedures must not be offensive or embarrassing to subjects
- Medical interventions and procedures are not permissible in this exemption
- Physical (bodily) tasks and physical exercise should not be included in this exempt category.
- Deception can only be used if the subject prospectively agrees to the use of deception. Subjects must be informed prior to initiating the intervention that they will be unaware of, or misled regarding the true nature or purpose of the research. They will also be told whether further information will be provided at the conclusion of the research activities. Researchers should consider de-briefing subjects.
- Research procedures in this exempt category should generally be limited to:
    - communication or interpersonal contact with the subject,
    - the performance of a cognitive, intellectual, educational or behavioral task, or
    - manipulation of the subject's physical, sensory, social, or emotional environment
- Data collection in this exempt category is limited to:
    - verbal (oral) or written responses by the subject
    - data entry by the subject
    - observation of the subject
    - audiovisual recording

This category does not include the introduction or administration of instruments, substances or energy onto or into the body for research data collection. For example: Fitbit, bioharness, eye tracker, EEG, etc…

Some examples benign behavioral interventions:

- Performing cognitive tasks
- Providing educational materials to participants with the intention of changing their behavior
  - (e.g. smoking cessation, eating habits)
- Playing an online game
- Playing economic games
- Being exposed to stimuli such as color, light or sound at safe levels
- Solving puzzles under various noise conditions

Note: If the research involves deceiving the subjects regarding the nature or purposes of the research, this exemption is not applicable unless the subject authorizes the deception through a prospective agreement to participate in research in circumstances in which the subject is informed that they will be unaware of or misled regarding the nature or purposes of the research.

Appendix K. GDM Whitepaper Guide

Implementing the Game Design Matrix

Aaron Pendleton
Air Force Institution of Technology
aaron.pendleton@afit.edu

Introduction

Serious Games can be a powerful tool for educators to boost the level of student engagement and application in academic environments, but the level of game expertise and knowledge required in order to design a game with playable mechanics and well integrated learning objectives can be overwhelming to a novice designer. Popular game design frameworks target experienced game designers with a particular vision for a game. This leads to poor results when a novice attempts to create a game, particularly when attempting to select mechanics and include learning objectives in the design phase. The Game Design Matrix (GDM) approaches this problem with a unique methodology in order to make game design more attainable in classrooms and education courses which do not have the resources to bring in game design experts. Additionally, GDM seeks to decrease the time it takes to develop games in order to make them more comparable to other classroom exercises.

Important Definitions

- **Game Mechanics:**

Primarily verbs which describe specific actions a player can have during gameplay. These are direct options a player has to interact with a game.

- **Game Dynamics:**

Player options which can be combined to create higher level system interactions than basic mechanics. These can be considered the system-behavior of a game, and are not as reliably created as Game Mechanics.

- **Game Aesthetics:**

The result of the player's direct and indirect interactions with the game. They are the emotional responses garnered by the game dynamics and mechanics for the purpose of making the game fun, sensational, or addicting.

- **Game Components:**

The pieces of the game which are used to create mechanics and dynamics. Examples include cards, tokens, boards, or digital infrastructure

- **Environmental Constraints:**

These are the limitations within an individual classroom or education program that must be accounted for when designing a game that is optimized for a particular course.

- **Learning Objective:**

A brief statement describing the expectations of what students are anticipated to accomplish over the course of a defined period of education. Within the GDM it is expected that learning objectives will be developed with a targeted level of Bloom's Mastery.

- **Learning Outcome:**

The end result of a student's skill level after a course or block of education. Typically a learning outcome is measured against the learning objective using an assessment tool.

- **Bloom's Level of Mastery:**

Bloom's Taxonomy is a framework originally designed to be used as a measuring tool when developing assessments for a course. It has since been applied to creating learning objectives and categorizing activities underneath a particular level of mastery required to complete it. The taxonomy is composed of a series of mastery levels, with descriptions shown in figure 1.

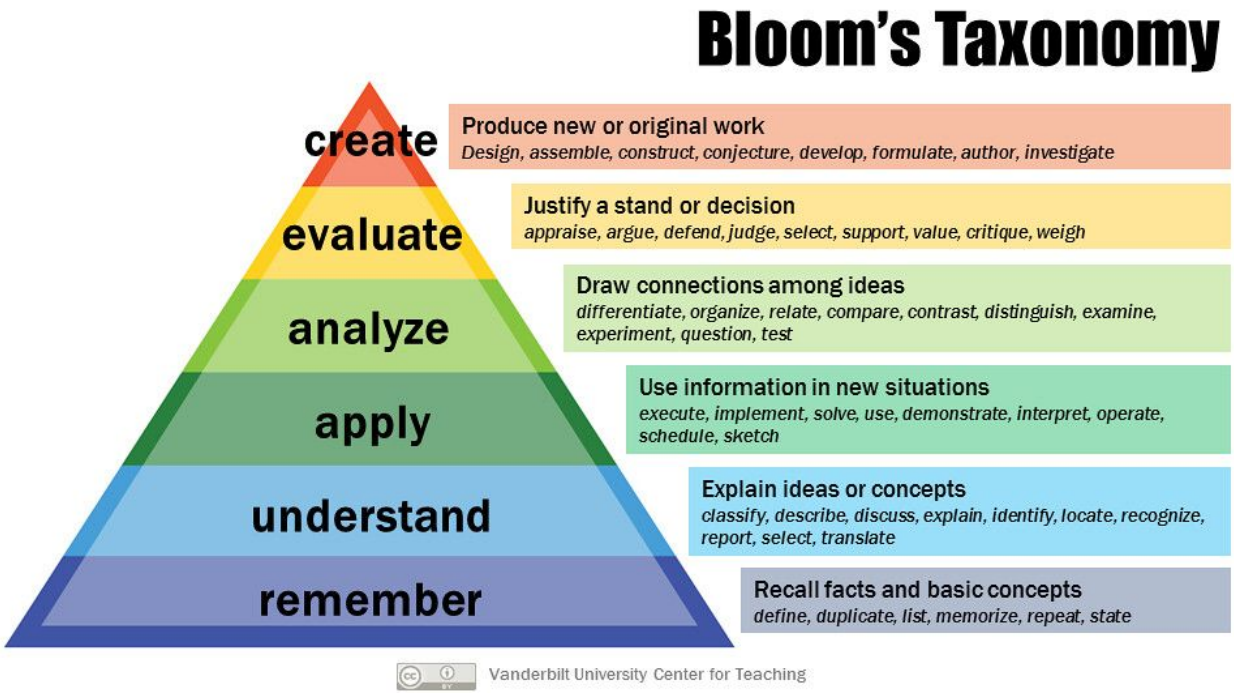

Figure 1. Bloom's Taxonomy (Revised)

Game Design Fundamentals

The GDM builds upon the Mechanics, Dynamics, and Aesthetics (MDA) framework. The core of MDA is that all games (including serious games) can be broken down into Game Mechanics, Game Dynamics, and Game Aesthetics. These core game elements combine to build a complete game, and in order to design a game they must be accounted for. Traditional implementations of MDA focus on developing mechanics first, but GDM specifically targets dynamics as the first step in order to target specific levels of Bloom's taxonomy.

Game Design Process

The GDM is designed to enable educators with established learning objectives and a desired subject matter to identify environmental constraints, and select appropriate game dynamics and mechanics. This game dynamics selection will be based on the "real-life" process which the game attempts to model, and target a specific level of Bloom's taxonomy based on the learning objective requirements. A mapping of Bloom's masteries to game dynamics allows the user to isolate dynamics that can be effective when designing the game, and a mapping of game dynamics to game mechanics allows for the selection of mechanics which can be incorporated to create the desired dynamic. The design of a "Enterprise" a cyber risk serious game will be used as a case study of executing each step of GDM.

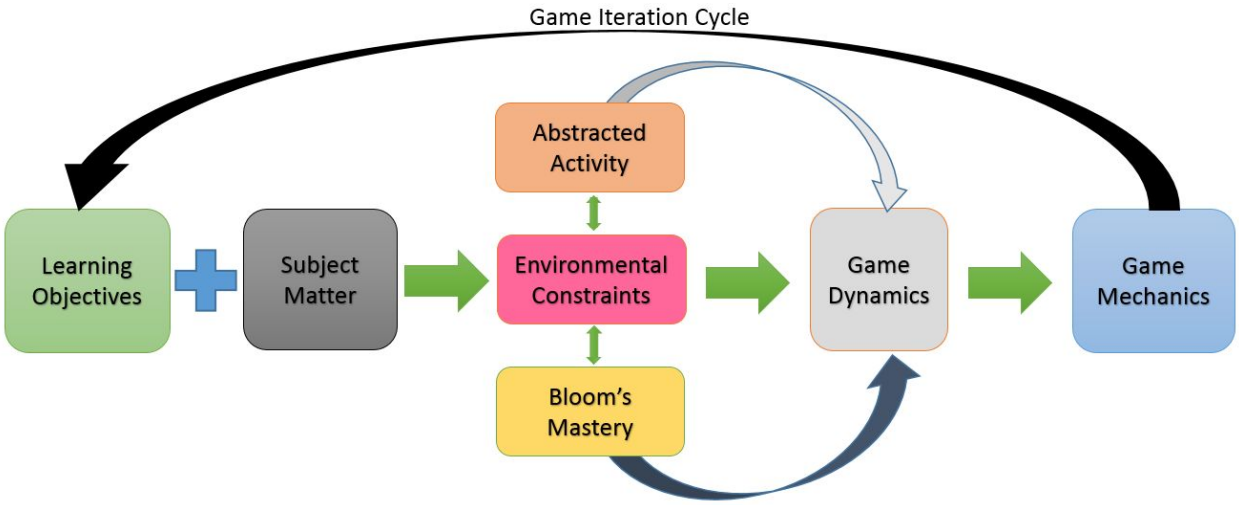

Figure 2. The Design Process of GDM

Step One: Identify Learning Objectives and Subject Matter

The designer must first determine the subject matter or topic of the game, and then the desired learning objectives and learning outcomes for the players. The learning objectives will be used to isolate the levels of Bloom's taxonomy (revised) that the game is targeting. The level of Bloom's that the designer targets largely determines the nature of the game. Serious games can be loosely defined as either learning oriented, or application oriented. Learning oriented games target the bottom two levels of Bloom's taxonomy and focus largely on relaying basic principles and information. Learning games often take the place of a lecture, and are used as a tool to mix up the classroom dynamic when students are expected to ingest large amounts of data. The application focused games are designed to use information students already know, in order to teach them how to employ that information in an activity which is too complex to learn from a simple lecture. Information is not taught, but used in these games, as they primarily target Bloom's level three and higher. Application based games often require an associated lecture or prerequisite knowledge level to be effective.

Step Two: Identify Environmental Constraints

Environmental constraints must be identified and anticipated by the game designer in order to narrow the scope of selected dynamics and mechanics. The primary goal of this step is to identify all potential challenges to game play/the game atmosphere in order to eliminate incompatible game dynamics in a later step. Accurate identification of game dynamics is the cornerstones of the GDM, and enables a significantly more effective game. An example of commonly identified environmental constraints is identified below, but the designer may need to define unique constraints in order to optimize performance.

Common Environmental Constraints

Class Size	Introduction Time
Seating/Table Space	Playtime
Student Knowledge Level	Camaraderie
Budget	Technology

All environmental constraints must be addressed prior to selecting dynamics. If new constraints are realized during the game dynamics or game mechanics selection, then the designer must return to the environmental constraints identification step. Every classroom situation can be adapted to GDM in some capacity because this mechanism allows for an abstract implementation. Environmental constraints are the primary driver for selecting game components and they are incorporation into game dynamics and game mechanics. The environmental constraints should also be used to eliminate game dynamics that are not compatible with the desired classroom application. Refining the list of game dynamics at this stage allows for a more targeted output.

Step Three: Isolate Game Dynamics

The game designer is only able to directly influence game mechanics, but the element which impacts player experience and directly affects their level of learning is the game dynamic. While unable to guarantee a particular dynamic is created, a designer can target key dynamics and then attempt to select mechanics which foster that dynamic. A list of common game dynamics has been compiled in an effort to comprehensively scope GDM. The user should attempt to select dynamics which have familiarity, extensibility, and pair well with other selected dynamics. Similarly, dynamics which do not contribute to the game or level of mastery targeted should be eliminated based on the environmental constraints. At this time it is necessary to determine whether the game is intended to be application based, or learning based. Application based games are typically modeled after a “real-life” situation or scenario with elements abstracted to a level that can be modeled in a game. Refer to Appendix A for the mapping of dynamics to levels of Bloom’s taxonomy to begin assessing which dynamics may be appropriate. When creating an application based game it is important to identify the dynamics of the real-life situation. The example game created is designed to model the function of several elements of an enterprise

network, which are all working together to keep the entire operation functional. This dynamic mirrors collaboration very closely, and collaboration is already highlighted as an appropriate dynamic for our targeted level of mastery in Appendix A. Using this method the selection of asymmetric abilities, chance, and multiple strategies similarly mirrors elements of real life risk management principles, and create a game environment that can allow for high levels of application, analysis, and potentially evaluation. Players balancing unknown (chance), multiple options which lead to different outcomes (multiple strategies), and several different capabilities that can be used to mitigate risk (asymmetric abilities) will inevitably have to make a decision based on an incomplete understanding of the situation. This has the potential to effectively model real life enterprise operations and risk management. It is important to select secondary dynamics when attempting to create a game with complexity and when the designer is targeting higher levels of Bloom's taxonomy. Learning focused games have a much simpler end goal, and as such there are fewer dynamics to choose from. It is recommended to select one higher level dynamic to pair with lower level dynamics from the understanding and remembering categories based on the nature of the subject matter. The focus in this style of game is on the information in the game components rather than the interaction of the dynamics and the mechanics. It is less important to create an accurate model of a real-life event, but rather to create a seamless interaction between players as they ingest new data and information. Game dynamics which the designer can draw from are defined as follows:

Modular Game Board:

Elements of the play space which can be manipulated by the players to introduce strategic elements to the game beyond the initial design. Examples: Settlers of Catan expansion packs can allow for shuffling the numerical designators for certain commodity tiles

Fog of war

Creating elements of uncertainty by obscuring partner or adversary resources or movements. Example: Card games where a player's hand is only known to themselves, video games where there is only vision within a certain range of the player's resources.

Deck/Hand Building

Enabling players to select pieces/cards from a larger group in order to facilitate a more specific strategy within a set amount of "in-play" cards. Example: Dominion and Hearthstone require players to establish which cards are played in the game from a larger pool

Bluffing

Allows players to force an adversary into a decision point based off of estimation or statistical analysis of a situation rather than known factors alone. Generally regarded as allowing a weaker player to corner a stronger positioned player into a high-risk high-reward situation. Often requires other dynamics such as fog of war. Example: A player betting high with a weak hand to influence other players into folding.

Chance

Incorporates an element of randomness into players decision making. Typically accomplished through introducing specific components such as a random number generator or dice. Example: Rolling die to determine attack power in Risk

Cooperation

Allowing players to work together towards a common goal, even if temporary. Example: Two players in Settlers of Catan working together to starve the leading player of a resource.

Competition

Creating an objective oriented dynamic which forces players to vie with each other, or their past performance, in order to complete the required tasks. Example: Multiplayer games that have a “winner”

Conflict

Allowing players to actively impede or degrade their adversaries. Example: combat or warfare games.

Collaborating

Games with player cooperation that is maintained throughout the experience. Requires defined group objectives. Example: Pandemic.

Level of Communication

Limiting the ability players have to communicate with each other, particularly teammates, allows for increased levels of critical thinking and analysis. Example: Spades, Pictionary or Euchre.

Information Control

Giving a particular role or player the agency to release information adds an additional strategic element to a situation, which can increase the level of critical thinking and analysis. Example: Viewing party affiliation in Secret Hitler.

Time Scarcity

Creating an environment which is reliant on performing under pressure can increase the difficulty of a seemingly simple task. Example: Games with timed turns such as Scrabble or Codenames.

Multiple Strategies

Creating separate methods of winning in order to diversify gameplay. Increases the level of analysis required for players attempting to determine a viable path to success. Examples: Shooting the moon in Hearts, or going nil in Spades.

Multiple endings

Multiple mechanisms to trigger the end of a game. Increases the level of analysis required for players attempting to determine a viable path to success. Example: Throwing a frisbee through the center hole in Can-Jam

Infinite Gameplay

Creating a game which does not have a defined ending. Works best when combined with many other dynamics such as multiple strategies, asymmetric abilities, and hidden objectives. Example: “Grinding” games such as Path of Exile

Player substitution

Allowing players to rotate in and out of positions or even the game in order to add flexibility. Example: Many casino games, such as 21 or Craps.

Player autonomy

Giving players substantial ability to make their own decisions, play the game in their own order, and opt in or out of content. Example: Open world video games such as Skyrim.

Team Modeling

Allowing players to select roles and traits for their character or position in order to optimize for the objective. Example: DnD, League of Legends, and most team sports.

Real Time Play

Games where players cannot pause or halt play in order to make a carefully thought-out decision, or where players might have to make a decision/react at any time. Example: First Person Shooters, Spoons.

Hidden Objectives

Games where players are unaware of all expectations. This can be an obscured questline, time-delayed random mission card, or an adversary objective that is hidden in the fog of war.

Limited Actions

Constraining player ability by forcing them to operate with a set or randomly defined actions list. Example: Dominion, Risk, or the Civ game series.

Feedback

Creating a mechanism for players to receive updates on actions/effectiveness. Example: hit markers in FPS game.

Realism

Adding lifelike effects to make the game more engaging or interactive. Example: limited stamina/heavy breathing noises in digital games where player characters can sprint.

Negotiation

Giving players the ability to barter or engage in trade. Example: Settlers of Catan

Diplomacy

Builds off of negotiation, but at a higher and more sustained level. Requires players to maintain relations with other players or player agents in order to further their efforts. Example: Stellaris, Axis and Allies

Player Ethics

Requiring players to make decisions within the context of the moral value of their agents that may have implications at a later time. Often paired with negotiation, bluffing, or diplomacy. Example: Stellaris

Asymmetric abilities

Giving players different classes/items/skills/etc in order to provide varied experiences. This must be appropriately balanced, but can favor particular matchups. Pairs well with deck/hand building. Example: Hearthstone

Resource Scarcity

Forcing players to compete for necessary items/objectives. Pairs well with cooperation, competition, or collaboration. Example: Settlers of Catan

Adversary Tracking

Requires players to pinpoint adversary agent positions or actions through memory or similar mechanisms. Pairs well with fog of war. Example: League of Legends

Teams

Requires players to account for the unknown of a teammate. Pairs will with cooperation, collaboration, competition, or team modeling. Example: Spades, FPS games

Step 4: Select Game Mechanics

Aki Järvinen compiled a list of game mechanics in *Games without frontiers: Theories and Methods for Game Studies and Design* which will be employed by GDM. The designer should attempt to select mechanics which are familiar to the students in order to make the game easier to play and adapt to using the Game Dynamics to Game Mechanics mapping in Appendix B. This mapping is a guide for the game designer to use for mechanics selection. It is important to note that this step is where the direct player interaction with the game is defined. Time spent learning tedious mechanics is time not spent learning the material intended to be taught by the game. Simplicity in mechanics can lead to faster game mastery, and better implementation of the game dynamics. When possible use the same mechanic(s) to create multiple dynamics. It is

also beneficial to choose dynamics that pair well with the same mechanic(s). Game mechanics are defined below:

Accelerating / Decelerating

Definition: The players are allowed to change the speed of the game element (often component-of-self) they are manoeuvring.Examples: Mario Kart, SSX.Notes: Often a sub-mechanic to Manoeuvring.

Aiming & Shooting

Definition: Taking an aim towards a target and trying to hit it with a component (ball, dart, ammunition, etc.).Examples: Throwing darts, kicking a football, shooting bubbles in Puzzle Bobble, shooting with firearms in Halo.

Allocating

Definition: Allocating component(s) in possession as quantifiable resource. Examples: Upping the ante in Poker, allocating resources to building hotels in Monopoly.

Arranging

Definition: Arranging the order, assembly, or location of game elements, typically components, into sets. Examples: Arranging jewels of Bejeweled into sequences of three, combining Tetris blocks, arranging a Magic the Gathering deck.

Attacking / Defending

Definition: Attacking opponent component(s) or defending one's own from them.Examples: Shooting in Max Payne, fighting in the Tekken series or Halo. Taking cover in Gears of War. Notes: Various sub-mechanics (techniques, actions) are possible for combat, such as shielding actions as a defending mechanic.

Bidding

Definition: Making an offer on a game component or an area of game environment which is possessed by the game system or another player. Examples: Bidding for paintings in Modern Art the card game.

Browsing

Definition: Browsing or moving through possible choices or instances of game elements. Only exists as a sub-mechanic (to, e.g., choosing or manoeuvring). Examples: Browsing inventory in various digital games, manoeuvring around the grid looking for diamond configurations in Bejeweled.

Building

Definition: Assembling constructions to the game environment, often with the help of components and patterns that emerge from components' combinations. Examples:

Building a city in SimCity, interior design in The Sims, building channels in board game Ta Yu. Notes: Combination of Placing and Arranging.

Buying / Selling

Definition: Buying or selling component, environment location, or information from or to the game system or another player. Examples: Buying real estate in Monopoly, buying accessories in Nintendogs, buying furniture in The Sims.

Catching

Definition: Catching a game component, thus gaining possession of it, or returning it to play. Often leads to a Controlling mechanic. Examples: Catching a baseball or basketball, hitting the ball back to play in Breakout.

Choosing

Definition: The player is presented with making a choice between a number of options. Examples: Playing Rock-Paper-Scissors, choosing weapons and items for a mission in Tom Clancy's Rainbow Six series, choosing a player role if there are different ones available (e.g, character classes and abilities in role-playing games, etc.).

Composing

Definition: The players are afforded means to create images and sounds. Examples: Sound effects in Rez, 'Viewtiful' mechanics in Viewtiful Joe, drawing in Pictionary.

Conquering

Definition: Conquering a game environment, thus gaining possession of it. Examples: Conquering a planet via exploration of space in Galactic Civilizations, stealing possession of ball in soccer/basketball/football

Contracting

Definition: A contract by two or more players is made through an agreement that is acknowledged by the game system. I.e. informal cooperation is formalised into a mechanic that makes the contract known to the game system.Examples: Assembling a team in sports games, becoming the Shogun player's samurai in the card game Honor of the Samurai.

Controlling

Definition: Keeping possession of a component and/or handling/controlling it. Examples: Keeping possession of the ball and dribbling with it in basketball or football, playing Croquet, keeping possession of the baton in a relay race in athletics, etc.

Conversing

Definition: Players are able to enter into dialogue with game system or other players, and this dialogue has formal consequences to the game state (unlike casual table-talk).

Examples: Engaging into conversation with non-player characters, chatting in MMORPGS etc.

Discarding

Definition: Discarding a component or using one to displace another. Examples: Discarding cards in a card game such as Gin Rummy or Uno, displacing opponent's token in Checkers.

Enclosing

Definition: Enclosing part of the game environment and/or components in order to gain its control. Examples: Enclosing an area in Qix, completing a castle in Carcassonne, Catching butterflies in Loop.

Expressing

Definition: Expressing oneself verbally with the means that the game system and technology affords. Examples: Verbally performing a character in a table-top/live action RPG, or expressing oneself by written language in MMORPGS, explaining a word in Alias, singing in Singstar etc.

Herding

Definition: Means to control indirectly a component's movement in the game environment and guide it to a certain location.Examples: Herding cattle in Sheep or Harvest Moon, encouraging Yorda character in Ico to jump etc. Notes: The indirect nature of herding means that in some cases its effect is achieved by another mechanic, and there is no particular herding mechanic (in the fashion that there is in Ico). This is the case in Sheep where the sheep components behave in relation to the shepherd’s movement, i.e. the manoeuvring mechanic with which the player controls her character takes the function of herding.

Information-seeking

Definition: Gathering information or making inquiries about surroundings, challenges, or other players. Examples: Scanning in Metroid Prime, asking the Game Master hints/elaborations in a table-top RPG, establishing diplomatic relations in Civilization, contacting team-mates.

Jumping

Definition: The players are allowed to jump in order to gain best possible result. Examples: Basketball, pole vault, rope jumping.Notes: In e.g. Basketball and Volleyball, this mechanic makes using the Aiming & shooting mechanic much more effective.

Manoeuvring

Definition: Manoeuvring a game element in a game environment, including possible chances to jump, fly, etc.Examples: Steering component(s)-of-self or character(s)-of-self

through game environments, e.g. downhill in Alpine skiing or along a road in Cycling, or in digital environments, such as the game environments of Pac-Man, Super Mario Bros, SSX, Super Monkey Ball etc.Notes: Often this mechanic has Speeding / Braking sub-mechanics, or the design of the game environment forces/enables change in speed (the labyrinth in Labyrinth Wooden Maze game, the levels in Super Monkey Ball, mountains in snowboarding games etc.).

Motion

Definition: The players' bodily stances (postures, gestures, etc.) produce input to the game system or benefit in dealing with its challenges. Examples: Playing Eyetoy games, jumping rope, dancing games, playing Twister.

Moving

Definition: Players are allowed to physically move within the game environment. Examples: Football, Basketball, Paintball, most outdoor games.Note: Often combines with Sprinting / Slowingsubmechanic.

Operating

Definition: Taking an action where an object belonging to the game system (a component, environment) is operated. Usually the operation executes a game system procedure that produces information or change in other game element. Examples: Rolling dice, spinning a wheel of fortune, opening a door in an adventure game.

Performing

Definition: Display of physical skill or physical performance, including simulations of physical performance, which is evaluated by the game system.Examples: Gymnastics, Ice skating, Snowboarding, LARPs, digital skateboarding and snowboarding games.

Placing

Definition: Placing a component or a marker on the game environment.Examples: Laying tiles in Carcassonne, playing Dominoes, jigsaw puzzles, drawing a symbol in Tic-Tac-Toe, placing directions in Chu-chu Rocket or waypoint markers in strategy games. Notes: In the case of games like Carcassonne or Ta Yu, this mechanic is used in constructing the game environment, i.e. components transform into another game elements via game dynamics.

Point-to-point

Movement Definition: Moving a component or oneself in sequences or turns, e.g., from point to point.Examples: Moving a piece in Chess or Monopoly, moving troops in Starcraft or Heroes of Might & Magic etc.Notes: Possibly includes a submechanic that gives the direction or length of movement. It could also be an operation mechanic in the form of a die roll.

Powering

Definition: Players are allowed to use maximum physical power to gain the best result. Examples: Boxing, Wrestling, Weightlifting, Athletics Notes: Strength is a submechanic in many games that use Attacking / Defending mechanics as their primary player actions, emphasizing their effect.

Sequencing

Definition: Producing input to the game system in a sequence within a time limit or specific tempo. Examples: Playing Hopscotch, matching the note sequences in Frequency or beats in Dance Dance Revolution, 'Quick-Timer Events' in Shenmue or Dragon's Lair.

Sprinting / Slowing

Definition: The players are allowed to change their speed of movement in order to gain best possible result. Examples: 100 meter sprint, Swimming, Cycling, Athletics, getting rid of chasing opponents and creating better scoring situations in Football/Basketball/Soccer. Notes: Often a submechanic for Moving. For instance, the mechanics of Long jump in athletics is a combination of Moving + Sprinting + Jumping + Strength+Motion mechanics.

Storytelling

Definition: Telling or creating a story with the means that the game system affords (and within its rules). Examples: Continuing a story in Once Upon a Time card game, pitching in GameGame.

Submitting

Definition: Submitting information (in a format specified in the rules) for evaluation by the game system or other players. Examples: Answering a question in a trivia game or a quiz, submitting a code in Mastermind.

Substituting

Definition: Substituting an element in possession, and in play, with another. Examples: Substituting a player into pitch in football or basketball, Sports fantasy leagues, substituting a superhero on a mission with another in Marvel Heroes.

Taking

Definition: Taking a game element or a number of them (components, environment locations, information) into possession.Examples: Drawing a card from the deck or another player in various card games, picking up a fish tile in Pingwin, looting items into an inventory in digital role-playing games, collecting items in Animal Crossing, collecting cards by purchasing sets in Magic The Gathering or Pokemon, accumulating cards into hand in Uno, building a game design in GameGame. Notes: Often combined with Choosing game mechanic.

Trading

Definition: Exchanging a game element (component, environment-of-self, or information) with another player or the game system. Examples: Changing cards in Poker, or in card game Go Fish.

Transforming

Definition: The players are given an ability to transform the flow of time or space to better their chances of overcoming a challenge, or to find out an outcome of their actions. Examples: 'Bullet time' in Max Payne, speed boost in Mario Kart etc., speeding up time in digital strategy games, such as The Sims.

Upgrading / Downgrading

Definition: Changing the attributes of a game element, including player role or player contract. Examples: Transforming a pawn into a queen in Chess, gaining a level in character ability in RPGs.

Voting

Definition: Casting a vote for one candidate out of a set of game elements. Examples: Naming and voting a resident for eviction in Big Brother television show, voting for the suspect in Werewolf/Mafia parlour game. Notes: Combination of Choosing and Submitting.

Step Five: Final Assembly

It is important to recognize that based on the audience, different game dynamics may reach different levels on the Bloom's taxonomy pyramid. As a general rule, each mapping reaches at least the level it is mapped to when properly implemented. Dynamics are selected using the environmental constraints, Bloom's level of mastery targets, and modeled to fit the real life activity or process that the game attempts to create. Mechanics are sparingly selected to support all dynamics chosen. When possible the GDM supports multiple dynamics with the same mechanic(s). This is the core of the GDM process, and is utilized to create the dynamics in the game. In many cases, not all mechanics mapped are required to develop the dynamic. When creating a dynamic, it is often only necessary to employ one or two mechanics. It is similarly important to group like-dynamics by using the same mechanics to achieve them in order to keep game complexity approachable. With mechanics and dynamics chosen the designer must now use their subject matter mastery to create the components. Many mechanics and dynamics have clearly defined components that they require (e.g. hand/deck building requires cards).

Design of a Serious Game

Enterprise is a serious game designed to teach students principles of applying cyber risk management.

Step One: The learning objective targeted by Enterprise is teaching students to apply principles of mission assurance and cybersecurity risk management in enterprise network operations. These learning objectives and subject matter were selected from a cybersecurity continuing education course, and the game was built to replace an exercise designed to accompany a lecture. The desired learning outcome indicates the selection of dynamics based on level three and level four of Bloom's taxonomy. This firmly classifies Enterprise as an application focused game. We now identify the activity that should be abstractly modeled in the gameplay. This is identified as simply operating a network, and maintaining services.

Step Two: Identifying environmental constraints is relatively straightforward. This game will be played in a classroom with up to 32 students, needs to be introduced and played in 20 minutes, and the content cannot greatly exceed the knowledge level of the accompanying lecture.

Step Three: Three primary dynamics were selected based on these requirements to target in the game design: Chance, Collaboration, and Asymmetric Abilities. These dynamics can all be supported by the mechanics Upgrading/Downgrading, and Choosing. This enabled a targeted development focused on creating the components and aesthetics within established constraints, using the selected mechanics and dynamics. This resulted in a playable draft within 15 hours of game conception, and a developed classroom ready iteration with only 25 hours of total design, testing, and production time. Shown in Figure VI is the basic board and player positions. It allows 4-5 players to take on different roles within the network operations, information assurance, network maintenance, and cybersecurity functions of a large network. The player is to keep the network operational for 10 rounds while addressing cyber attacks, hardware failures, user errors, and equipment upgrades. Players must collaborate to make purchases/network upgrades, mitigate attacks, fix failures, and ultimately restore services if they are out. The game is designed to be played in 10-15 minutes and requires a 5-10 minute introduction time. It is intended to be played by students that already understand basic enterprise operations concepts as taught by the preceding lecture, and does not explain roles or equipment used during play. This allows for significant time savings, and students are expected to immediately begin applying their knowledge to "emergencies" created in the game.

Conclusion

The step by step process of GDM provides a guide for the selection of mechanics and dynamics, but still maintains a level of abstract design. This allows for intentional elements of the game to be very simply interwoven. The process of isolating mechanic/dynamic interaction simultaneously with the learning objective incorporation phase is intended to create a more cohesive player interactions than a game designed with components first, and mechanics/dynamics second. This effect empowers the less experienced designer to create a

learning objective focused game. The next step in GDM development is to conduct long term assessments of game effectiveness, and continued game design tests for different applications, objectives, and constraints. This long term study needs to examine games created by multiple educators with learning objectives targeted at different levels of mastery in order to assess the entirety of the framework rather than the single example used in this paper. Testing more games in a variety of environments will demonstrate the robust and extensible design of the model, including the ability to design board games, live action games, and digital games. To account for this diversity, several iterations and types of games must be created and evaluated to validate the efficacy of the matrix.

Appendix A: List of Game Dynamics and Dynamics - Bloom's Mapping

Level of Mastery	**Mapped Dynamics**
Creating	Not Directly Targeted
Evaluating	Targeted through combining level 4 dynamics
Analyzing	Multiple Strategies, Modular Game Board Resource Scarcity, Adversary Tracking Hidden Objectives, Fog of War, Feedback, Bluffing, Player Ethics, Limited Actions, Diplomacy Team Modeling, Information Control, Multiple Endings, Deck/Hand Building, Asymmetric Abilities
Applying	Chance, Cooperation, Collaboration, Conflict, Negotiation,
Understanding	Teams, Realism, Real-Time Play, Time Scarcity, Player Autonomy
Remembering	Infinite Game Play, Competition, Player Substitution, Turn Based

Appendix B: List of Game Mechanics and Dynamics - Mechanics Mapping

Game Dynamic	**Game Mechanic**
Modular Game Board	Building, Allocating, Choosing Controlling, Discarding Enclosing, Placing, Substituting Taking, Transforming Upgrading / Downgrading
Fog of War	Moving, Point-to-Point Movement Controlling, Enclosing, Herding Information-seeking
Asymmetric Abilities	Allocating, Browsing, Choosing Substituting, Taking Upgrading / Downgrading
Hidden Objectives	Buying / Selling, Contracting Controlling, Enclosing Herding, Information-seeking
Teams	Contracting, Conversing
Adversary Tracking	Controlling, Herding Point-to-point Movement
Resource Scarcity	Allocating, Choosing, Controlling Enclosing, Herding, Placing Taking, Trading, Transforming Upgrading / Downgrading
Player Ethics	Buying / Selling, Enclosing Placing, Substituting, Taking
Diplomacy	Conquering, Contracting, Controlling Conversing, Enclosing, Storytelling Information-seeking, Voting, Trading
Deck/Hand Building	Arranging, Building, Controlling Discarding, Taking, Trading Upgrading / Downgrading
Bluffing	Conversing, Expressing, Storytelling
Chance	Operating
Cooperation	Conquering, Contracting, Conversing Substituting, Attacking / Defending
Conflict	Buying / Selling, Conquering Controlling, Enclosing, Taking Trading, Attacking / Defending
Collaboration	Contracting, Conversing, Substituting Voting, Attacking / Defending
Level of Communication	Controlling, Conversing, Expressing Information-seeking, Storytelling

Information Control	Controlling, Conversing, Enclosing Taking, Expressing, Choosing Information-seeking, Storytelling, Trading
Time Scarcity	Operating
Feedback	Conversing, Expressing, Information-seeking, Submitting, Voting
Limited Actions	No Mechanic Required
Infinite Game Play	No Mechanic Required
Real-Time Play	Accelerating / Decelerating, Expressing Catching, Conversing, , Aiming & Shooting Manoeuvring, Motion Moving, Powering Sprinting / Slowing , Jumping
Team Modeling	Choosing, Contracting, Conversing
Multiple Strategies	Buying / Selling, Choosing Conquering, Enclosing, Taking Transforming, Upgrading / Downgrading
Multiple Endings	Choosing, Controlling, Storytelling
Player Substitution	Choosing, Conversing, Substituting
Player Autonomy	Taking, Placing, Point-to-point Movement Submitting, Choosing, Transforming Upgrading / Downgrading
Realism	Operating, Sequencing, Voting
Negotiation	Bidding, Buying/Selling, Contracting Conversing, Controlling, Enclosing Storytelling
Competition	Conquering, Enclosing, Choosing

Appendix L. Agile Adventure Player Survey Results

- **Student One**

Nov 25, 2019 at 3:58pm

Software is intangible; hence, its development progress cannot be visualize making it difficult for Program Managers to see progress. This is why I really like the idea of an Agile Adventure Game that will provide clarity and a tangible look into the world of software development.

Introduction and Learning Objects – might I say “perfect”? This part is really really good. I love how it immediately states what you are going to get out of the game even before you begin playing it. I also really like how concise the objectives are and the way they are laid out makes it easy to read.

Equipment Description – most of this is good, but I think the card interface could use some work. Here is the current issue: For Role Cards, there are a few specific role cards that have ‘*extra’* abilities like SMEs, Customer, Operations Team, and Security Expert. It is very difficult to remember these special abilities and these abilities are easy to forget. My solution would be to concisely list on these specific cards their extra abilities (like you did for the Automation card) which would increase player friendliness. The rest of the cards are good.

Solution Point System – overall very good section, clear and concise. Easy to understand.

Setup and Scenario – no time limit listed. How long do team’s get to setup and discussion in the Scenario section? No time limit is given in the instruction, PowerPoint says 30 minutes.

Agile Teams – I like this. Very similar to our homework’s!

Program Increment Planning – great, only confusion part was this phrase, “by physically passing the card,” took me about 20 seconds to figure this out. To remove any possible confusion I would say, “by physically passing the User Stories Card.”

Sprint Execution – times given on the PowerPoint and on the directions don’t match. PowerPoint says 30-45 minutes, Word Doc instructions say 20 minutes. This increases confusion. Still confusion on how stuff moves through the sprint. I like how Requirement Decomposition pushes teams to break up big chunks into smaller chunks, this is really good. Rest of it looks good.

Conclusion – very clear, overall good.

Even after reading the instructions and going through the PowerPoint the Engineering Effort Point System still really confuses me. I don’t understand how you go from Apprentice to Journeyman (aka get + points). Most confusion part of the game in my opinion. I would make a visual showing how cards get ‘upgraded’

Regarding the learning objective, although I haven’t played this game would provide a valuable Agile tool. It requires foundational knowledge of Agile but by the end of play, that foundation would have grown. It seems like an effective tool to me. But again, this is difficult to determine without playing the game. It is like talking about riding a Bike without ever riding one. Again, I have no idea if this is fun to play since, I’ve never played it. But I am optimistic!

My only ugly is in regards to who is this game specifically designed for? It's too specific for someone unfamiliar with Agile (like I was at the beginning of the semester), it's too general for someone familiar with Agile (like I am now). I really don't see how it can be used a learning tool except for Program Managers to get a quick idea on how progress happens using an Agile Method. Maybe it's just for 'practicing' the Agile method?

Student 2

Nov 26, 2019Nov 26, 2019 at 10:28am

Manage Discussion Entry

Instructions are good. Having the learning objectives listed at the front is good. Also like them being short so players will be actually read them. It looks like it will accomplish the learning objectives, and could be fun for most players. I really like the listing of terms at the end, that will help new players with game play and learning because Agile has a lot of new terms.

I would like to have more information on the cards, especially for the roles. A short definition for that role on the card will help new players remember, and learn, what each role does. Also, a pre-made form for tracking user stories and NFRs would be helpful in keeping game play organized. This would allow players to focus more and playing, and learning, if the information is organized easily. And as mentioned by Eugene, the times for sprints don't match.

Overall I think the game looks good and I think it will be especially good for leaders to play so they can get experience with how agile might play out (pun intended) so they will be more effective in their job when implementing Agile.

Game on!

Student Three

Nov 26, 2019 at 10:46am

Word Doc:

Not sure what learning level students are supposed to start at, these instructions assume the players have a basic understanding of Agile terms – scrum master, release train engineer, etc. A definitions section might be helpful. Case in point, the instructions ask to identify who is the RTE, but then in the next paragraph, it says that the RTE is typically the instructor. Recommend correcting the order of operations and assisting setup by describing each role and who typically plays it as they are each introduced.

Limits should be placed on how large or small each agile team should be – giving the teams some basic guidance instead of punishing them later (e.g. for not having a security expert on their team).

It's very unclear what the MVP is defined as – is that something that the RTE decides on, or the customer? It was stated that a Customer is not a necessary role in this game, so that should be clarified.

Are teams allowed to reorganize personnel between sprints? I think they should be, especially since this is a teaching tool, players are bound to get it wrong the first time and shouldn't be punished for the entire game for an initial mistake. Edit: this is shown in the powerpoint but not in the word doc, both documents should have the same information.

No instructions are given as to how the breakdown of features should happen, if there is a time component to it, or who leads it.

All in all, this word doc is written from the perspective of someone who knows what Agile and SAFe are, which is unhelpful to new players. While it might be wordier to do so, all terms should be defined when they are first used.

Powerpoint:

Good discussion on roles, but maybe describe all Agile roles as well, so that each person understands what their actual role is on the team and a real-life example.

Slide 6 is confusing on what it is trying to teach.

Slide 8: having two of each requirement type is helpful for the team in trying to generate broken down requirements, but I was left confused as to if F12 was a higher priority than N1.

Unclear which role manages the Kanban board (if one doesn't understand SAFe).

What happens if a build fails? Does the task return to the Review stage, or just sit in the Build portion for more time? I also think that upon playtesting, more things will

fail to build and the +4 should be decreased to a +2. This would be more realistic, because ideally the task is broken down into something manageable.

How does eliciting decomposition work? Are there dedicated team members to do the decomposition of features? Game Variants slide needs to either be fleshed out or hidden.

Training slides should be self-sufficient and not require an explanation or spoken material (e.g. if the slides are sent to someone geographically separated and they want to conduct their own training session, the game needs to be taught in the same way each time). Overall slides are a good start but need some serious fleshing out.

Student Four

Nov 26, 2019 at 10:47am

Manage Discussion Entry

Some general comments on my perception of the game without having actually played yet. This card game seems like it could be quite complex similar to Battle Space Next. It also appears that a general understanding of long duration, strategy based card games such as BSN or Magic the Gathering would be beneficial to potential players. Due to the perceived complexity, I would conclude that it may be difficult for a new player to pick the game up and enjoy the process the first time around. The overall goal of the game is admirable, but having been developed by a group that has a firm understanding on the topics being taught may have resulted in a game with too much information. This assessment may change completely once I have the opportunity to play the game as I am very "hands on" in understanding new information.

Specific Feedback:

The Student Learning Objectives seem to be well thought out and attainable. They are concise and tell students upfront what the end goal is.

SLO B- mentions decomposing requirements as a learning objective yet the instructions say this step is optional. If decomposition of requirements is optional maybe the learning objective should state something along the lines of "understand the decision process used to decide if a requirement should be decomposed further."

The Event Cards cover a wide variety of events that can happen in a procurement/development environment. 1 issue I have is with the Customer Visit card and that it seems to increase the amount of work that can be done in a single day. From my experience this is not true and if anything a customer visit slows down or even stops value adding work the day prior for preparation and the day of while you're in meetings/tours.

For the flow of the game why does the Analyse step only allow 1 item to move forward to SME review when the next step allows 1 item per SME to move forward? This implies that the SME's will be waiting for a new item to show up everyday instead of having an inbox of work to accomplish. From my experience, SME's are in high demand and become "bored" very quickly. If they are waiting on you to give them work, it is very likely they will find something else to do and will no longer be available to you.

Overall, the concept of the game is well thought out but may be more suited to improving the knowledge base of someone who is already doing Agile development rather than teaching someone new about Agile development.

Student Five

Nov 26, 2019 at 4:14pm

The Good:

1. The instructions were well written. The role cards cover all the major scrum team members. The point system of functionality, usability, security, and quality was very creative, but slightly confusing.
2. I love classroom games! They are a fun way to keep students engaged with a hands-on activity.
3. I like the idea of having students roll a dice to simulate uncertainty, complexity, and mistakes within SAFe. Nothing ever goes as planned!

The Bad:

4. I would suggest adding at least 10 more role cards to make the game more realistic and allow for more diversified teams.
5. What is the time limit? I read two different times from the instructions to the slides.
6. From the instructions, it states that “in order to upgrade from DevOps to DevSecOps a Security Expert Role Card must be included.” After writing the DevSecOps paper, I thought DevSecOps was about integrating security throughout the project and it was the responsibility of everyone on the team, not just a Security Expert. Just wanted to make you aware that this could confuse students into thinking that a Security Expert has to be on the team to implement DevSecOps.
7. The instructions are written very well, but only allow students with a solid agile background to fully grasp the concepts and ideas. The student has to fully understand all Agile terms (sprint day, points, user stories, features, NFR, kanban board etc.) to play this game.

The Ugly:

8. I think it is a great idea to make a systems development game, but I am slightly confused on your targeted audience. It would not make sense to play this game at the beginning of SE593 because students would not be familiar with any of the terms and the point system would just confuse them throughout the semester. It doesn’t make sense to play this game at the end of the semester because now we are familiar with the Scaled Agile Framework and realize that the point system is **not** part of SAFe. At this point in the semester, students should already understand and be aware that SAFe components can be unpredictable and complex without playing the game.

Suggested Changes:

9. I suggest redesigning this software development game for AF organizations attempting/transitioning to SAFe. Find a way to incorporate cards that explain how Agile looks in a AF unit or common mistakes with Agile in an organization.

Student Six

Nov 26, 2019 at 8:08pm

The good:

10. In terms of the self-organizing skill, I imagine that students will struggle to determine what team arrangement is most appropriate, especially in the first run-through of the game. This people management aspect will likely present initial challenges as students have to choose who fills each role to contribute to effective team performance. Hopefully students will develop this skill as they play the game and recognize how to best keep everyone motivated, involved, and not over- or under-utilized. It is also important to consider that in the process of self-organizing, people may realize that they lack the ideal team member for a certain role or task. This provides people with the opportunity to gain experience and develop skills. Overall, I anticipate that the game will provide good exercise and practice for organizing members and promoting group cohesion to further progress for a project.
11. Since the Customer Role Cards allow a team to analyze one additional user story per sprint day, this will likely help students in their development and, later, evaluation of team velocity within their ART performance.
12. Aspects I appreciate:
    a. The idea of “upgrading” to DevSecOps via inclusion of a Security Expert
    b. The Automation Event Card to help mitigate technical debt (presumably) via speed, consistency, and repeatable processes
    c. How each team selects User Stories from the backlog in response to the RTE discussion – students should get experience with thinking through how to prioritize tasks.
    d. Bonus points for security – people should be rewarded for bettering environment and product security.
    e. Overall need for student game play decisions – students have the discretion to determine what they want to take on (complicated User Story vs. decomposition).

The bad/ugly:

13. Similar to Student 5’s thread, after completing the DevSecOps research paper, I was under the impression that security should be a shared responsibility as opposed to solely the security expert’s concern. Having a security expert role is a good option, but if we truly want to promote this shared responsibility mentality, we may need to revise role cards.

14. For requirement composition, the instructions of *"The summation of child requirement characteristics must be equal to or exceed those of the parent requirement. If a child requirement is still too complex, it may be returned to the Product or Team backlog.*" are not entirely clear to me. If a team attempts to decompose a complex requirement, and they get to a point and determine that the child requirement is still too complex, what threshold or determining factor helps them decide when to continue with decomposition or instead pass it back to the backlog?
15. If the maintenance features exceed 20% of the backlog, does the team fail by this criteria (thereby ending the game)?
16. Overall I am concerned about time constraints. I understand the concept of pressing team members for time because they need to establish a good work pace and contribute to continuous development and delivery. However, as David mentioned, I anticipate that a team may only complete one sprint before permitted time expires (which, I am also unclear as to what the official time constraint is).
17. Is the target audience supposed to be SENG593 students towards the end of the quarter? Even after weeks of exposure to SAFe principles and aspects of an agile team, demonstrating mastery of these concepts will be difficult as we try to acquaint ourselves with the game logistics (similar to how we struggled through Battlespace Next).
18. A follow-on to my previous point: The Game Prep slide states that "Students propose increment and sprint length," but they will likely grossly underestimate or just overestimate to help themselves complete tasks. Speaking to the issue of target audience, people with no experience will likely not make a good estimate for how much time they need for the exercise.

Proposed changes/enhancements:

19. In terms of revision related to the DevSecOps security expert comment, we could potentially look into making multi-faceted roles or somehow incorporate/modify role description so students are aware that a Software Developer (and this is just one example) is responsible for incorporating security measures into his/her thought and work processes.
20. Maybe we could split the Automation Event Card into multiple cards that break down "Automation" more specifically (into cards such as "Automated Testing" or "Automated Deployment") so students can learn more about the automation part of CALMR.
21. Maybe there is potential for this game to be split into related games of different focuses. Within software technical project management, success criteria include on-time delivery, keeping costs within budget, meeting customer expectations, and maintaining a coherent development team. Each of these aspects involve various demands and processes that could potentially be implemented in separate game exercises. In trying to combine everything into an all-in-one type of game, students may be overwhelmed and task/objective-saturated, and the learning objectives might get lost in translation.

22. Within the PowerPoint slides, I think the “(1-7 students each)” by the Multiple Agile Teams bullet should be more along the lines of “4-7 students each” because realistically (especially for purposes of this exercise), an agile team will require multiple roles and multiple people rather than a single person, pair of people, or small trio.

Student Seven

Nov 27, 2019 at 6:03am

Current State Assessment:

I like the frequently asked questions and suggest tracking/building more FAQs as more students are exposed to the game. As of right now, the questions are SAFe focused, which some students may not be familiar with yet (depends on target audience).

I’m having a hard time visualizing how this would carry class to class. What is the plan to track a team’s status from if each class is treated as a PI when playing campaign style? The points/rules are fairly complex and would require a way to track status from class to class. Without playing the game, it’s hard to say if there would be any challenges picking up where you left off from the last class.

The instructions and PowerPoint mention that the MVP is the goal, but it’s not clear what that is. Also, I’ve read this sentence in the conclusion a couple times and can’t figure out what it’s getting at: “Multiple campaigns may be played, each resulting in a new MVP. However, for each released MVP, the number of maintenance features increases by one per sprint and must be remain less than 20% of backlog.”

Enhancement Suggestion:

Similar to Battlespace Next, it would be awesome if there was a training/demo video since the game is hard to visualize. This is necessary/beneficial for visual learners and would be a great prep tool for students before playing the game in class.

The game needs creative scenarios to keep students involved and jazzed about agile. It would be interesting to include real Air Force programs, or even futuristic technologies to develop.

Student Eight

Nov 29, 2019 at 8:31am

I agree with your enhancement suggestions. I'm kind of a board game nerd, and before I buy new complicated games, I look to the internet to watch the videos people upload to youtube. There's one channel called Geek & Sundry that does a series called "Game the Game," where they make a how-to video that summarizes the rule book and then play a game on camera, highlighting some of the nuances to the viewer. Something similar would make this much more approachable than having to decipher a slideshow and a word doc and try to reconcile the differences.

I also agree with your final suggestion for including real air force program material. It'd be a bit of work on the part of the game designer, but I think there should be some template/cookie cutter scenarios that mirror real life. If I'm brand new to this entire concept, I'm going to do an absolutely terrible job of decomposing user stories, similarly to how badly we did in class the first time we tried. I think you'd get a ton of value from the game even if that aspect was more or less provided to you. Similarly to how in Dungeons and Dragons and the like, there are pre-made characters and pre-made campaigns that newer players can take advantage of to get right into it.

Student Nine

Nov 27, 2019 at 11:05am

Manage Discussion Entry

The methodology for assigning FUSQ points to stories, features, and NFRs wasn't clear to me. Given each sprint lasts 20 minutes, and the total capacity of the entire team is bounded by the number of role cards in the deck (and people playing the game), it seems like you could run into a situation where you don't complete an MVP due to assigning too many points to features.

When taking on a project in reality, you would be bounded by either cost, schedule, or performance, with some trade space between some of them, but not necessarily all of them. So if you had a set team and couldn't hire too much, you would only be able to complete a certain sized project if also given a time constraint. Or you could take a bigger project if given more time. Or, if your scope AND schedule were more rigid, you would need to scale up the team appropriately to be able to meet those objectives.

So in the game, you're given a set number of people/roles, and a set time period. It seems like you could to end up in a situation where you're assigning FUSQ points based on how much time you have to play the game, and not how many points a given story/feature/NFR is actually worth. This characterization may not be totally true, since if you end up with a ton of points, you may be able to extend the length of your campaign.

Since this may happen, it may be useful to make it more explicit so there's at least some control over it. A potential solution may be to figure out approximately how many FUSQ points are required for a given class size and desired game duration, then have that set number to "divy" out to the various stories/features/NFRs. The drawback to this is it's another "gameism" that doesn't mimic reality very well - ideally you estimate features based on their content.

It is also not clear to me what the SMEs are for. Yes, they "review" stories/features/NFRs, but presumably they can only review things that correspond to their specialty. So how do teams "assign" their specialty? I'm assuming they'll assign the specialty based on whatever that team is working on for that

sprint. There could possibly be things they're working on that don't fit with the SMEs speciality, so they'll have to be reviewed in another sprint when that specialty is available? There's also some squishiness here - since the players can assign whatever specialty they want, could they not come up with a more general and high level specialty to increase their chances of being able to review the work? For example, saying someone is a "video game" SME, could cover a lot of the bases if working on a video game. I'm not sure if there's actually a "problem" here, so I'm not sure about solutions either. Just a thought.

To further the DevSecOps approach, perhaps an event card could be added along the lines of "Learned Security, obtained certification!" This way other team members could contribute to security besides just the expert. Ideally, experts in a company would be teaching various aspects of security to the team to make "mini experts" out of everyone. This card would be similar to the "upgrade" card. Perhaps you could only use it if you already have a security expert on the team.

Student Ten

Nov 27, 2019 at 5:17pm

The good:

The game seems to do a good job of getting students used to organizing into appropriate teams in order to accomplish their designated goals. The game also seems to present a logical manner for getting students to understand and utilize the Kanban boards and backlogs (program and sprint).

The bad:

The game seems to flounder regarding presenting the usefulness of evaluating ART performance (measure aspect of CALMR approach). There lacks an element that ties the making of the graph back to any game metrics (such as gaining some advantage by doing so). As the game is currently designed students can already grasp a high-level understanding of their team's performance, so the evaluation doesn't seem to provide much value.

The ugly:

As the game is designed a student may have a hard time decomposing user stories into more manageable pieces. This is something that will not be easy to solve and is almost a necessity for effective game play.

Possible solutions:

Make the creation of measurement tools (such as graphs to depict performance) benefit the teams by giving them a point in functionality or quality if the tool is utilized (limit one per team). To address story decomposition there are a couple of choices 1) provide a generic list of possible higher level stories that are decomposed for students to reference 2) a class pre-requisite could be imposed that ensures students taking the class have software development/acquisition experience 3) remove the element of requiring students to decompose requirements and allow

them to genericize the requirement (i.e. req(A)= F8 U4 S2 Q4, req(A1)= F4 U2 S1 Q2, req(A1.1)= F2 U1 S0 Q1). Any of the listed solutions will generally solve the problem, however, they will alter the learning objective of decomposing complex requirements. For students to have the ability to decompose a complex requirement a high level of understanding of the requirement is necessary and consideration should be given to how that student should acquire that level of understanding.

Student Eleven

Nov 29, 2019 at 8:38am

I was having the same issue with imagining new players/students decomposing stories, and I like the possible solutions you propose. The game should be a little narrower in learning focus, and taking away some of the effort to decompose stories is how I see the game focusing more on general SAFe principles and understanding. I especially like your solution #2, where the game could perhaps provide an example list so students can see what they might actually look like for a real program. They're still experiencing the process, just not in a way where they could seriously mess up the game. If you fundamentally get the user stories wrong, the game won't be very useful, and I see many students getting that part wrong.

Student Twelve

Nov 29, 2019 at 9am

The Good:

23. I generally think games are a great way to learn by doing. That's how I learn best. I'd learn these concepts much faster playing through a game than reading generic role descriptions, etc. in the textbooks.
24. The instructions were well written and the pictures were appropriate. I think one document should be able to suffice instead of two, but the content is mostly there.

The Bad:

25. The other members of the class have already harped on the common inconsistencies between the slides and the word doc, so I won't repeat those.
26. I'm also not clear what happens if you fail to build. I'm visualizing scenarios and I'm not sure what would happen.

The Ugly:

27. Similarly to several others, I'm confused as to when/who would play this game. If it's for introducing Agile and Scaled Agile to people, I think it's too complex as it currently is and invites failure (but maybe that's the point?). If it's for people quite familiar with Agile and Scaled Agile, I think it's in better shape and would need

less change, but that isn't clear to me. I'd personally think I would've learned a bit from this game if it was baked into the course, probably moreso than the excel spreadsheet homeworks.

Suggested Changes:

28. I've played a lot of board games, and I've never seen one that comes with instructions in multiple formats. I think there's a good reason for this, as we see in this example. With a word doc and a slideshow to reconcile, there are opportunities for inconsistencies as we see here. I think a fleshed out PDF would be much more useful than powerpoint. Something that could be printed out, perhaps even a booklet,
29. The game manual should also define the concepts for those less familiar. Maybe a better fleshed out introduction that describes SAFe at a high level and a brief background on what makes teams successful (highlighting how security is important early on is also helpful to not surprise punish teams who didn't think of that). The glossary at the end of the word doc does provide very brief role definitions from the book, but I think some ART concepts would be helpful, depending on the target audience.
30. Just like with actual Scaled Agile implementation, I think there should be some element of coaching. Whether that's some hints in the beginning from the instructor or a defined time to get feedback and course correct, or even just a debrief at the end, there should be time built in for students to hear what they're not understanding. For example, if we played this early on in our class, I think we would've argued and come up with some terrible user stories that would make the game quite difficult.

Student Thirteen

Dec 1, 2019 at 3:31pm

Based on my understanding this game is designed to be incorporated into SENG 593, at least that's what the word document briefly mentions. I agree that this game would most likely be more beneficial then a lot of the excel homework's we did. If this game is to be incorporated with the class I think a more effort should be put in to define how and when this incorporation would occur.

Student Fourteen

Nov 29, 2019 at 12:24pm

The Good:

31. Anything that can be made into a game always makes it easier to stay focused and learn, so big positive there.
32. The rules are not so complex that it completely loses the reader which is something I find to be one of the most important features games, however I

admittedly have not played it yet so my opinion is subject to change if the gameplay doesn't as smoothly!
33. The dice and random card drawing will help keep interest in the game over long periods of time. I can't explain that one, but humans seem to keep coming back to things that have elements of randomness i.e. see gambling.

The Bad:

34. I think the word doc rules could benefit from a few more graphics included to help players visual what is happening. Or if resources were available, the youtube video for Battle Space Next really helped, so something similar here could be valuable.
35. It has already been mentioned, but the time limits do not match up between the documents. But as we saw when we played Battle Space Next, the first time you attempt the game there will be lots of questions and confusion so maybe it would be best to not define any specific time limits in the rules and just leave that up to the instructor who can base it on the experience of the players.

The Ugly:

36. It isn't actually to this point yet, but I would be worried that the complexity of the game might continue to increase and increase and increase during the Beta phase to a point where it becomes too complicated and new players lose focus. There already were some suggestions to add cards, which I do not disagree with, but I would try to make sure you do not add a layer of complexity with each card. For example, the SME card has its own layer of complexity.

Suggestions:

While I was able to follow along, I did not completely comprehend the game until I got to the conclusion. I think it would be helpful to include a "summary" at the beginning, which is essentially the same thing as the conclusion so you kind of understand what to look for in comprehension as you go along. Currently the Intro/Overview focuses on the learning goals of the game rather than the game itself.

Student Fifteen

Dec 1, 2019 at 5:05am

The Good:

-Overall, I for one appreciate a hands-on learning experience. I find myself retaining more information if it can be applied, rather than just lectured or read. Therefore, I think that the game is a worthwhile pursuit.

-I can see it satisfying the learning objectives, I would find it helpful seeing agile efforts executed in a high level rapid fashion vs the in-depth homework scenarios accomplished over a longer time period.

-For the role cards, I appreciate that you must randomly draw your role. This forces students to be a variety of roles over always choosing the best known one.

-I really like the build roll aspect. I am glad to see that there is some chance in the game. Still a little confused on the numbers, but I am sure that will come with play.

The Not Understood:

-Overall, I think a lot of my misunderstanding will come with playing the game, but I also see that this would be difficult to play before one really understands the Agile Process. Therefore, not sure if it could be played until most of the material has been covered.

-Without having played the game, I am still a bit confused on what the MVP will be?

-I am not sure the role of the event cards, and assuming it is to mimic real-life scenarios?

-I am also a little confused by the requirement decomposition that comes in step 3. I find it interesting that we haven't already done this before getting into individual teams, else how would you know what teams to assemble?

-It will also be interesting to see how the team formation occurs. I can see that being a bit chaotic, but maybe that is the purpose?

Student Sixteen

Dec 1, 2019 at 2:19pm

Overall the idea of the game seems like a great way to drive home the fundamentals of the course, given that the class actually focuses on teaching students about the fundamentals of Agile/SAFe, Dev(Sec)Ops, Technical Debt, MBSE etc. Given the proper background instruction and a viable example to work from, it could help to strengthen lessons learned in class.

Simply reading the instructions for a game, doesn't do much in the way of helping to actually teach someone about the game. How many times have you tried to teach a friend a new game, and you end up saying let's just play a round and you'll see how it works"? I have more questions than answers at this point.

For basic gameplay, we are given a project by a customer and distill their requirements into user stories.
Are these user stories physically written on the cards? Do we use scrap paper or whiteboard draw out the Kanban board?

Then we each draw a role card for an assigned team member role, and self-organize into teams. Do the students who pull the Scrum Master cards get together and organize the other students roles into teams?

It's not clear what it is we are actually delivering as the end game, MVP. According to the "Execute Game Play' slide, it looks like we are just moving work items from the backlog, through the different phases of the Kanban board and rolling a die to determine the amount of time it stays in each section. Are we supposed to record these hypothetical situations on our scrap paper?

I feel like we need to actually play through this game, more than once, to provide effective feedback.

Student Seventeed

Dec 1, 2019 at 3:22pm

Manage Discussion Entry

Based on my understanding of the game without playing it yet, I think it would be a great opportunity to get hands on experience simulated the agile approach. Would the game be fun? Probably not, however, reading over PowerPoints is a lot less fun and this game would most likely provide a much better learning experience as well.

The rules seem to be set up sufficiently well, although as many other students have pointed out I think one set of complete rules would be much superior than two sets of somewhat incomplete rules. Also the discrepancies between the two need to be resolved.

My main concern for this game is how it will actually be integrated into the classroom setting, especially a class such as SENG 593. The word document states the game will be associated with SENG 593, however it doesn't go into much detail on working with and around the current course layout. A key question to be answered is what the base scenario for the game would be. Would this game revolve around the same base scenario as the class homework's or introduce a new scenario? A lot of the scenario building for this game such as user interfaces, architecture, user stories, and program backlog were completed during our rendition of SENG 593 through homework and in class discussion. However, to complete all tasks took up a great deal of the course's length. My understanding from combining information from the word document and power point is that it will run for 4-6 weeks during the course, twice a week, with a duration of 20 minutes or 30-45 minutes. I am not sure there is sufficient class time to set up the scenario and then complete a full rendition of the game.

Overall, I think the game could be very useful, but a lot of work would need to be done to properly implement it into a class structure. In my experience when courses have attempted to run games/ simulations to give the student a fist hand experience, there is a lot of upfront work to teach the game. Generally, this upfront work is not paid off because the teacher doesn't invest sufficient time for the game to be played

to completion because other aspects of the class take priority. Because of this a lot of time was spent learning a game but not enough time playing the game for its learning objectives to be met.

Student Eighteen

Dec 1, 2019 at 5:07pm

The good:

- The game is comprehensive of every aspect that we have discussed in this class which will satisfy the learning objectives once the students learn how to play the game correctly.

- The game design reminds me to our homework which I hope will help when understanding the in depth play during the game.

- I really like the breakdown of capability to feature to user story with points incorporated with each.

The bad:

- I am afraid the complexity will lead to mass confusion when trying to play for the first time. I can imagine students asking clarifying questions constantly throughout the first game. I think this is a result of Agile being a bit overwhelming and complicated itself, but the instructions didn't help my understanding.

- If game is played in the first half of the quarter of the class, I don't think it would aid in learning because students won't have the full knowledge that is needed to understand the aspects of the game.

- If its meant to be played throughout the class, as is mentioned on the “Execute Game Play” slide of the game overview, then I feel like it would take valuable class time away that could be used for discussion, lecture, or other proven methods of teaching agile software systems engineering.

The ugly:

- I may be in the minority, but I personally don’t learn well from playing games like these in place of traditional methods of teaching.

- If the point is to convey agile methods and teach the basics, then there are way too many moving parts to keep track of to also enhance learning at the same time. However, I can't really think of any ways to simplify due to the complex nature of Agile.

Suggestions:

- Maybe create a video that shows how the game is played to help first time players understand because its so complex which allows the students to achieve the learning objectives

- Have a whole class period dedicated to teaching the working of the game so students can ask questions about what they don't understand before they actually go to play the game. This would allow the play of the game to run more smoothly and allow the students to have a better understanding because they won't have to stop the play to ask a simple question.

- If "fun to play" is a priority, then it might be advantageous to try to implement some sort of competition. I'd imagine most people are competitive so all the games that are popular are based on a clear way to win and a way to have competition between players, teams, or even competing with yourself.

Student Nineteen

Dec 1, 2019 at 6:27pm

3. Provide an assessment of the current state of the game (the good, the bad, the ugly). Does the game satisfy the learning objectives? Fun to play?

My mental image of class playing the first run through is one where things are somewhat chaotic and high energy with orderly communication being at a premium. I imagine that people will be simultaneously trying to figure out the whole workload and the best way to solve it implying a lot of duplicated efforts. I am interested to see how MVP(s) will be decided during the planning session and how organized we are about determining what our role distribution and capabilities are and how we apply that to the initial user stories we tackle. Regarding the Sprint days I think this will could either be waiting on a timer or trying to figure out our next moves after we complete the objective we are working on. If people are idle, I think that will deteriorate the overall interest in the game.

4. Propose game changes and/or enhancements. Justify why these are a) necessary and b) sufficient to meet the learning objectives.

I am hesitant to suggest changes without seeing a few iterations of the game. One issue that I could foresee causing inefficiency would be that once teams are set they are only optimized to the first task or two and this could lead to decline of output later in the program increment as the FUSQ point requirements shift according to different tasks. An organizational mapping of the teams + FUSQ point output capabilities that they produce each sprint day would help the students tackle this potential issue. This could also give the students a better understanding of the self-organized teams and how they might be dynamically reorganized throughout the program increment. I suggest the medium of an easy to read bubble chart that will enable everyone to see what teams are working what tasks and a total of FUSQ point output capabilities per team and role composition per team. This will enhance learning by demonstrating a team management tool that would be employed by an ART to efficiently manage talent.

Student Twenty

Dec 1, 2019 at 7:17pm

Good:

The game creates an interactive way to learn a complex system. Seems like a great way to get an introduction on how a Program Increment flows and what each role actually does.

I think the point system is a good way to quantify different needs of various user stories and features.

The dice roll is a good idea. I like that just because you have all the points necessary, it doesn't necessarily mean you'll be successful.

Bad:

I'm unsure how features are dealt out. The instructions recommend that students are encouraged to decompose complex tasks, but I'm not sure how that works in the game.

Estimation is difficult, especially for people that don't have very much software background.

I understand that different teams are composed of different roles, but I'm confused if the CFT's work together outside of just deciding which user stories to work on.

Suggestions:

A demo video would be very helpful in getting a better idea of how the game works. I'm sure a play through will be very helpful for understanding the game.

Student Twenty-One

Dec 1, 2019 at 9:58pm

Current Assessment:

Based on the learning objectives of the game, the current state of the game certainly seems to satisfy them. This is primarily due to the game elements and gameplay accurately reflecting the SAFe process, to a fault. As a teaching tool or hands-on experience for students of Agile, this game is likely a great tool, that will enhance the classroom environment as an alternative to homework or lectures. However, outside of that demographic, I think Agile Adventure could use some work on the gamification side. As a few have stated, just reading through the instructions and looking over the cards requires knowledge of Agile, SAFe, and systems engineering as a whole. Also, the prep work to build the scenarios are fairly significant for anyone just wanting to pick up the game.

From a technical management perspective, the game seems to take out some of the hardest parts of a managerial role and leave it to randomness or points. A lot of team building is personality driven and the problem-solving aspects involved in SAFe are already resolved (what needs to be accomplished, how “hard” a task is, etc). These would of course be incredibly difficult to simulate, but it does present one of the most challenging aspects of the process and somewhat falls under the

learning objectives. With the level of detail the game goes into, it wouldn't be unreasonable to consider it.

Enhancements/Recommendations:

One enhancement that comes to mind would be to incorporate a gameplay mechanic that allows for fluctuating requirements and/or objectives. Something similar to a Phase 10 or Fluxx game where there are multiple or constantly shifting goals. This would help reflect the concept of requirements flexibility, user feedback, or scope change. This would also help to build some of the scenarios into the game to cut down on prep work.

Bibliography

1. R. Hunicke, Robin; LeBlanc, Marc; Zubek, "MDA: A Formal Approach to Game Design And Game Research," *Workshop on Challenges in Game AI*, pp. 1–4, 2004. [Online]. Available: https://www.aaai.org/Papers/Workshops/2004/WS-04-04/WS04-04-001.pdf

2. S. Arnab, T. Lim, M. B. Carvalho, F. Bellotti, S. De Freitas, S. Louchart, N. Suttie, R. Berta, and A. De Gloria, "Mapping learning and game mechanics for serious games analysis," *British Journal of Educational Technology*, vol. 46, no. 2, pp. 391–411, 2015. [Online]. Available: http://dx.doi.org/10.1111/bjet.12113http://researchrepository.murdoch.edu.au/25898/

3. A. Echeverría, C. García-Campo, M. Nussbaum, F. Gil, M. Villalta, M. Améstica, and S. Echeverría, "A framework for the design and integration of collaborative classroom games," *Computers & Education*, vol. 57, no. 1, pp. 1127–1136, 2011.

4. D. R. Krathwohl and L. W. Anderson, *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman, 2009.

5. C. W. Starr, B. Manaris, and R. H. Stalvey, "Bloom's taxonomy revisited: specifying assessable learning objectives in computer science," in *ACM SIGCSE Bulletin*, vol. 40, no. 1. ACM, 2008, pp. 261–265.

6. L. Buchanan, F. Wolanczyk, and F. Zinghini, "Blending bloom's taxonomy and serious game design," in *Proceedings of the International Conference on Security and Management (SAM)*. The Steering Committee of The World Congress in Computer Science, Computer . . . , 2011, p. 1.

7. S. Theodosiou and I. Karasavvidis, "Serious games design: A mapping of the problems novice game designers experience in designing games," 2015.

8. J. Petters, "Risk Management Framework (RMF): An Overview," 2018. [Online]. Available: https://www.varonis.com/blog/risk-management-framework/ [Accessed: 2019-10-16]

9. D. G. Srh and H. Heidelberg, "Design, Dynamics, Experience (DDE): An Advancement of the MDA Framework for Game Design." [Online]. Available: https://www.researchgate.net/publication/315854140

10. *Aki Järvinen Games without Frontiers Theories and Methods for Game Studies and Design*. [Online]. Available: http://acta.uta.fi

11. A. Pendleton and J. Okolica, "Creating serious games with the game design matrix," in *International Conference on Games and Learning Alliance*. Springer, 2019, pp. 530–539.

12. "2018 aetc strategic plan," 2018. [Online]. Available: https://www.aetc.af.mil/Portals/88/Documents/2018AETCStrategicPlan-Final.pdf?ver=2018-02-09-110329-537

13. J. L. Bishop, "The Flipped Classroom: A Survey of the Research."

14. A. Karabulut-Ilgu, N. Jaramillo Cherrez, and C. T. Jahren, "A systematic review of research on the flipped learning method in engineering education," *British Journal of Educational Technology*, vol. 49, no. 3, pp. 398–411, 2018.

15. P.-C. Ho, S.-M. Chung, and M.-H. Tsai, "Case Study of Game Design for E-Learning," Tech. Rep. [Online]. Available: http://www.savie.ca/SAGE/Articles/1625{_}000{_}PIE-CHI{_}2006.pdf

16. T. Susi and M. Johannesson, "Serious Games-An Overview," Tech. Rep. [Online]. Available: www.americasarmy.com;

17. C. Girard, J. Ecalle, and A. Magnan, "Serious games as new educational tools: how effective are they? a meta-analysis of recent studies," *Journal of Computer Assisted Learning*, vol. 29, no. 3, pp. 207–219, 2013.

18. J. Breuer and G. Bente, "Why so serious? on the relation of serious games and learning," *Journal for Computer Game Culture*, vol. 4, pp. 7–24, 2010.

19. M. Olano, A. Sherman, L. Oliva, R. Cox, D. Firestone, O. Kubik, M. Patil, J. Seymour, I. Sohn, and D. Thomas, "SecurityEmpire: Development and Evaluation of a Digital Game to Promote Cybersecurity Education," Tech. Rep. [Online]. Available: https://www.usenix.org/system/files/conference/3gse14/3gse14-olano.pdf

20. A. Shostack, "Elevation of privilege: Drawing developers into threat modeling," in *2014 {USENIX} Summit on Gaming, Games, and Gamification in Security Education (3GSE 14)*, 2014.

21. M. F. Thompson and C. E. Irvine, "Cyberciege: a video game for constructive cyber security education," 2015.

22. U. Fuller, C. G. Johnson, T. Ahoniemi, D. Cukierman, I. Hernán-Losada, J. Jackova, E. Lahtinen, T. L. Lewis, D. M. Thompson, C. Riedesel *et al.*, "Developing a computer science-specific learning taxonomy," *ACM SIGCSE Bulletin*, vol. 39, no. 4, pp. 152–170, 2007.

23. S. Lundgren and S. Bjork, "Game mechanics: Describing computer-augmented games in terms of interaction," in *Proceedings of TIDSE*, vol. 3, 2003.

24. B. Kreimeier, "The case for game design patterns," 2002.

25. M. Sicart, "Defining Game Mechanics," Tech. Rep., 2008. [Online]. Available: www.miguelsicart.net

26. F. Bellotti, M. Ott, S. Arnab, R. Berta, S. de Freitas, K. Kiili, and A. De Gloria, "Designing serious games for education: from pedagogical principles to game mechanisms," in *Proceedings of the 5th European Conference on Games Based Learning. University of Athens, Greece*, 2011, pp. 26–34.

27. I. W. Widana, "Higher Order Thinking Skills Assessment towards Critical Thinking on Mathematics Lesson," *International Journal of Social Sciences and Humanities (IJSSH)*, vol. 2, no. 1, pp. 24–32, 2018.

28. E. S. Quellmalz, "Needed : Better Metho ds for Testing Higher -Order Thinki ng Skills."

29. Á. Serrano-Laguna, I. Martínez-Ortiz, J. Haag, D. Regan, A. Johnson, and B. Fernández-Manjón, "Applying standards to systematize learning analytics in serious games," *Computer Standards & Interfaces*, vol. 50, pp. 116–123, 2017.

30. S. V. Chavez, "Serious game design using mda and bloom's taxonomy," 2019.

31. A. J. Pendleton, D. Pettit, and R. Dill, "Surveying the incorporation of iot devices into cybersecurity risk management frameworks," *SECURWARE 2019, The Thirteenth International Conference on Emerging Security Information, Systems and Technologies*, p. 128–133, Oct 2019.

32. [Online]. Available: https://www.gao.gov/assets/690/686203.pdf

33. S. NIST, "800-37," *Guide for the security certification and accreditation of federal information systems*, 2004.

34. R. M. Framework, "AFI17-101 _ AFGM2019-01 MEMORANDUM FOR DISTRIBUTION C MAJCOMs / FOAs / DRUs FROM : SAF / CN 1800 Air Force Pentagon," no. July, 2019.

35. S. NIST, "800-53," *Recommended security controls for federal information systems*, pp. 800–53, 2003.

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Air Force Institute of Technology
Graduate School of Engineering an Management (AFIT/EN)
2950 Hobson Way
WPAFB OH 45433-7765

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14. ABSTRACT

The Game Design Matrix makes effective game design accessible to novice game designers. Serious Games are a powerful tool for educators seeking to boost the level of student engagement and application in academic environments, but the can be difficult to incorporate into existing courses due to availability and the cost of quality game design. The Game Design Matrix was used by two educators, novice game designers, to create a serious game. The games wee assessed in an academic setting and observed to be effective in engagement, interaction, and achieving higher levels of learning.

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U	U	U	UU	207	19b. TELEPHONE NUMBER *(include area code)* (937) 255-6565 x7255; gilbert.peterson@afit.edu