January 2015

# Scaffolding Early Engineers' Design Learning with a Videogame: Investigating the Influence of Minecraft as a Platform for Design Ideation

Corey Schimpf
*Purdue University*

*Graduate School Form 30*
*Updated 1/15/2015*

**PURDUE UNIVERSITY**
**GRADUATE SCHOOL**
**Thesis/Dissertation Acceptance**

This is to certify that the thesis/dissertation prepared

By Corey Schimpf

Entitled

Scaffolding Early Engineers' Design Learning with a Videogame: Investigating the Influence of Minecraft as a Platform for Design Ideation

For the degree of Doctor of Philosophy

Is approved by the final examining committee:

Alice Pawley
Chair

Alejandra Magana

Brent Jesiek

Monica Cardella

Brian Castellani

To the best of my knowledge and as understood by the student in the Thesis/Dissertation Agreement, Publication Delay, and Certification Disclaimer (Graduate School Form 32), this thesis/dissertation adheres to the provisions of Purdue University's "Policy of Integrity in Research" and the use of copyright material.

Approved by Major Professor(s): Alice Pawley

Approved by: Ruth Streveler 11/23/2015

Head of the Departmental Graduate Program Date

# SCAFFOLDING EARLY ENGINEERS’ DESIGN LEARNING WITH A VIDEOGAME: INVESTIGATING THE INFLUENCE OF MINECRAFT AS A PLATFORM FOR DESIGN IDEATION

A Dissertation

Submitted to the Faculty

of

Purdue University

by

Corey T. Schimpf

In Partial Fulfillment of the

Requirements for the Degree

of

Doctor of Philosophy

December 2015

Purdue University

West Lafayette, Indiana

I dedicate this dissertation to my mother, whose unyielding support and encouragement propelled me to finish the degree even after her passing.

# ACKNOWLEDGEMENTS

I want to thank my advisor, Dr. Alice Pawley, for her support, patience and thorough feedback on several drafts of this dissertation. I also want to thank my committee members, Drs. Monica Cardella, Brent Jesiek and Alejandra Magana for their critical feedback and measured appraisals that helped this document coalesce. I particularly want to thank my committee member, mentor, and colleague Dr. Brian Castellani who pushed me to pursue graduate school, served on both my masters and PhD theses and acted as a sounding board through my graduate career.

I also want to thank Dr. Kacey Beddoes for her support and acting as an outside observer as I navigated writing the dissertation.  I owe deep thanks to Dr. Joyce Main for allowing me to work on her research team and explore several interesting and important studies that also gave me a much needed break from the solitude dissertation writing. Finally, I want to thank Dr. Ming-Chien Hsu and Matilde Sanchez-Pena for their support as we commiserated on the challenges of dissertation work.

# TABLE OF CONTENTS

Page

Page

# LIST OF TABLES

# LIST OF FIGURES

# ABSTRACT

Schimpf, Corey T. Ph.D., Purdue University, December 2015. Scaffolding Early Engineers' Design Learning with a Videogame: Investigating the Influence of Minecraft as a Platform for Design Ideation. Major Professor: Alice Pawley.

In this manuscript a modified commercial game, *Minecraft,* was used to assist early engineering students' learning the design process. More specifically, a designed-based research approach was employed utilizing a concurrent mixed methods to investigate the use of Minecraft for learning about the concept generation stage of design. Survey instruments measuring understanding of the design process, in-depth interviews on students' interactions with the platform and iterations of students' virtual artifacts were captured for analysis. Although no learning gains were detected from pre to post instrument, several analytical methods including visual content analysis of students' artifacts, discourse analysis of students' framing of the platform and thematic analysis of their reported formal and informal use of the game provided some evidence of students' engagement with the game, the mechanisms of that engagement, an array of ways in which students may use the platform informally that related to class-work, and the promise of virtual worlds for design learning.

# CHAPTER 1. INTRODUCTION TO GAME-BASED LEARNING FOR DESIGN

## 1.1 Introduction

In this manuscript I used a modified commercial game to assist early engineering students' learning the design process. Although no learning gains were detected from pre to post, several analytical methods provided some evidence of students' engagement with the game and the mechanisms of that engagement, an array of ways in which students may use the platform informally that related to class-work, and the promise of virtual worlds for design learning. Below I first detail the state of design in engineering education and the difficulties engineering students face when learning design; and second, I discuss the state of game-based learning and what potential it holds for design learning. I then turn to the main research questions I seek to answer, discuss the research design of the study, give some background on the game itself and briefly outline the theoretical and epistemological framework I use.

Until the 1990s, design received limited attention in the engineering education curricula in the United States (Seely 1999). In the 1990s there was a shift toward better integrating design into the engineering curricula (Seely 1999) including first year engineering design projects (Bertozzi et al 2009; Kalkani, Boussiakou & Boussiakou 2005; Daily & Zhang 1993; Agogino, Sheppard & Oladipupo 1992).

Many researchers also argue design is what distinguishes engineering from other technical fields (Gainsburg, Rodriguez-Lluesman & Baily 2010; Vincenti 1990; Simon 1969) or that design is a critical component of engineering (Figueiredo 2008). However, research also indicates engineering students often struggle with design work due in large measure to the open and often ambiguous nature of design (Von Lockette et al. 2007; Neely, Sheppard & Leifer 2006; Dym, et al. 2005). Difficulties in learning design is compounded by the centrality of engineering science in the curriculum and limited emphasis on other elements, including design (Sheppardet al. 2008; Dym et al. 2005). Dym et al. (2005) and others have argued that engineering science as taught typically employs a “convergent” approach whereby the complexity of a problem is reduced through analytical techniques to identify a correct or optimal answer. Practically speaking, most learning activities and performance evaluations in engineering classes usually take the form of closed-answer problems sets and exams.

Learning how to design does not lend itself well to closed-answer problem sets and exams. Particularly in the early stages, design typically involves divergence, where many different ideas or concepts are generated (Stones & Cassidy 2010; Prats et al. 2009; Eris 2003), followed by a process of convergence where ideas are evaluated, dropped or combined (Toh & Miller 2015).The divergence component may lead to several different designed artifacts or pathways to a final design and thus is part of the reason design work is often open and ambiguous (Crismond & Adams 2012). Although design courses are often part of the first year and final year engineering curriculum (Sheppard et al. 2008; Dym et al. 2005) several researchers studying more senior engineering students find that these students placed greater importance on engineering science as "real" engineering rather than design or other collaborative work (Leonardi, Jackson & Diwan 2009; Downey & Lucena 2003). This finding is problematic as engineering graduates are expected to participate in design teams (Bucciarelli 2003, 1996) and may be ill-equipped for doing so. Furthermore, the difficulties students face when they are first exposed to design raise questions as to whether there may be ways to better integrate design into the engineering curriculum. Better integration of design early in their engineering careers may lead to more balanced engineering students who excel at using both convergent and divergent processes.

Game-based learning represents one potentially fruitful way for better integrating design with the engineering curriculum. Recently, video games have received increasing attention as educational tools across many fields including health, science, humanities and others (Gee 2010; Ritterfield, Cody & Vorderer 2009; Wankel & Kingsley 2009; Shaffer2007; Michael & Chen 2006). While many termshave been created for games used toward educational ends, this paper will use game-based learning unless otherwise specified. Game-based learning and related digital platforms have been argued to offer several learning affordances offering collaborative knowledge construction (Moskaliuk, Kimmerle, Cress & Hesse 2011), allowing for continuous instantaneous feedback (Ritterfield, Cody & Vorderer 2009; Gee 2002), promoting student—or user—driven goal-setting (Gee 2010, 2002) and simulating professional practice (Arastoopour, Chesler, Shaffer & Swiecki 2015; Chesler 2013 et al.; Svarovsky 2011).An additional affordance for early engineering design learning stems from the fact that all digital platforms constrain how users interact with the platform(Song 2009; Selfe & Selfe 1994; Hawisher & Selfe 1991).

In this manuscript I argue that these affordances may make game-based learning a promising means for integrating design and engineering education for several reasons. First, given that one of the difficulties early engineering students face with design is how open the process is (Chong et al. 2013; Dym et al. 2005), the constraints of digital platforms, if coordinated appropriately by instructors/researchers, could gently scaffold student design learning by constraining the problem space they have to traverse. Second, in terms of collaborative knowledge construction, multi-user virtual world games offer a means for students to build designs synchronously or asynchronously with other team members (Moskaliuk, Kimmerle, Cress & Hesse 2011). Furthermore, if all of the class members' design work is housed in a single virtual (game) world, this world can double as a large virtual design studio. Here students may encounter new or surprising ideas from their teammates, or from other teams in the class. Moskaliuk, Kimmerle, Cress and other colleagues argue that digital platforms including virtual world games allow for the individual creation of objects (Moskaliuk, Kimmerle & Cress 2012; Kimmerle, Moskaliuk, Cress & Thiel 2011; Moskaliuk, Kimmerle, Cress & Hesse 2011; Kimmerle, Cress & Held 2010; Kimmerle & Cress 2009; Cress & Kimmerle 2008). These objects, when viewed by others (i.e., not the creator) may create discontinuities or surprises in their understanding of the problem and lead to new creations from the other users, thereby resulting in collaborative knowledge building. Collaboration may also happen more generally through coordinated acts on the platform.

Third, in terms of feedback, on the cognitive level a game provides immediate continuous feedback (such as presenting an evolving design artifact) to which the user or student can respond. Student responses to continuous feedback leads to a feedback cycle

(Ritterfield, Cody & Vorderer 2009; Gee 2002). Both continuous feedback and collaborative knowledge building may help students individually or collectively develop their design ideas. Fourthly, in terms of goal-setting, Gee (2010, 2002) has argued that games allow for individual goal-setting beyond the intent of game designers. In the case of design, this may also present students with opportunities to conduct self-driven inquiries (Justice 2007) and promote informal (i.e., not instructor defined) learning (NRC 2009).Finally, in terms of simulating practice, when design learning happens through projects a greater emphasis is placed on professional practices. Game-based learning also lends itself well to a practice-oriented type of learning (Arastoopour, Chesler, Shaffer & Swiecki 2015; Chesler 2013 et al.; Svarovsky 2011).This set of affordances, properly utilized, appears to offer much promise for integrating design learning into the engineering curriculum.

While there is much *theoretical* work discussing games' potential (Bertozzi 2012; Lenhart 2011; Duncan 2010; Gee 2010, 2004, 2002; Squire 2006) there is limited *empirical* work, as the field of gaming research is nascent (Connolly et al. 2012; Tobias & Fletcher 2012; Young et al. 2012). Additionally, little research has been conducted on the use of game-based learning for design education, in engineering or more broadly. Some exceptions include an intriguing older article that discusses developing a board game for design learning (Habraken & Gross 1988), and a paper that discusses the use of the popular massive world game *Second Life* for architectural modeling (Gu et al. 2009). Shaffer, Chesler and other researchers (Arastoopour, Chesler, Shaffer & Swiecki 2015; Chesler 2013 et al.; Svarovsky 2011; Shaffer 2007, 2006) have dedicated much work to virtual internships (which are a form of simulation) that are similar to games; however most of the engineering platforms they have studied are highly constrained (i.e., they only allow for the design of a small set of objects).Many of the affordances discussed above, including self-driven goal setting and collaborative knowledge building, better thrive with a wider problem space for students to explore.

## 1.2 Study Overview

In light of the promise of game-based learning for better integrating design into the engineering curriculum and the relative paucity of gaming research, I propose the exploratory use of an expansive virtual world game, *Minecraft*, that has building as a core mechanic (in the literature review I discuss *Minecraft* in relation to the affordances detailed above). I used *Minecraft* in a series of activities in a first year undergraduate engineering class, called engineering 1 in this manuscript, as part of their design project, specifically targeting the early design stage of concept generation/reduction where convergent and divergent processes are most pronounced. This project aims to begin to advance our understanding of how game-based learning can assist design education in engineering.

For this study I use a design-based research approach (Barab & Squire 2004). Design-based research, like traditional experimental research (Whitehurst 2010) seeks to intervene in the classroom. However, in contrast to experimental research, design-based research also examines and seeks to leverage contextual factors such as classroom norms, student-platform interactions, and contingencies of everyday learning (Barab & Squire 2004; Cobb et al. 2003).Experimental research, in contrast, attempts to hold all contextual variables constant while manipulating a sole or small set of variables of interest

(Whitehurst 2010, Slavin 2002).With little research to build on, drawing on a design-based approach allows for a more comprehensive study of the game-based intervention, exploring several factors simultaneously. Furthermore, games are unlikely to present exactly the same intervention to all students, as the interaction between game and student will vary by student because a game may be played in different ways (Ennemoser 2010) and students may approach games from different angles. In brief, the dynamics of the student-game interactions are important contextual factors in students' learning with games. Therefore, a design-based research is more appropriate for this research project than a traditional experimental design.

In order to comprehensively study the use of *Minecraft* as a design platform, I take a mixed methods concurrent design approach (Teddlie & Yu 2007) to capture data on students' learning gains, use, and discursive framing of the platform and the artifacts they construct on the platform. The research questions driving the study are:

1) Does the gaming platform *Minecraft* help students develop along the pathway from novice designers to more informed designers?
2) How do students discursively frame and use *Minecraft* and what does this suggest for learning?
    a. How do students' engineering discourses relate to their use of the gaming platform?
    b. How do students' gaming identities and discourses relate to their use of the gaming platform?
    c. What kind of informal learning activities, besides those game activities set up by the instructor, do students engage in through the platform?
    d. Is there evidence from the artifacts students built in the game that they are able to use the platform for their design project? How are the artifacts distributed across time and (in-game) space?
3) How might insight from students' discursive understanding of, use of, and learning gains from, the platform shape a future serious game dedicated directly for early engineering design students?

The first question is quantitatively-oriented and seeks to explore students' learning gains. The second set of questions are qualitative and seek to explore students' discursive framing, use of the platform and built artifacts. For the third question I draw on results from the previous questions to generate recommendations for a game platform for engineering design learning.

This study contributes to our understanding of game-based learning in general and in specific for design in engineering. This study also contributes to our understanding of how different students, with different discursive framing of engineering and gaming, and gaming identities, interact with the game and engineering content. The study also contributes to our understanding of informal learning, particularly the use of informal media like games. While informal learning research has been growing in popularity, much research remains to be done on how informal learning might affect or be synergistic with formal learning (NRC 2009).Finally, the manuscript contributes recommendations for a gaming platform dedicated to engineering design. The recommendations draw on results from the all the analyses.

In the remainder of this introduction, I briefly discuss *Minecraft* itself, and then the theoretical frame taken for this manuscript: situative cognition (Greeno 1997). Then I turn to the literature review (Chapter 2) where I give an overview of informal learning, followed by gaming literature, then turn to the design literature with a specific emphasis on sketching/concept generation and the typical affordances (i.e. design skills) sketching/concept generation invokes or develops. Finally, the literature review concludes with a discussion of gaming culture and the potential risks game-based learning may have due to its connections with gaming culture. For each section of the literature review, aside from informal learning, I discuss my implementation strategy for using *Minecraft* in relation to the literature covered in that section at the end of the section. In the methods section (Chapter 3), I first describe the context of data collection and then data collection procedures. Next I give a brief overview of the mixed methods design used for this paper, concurrent design, and discuss some points about mixed methods research. I then detail each method used. I close the section with a discussion of the pedagogical method used for the class, Content Assessment and Pedagogy (Streveler, Smith & Pilotte 2012), apply the method to the quantitative portion of the study and detail the game-based learning activities. I then report the results (Chapter 4) for each method, and then discuss the results for each analysis in more depth. In the final chapter of the manuscript (Chapter 5) I synthesize the weaknesses and strengths of the game-based learning activities used for this class and derive recommendations for a future serious game platform, in accordance with the final research question. I then discuss implications of the manuscript and give concluding remarks.

### 1.3 Overview of Minecraft

The game used for this study is a commercially-released title called *Minecraft*. *Minecraft* is an "open world" game (that is players are free to "explore" most of the virtual world with minimal constraints) where nearly all elements of the virtual world can be collected and used to build small objects, to enormous castles, cities and other constructs. The world itself mimics the real world with a variety of biomes, geographical features, flora and fauna as well as weather conditions. Unlike popular "massively multiplayer online" games, *Minecraft* is run through an individual user's server instead of through a company's server. (This is important as the class had a server dedicated to the participating students.) While the game was released in 2011, it was not designed to require high-end computers and can therefore run on older computers, including those predating its release year.

Building within *Minecraft* is similar to building with Lego bricks in that the primary units used to build things are mostly block-shaped. Items such as wood and stone can be combined to create new units and tools. Some mechanical as well as electrical objects and functions can also be built. Building within *Minecraft* is reasonably intuitive and involves selecting an object to use and clicking on the appropriate location to place it. Once placed, objects can also be removed. *Minecraft* has started to catch the attention of educators, who have now created lessons in physics, chemistry, and geology (Short 2012; Wingrave et al. 2012) for students through the platform. Furthermore, Minecraftedu emerged as a joint effort of American and Finnish educators and programmers working with the original publisher of Minecraft, Mohjang, to modify the game and make it accessible to more educators. Later in the literature review I will discuss some of the important modifications as they relate to this study.

Comparisons between Minecraft and other existing platforms will be addressed more thoroughly in the literature review below (2.3).

## 1.4 Educational Framework

In this study I use situative cognition framework. Note situative cognition is the term used by Greeno (1997), others researchers have also used the term situated cognition (e.g., Choi & Hannafin 1995) or situated learning (Lave & Wenger 1991). The situative cognition framework focuses on individuals as social entities in some environment where they interact with others. Their interactions or practices are an important part of how they make sense of the situation and/or tasks (Johri & Olds 2011; Greeno 1997; Choi & Hannafin 1995). In a seminal piece on situative cognition, Lave and Wenger (1991) argue that learning happens in "communities of practice," tying situative cognition to learning to become part of a community with some shared practice (e.g. a profession or hobbyist group). Becoming part of a community involves moving from being a peripheral member of the community toward being a full member. People accomplish this by mastering the practices, thinking, and other components of a given community. Thus situative cognition relates very clearly to professional practice and becoming part of a professional community. However, as Greeno (1997) argues, while the situative cognition framework is focused on the social situation and the outward practices people make within it (and thinking therein toward those practices), its situational emphasis does not mean it is incompatible with cognitive frameworks that focus on mental schema. Instead, Greeno (1997) argues that situative cognition, along with cognitive and behaviorist perspectives, can be grouped into a cognitive system. In this cognitive system, cognitive and behaviorist elements are sub-systems of the situative cognition an individual exhibits. I follow Greeno (1997) in taking a systems view of a person's cognition.

In this manuscript I will analyze the practices, professional thinking (including professional identity and ways of thinking) students engage in through the gaming platform. These practices and ways of thinking, with respect to the first research question, are intended to transform from novice design practices to more informed design practices (Crismond and Adams 2012). But while these practices and ways of thinking will come out through qualitative analysis, changes in students' thinking may also be viewed as changing schemas in students' understanding of the design process. Indeed, as the methods section will reveal, the quantitative survey instrument used for the first research question does not directly measure practices; instead it measures something closer to schemas students have about design.

Without delving into fine details, I assume a critical realist epistemology for this paper (Maxwell & Mittapali 2010; Steinmetz 1998; Reed & Harvey 1992). This epistemological stance frames my study and the way I analyze data. Critical realism strikes a balance between positivist epistemology and pure social constructionist epistemologies: in critical realism there is a material world outside of people but events and processes in this world primarily happen in open systems where it is not possible to directly measure all forces or events that may cause other events to happen (Steinmetz 1998; Reed &Harvey 1992). Theories and interpretation (in the social science sense of the words) therefore remain core tools for understanding the world. While I do not discuss critical realism at great length in this manuscript, I make reference to it in a few places. Nonetheless, critical realism sets epistemological boundaries for my study, so I make my stance transparent here.

# CHAPTER 2. LITERATURE REVIEW OF GAMES AND DESIGN

To situate this work in existing research, I cover four areas. First, I discuss academic work on informal learning, which can be viewed as bringing informal learning means into the classroom (other work studies informal learning in the beyond the bounds of educational settings), and relate it to research on game-based learning. Informal learning has the potential to supplement formal classroom learning (NRC 2009). Second, I give an overview of the gaming research terrain, and some important debates within it as they relate to this project. Third, I review design research, with particular emphasis on sketching/concept generation research and design skills that researchers find are influenced by sketching or concept generation. In the fourth and final section of the literature review I discuss some important considerations for implementing a gaming platform into a classroom, including the status and potential impact of current gaming culture and also differences in students' familiarity or experience with games. At the close of the section on game research, design research and gaming culture, there is an implementation strategy subsection where I discuss how I will structure the game or the pedagogical content around the game in light of work just presented for that section

## 2.1 Informal Learning

Informal learning is a multifaceted concept that researchers have used to refer to many aspects of learning outside, or somehow separated from, formal learning. Formal learning is often associated with classroom-based learning. Researchers have explored different aspects of informal learning including: everyday learning in daily activities (NRC 2009), learning in museums, learning in the workplace (Ferguson, Cawthorne, Schimpf & Cardella 2013), learning in social gatherings and zoos (NRC 2009, Thompson 2010), and learning from media (Hung, Lee & Lim 2012; NRC 2009; Hall 2009).Most of these studies focus on identifiable environments, settings or media in which informal learning can happen. Furthermore, some have called for fusions between these environments and media as a learning ecology of sorts (Hall 2009; Barron 2006). Extant research evinces a binary view of informal and formal learning by focusing on learning outside of formal institutions (i.e. schools/colleges) or on learning environments as discrete elements (either formal or informal) that can be combined serially.

Others researchers, such as Marsick and Watkins (1997, 1990),have claimed that characteristics that distinguish informal learning from formal learning environments include the level of control over a class and assignments as well as the amount of structure employed there in. Marsick and Watkins (1990) state that informal learning may happen in formal settings like schools, but is typically less structured than school learning and offers learners more control over their learning—i.e., is more student-centric. Hung, Lee and Lim (2012) discuss the use of non-class media (in this case, a videogame) in a classroom as an example of informal learning in the classroom.

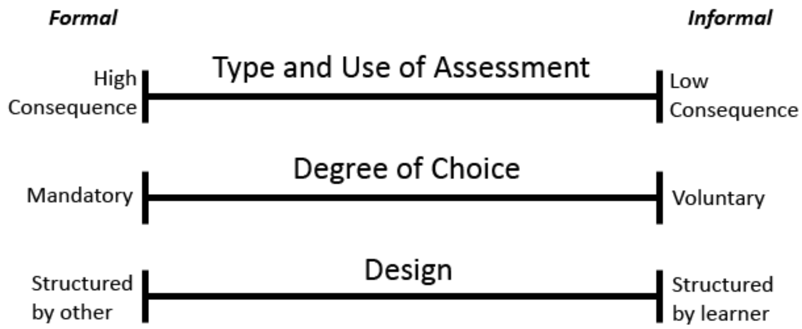



*Figure 2.1 - Learning Environments Formal to Informal Continuum*

The NRC report (2009) displays a useful figure, modified here as figure 2.1, depicting the continuum of learning environments from the most formal to the most informal. Like Marsick and Watkin's (1990) definition of informal learning, the NRC includes level of structure, student choice and assessment. In figure 2.1 the left-side of the continuum reflects highly formal classroom or learning aspects, whereas the right-side of the continuum reflects highly informal classroom or learning aspects. While activities that are closer to the right side of the continuum may happen outside of the classroom, activities that are structured by students, include situated feedback and may have voluntary aspects can also happen in the classroom. For example, in the classroom there could be limited structure, exploratory activities or projects where students can define major attributes of the project. In this way activities within the classroom can be more or less informal.

## 2.2 Gaming Research

Research on gaming is a new and growing area (Connolly et al. 2012; Tobias & Fletcher 2012; Young et al. 2012; NSF 2008) which has been largely theoretical (Gee 2010, 2002; Bertozzi 2014, 2012; Przybyski, Ryan & Rigby 2010; Rigby & Przybyski 2009; Salmani-Nodoushan 2009; Shaffer 2006) or descriptive (Rajan, Raju & Sankar 2013; Budnik & Budnik 2011; Barab, Gresalfi & Ingram-Goble 2010; Kafai 2009; Thompson et al 2010; Connolly, Stansfield & Hainy 2007). As Connolly et al. (2012) report, of the approximately 8,000 papers they identified as related to gaming research between 2004 and 2009, only 130 had any empirical results. Importantly, these studies all had participants who were 14 or older, as this was the population Connolly and colleagues wanted to study (Connolly et al. 2012). As I will discuss in section 2.2.3, there is some evidence that there is cumulatively more research on games for younger populations (Ratan & Ritterfield 2009).

While empirical papers in gaming research may use quantitative or qualitative data collection, their research design is often simplistic. For instance, Nilsson and Jacobsson (2011) conduct a study where students used the popular commercial game *SimCity* (where a player builds and manages a city) to learn about sustainability. They conducted group interviews with students (who were on teams) and concluded that, by using the game and interviewing the students, it was possible to identify conceptual development and understanding through the students' speech. They did not, however, study how students learned through the game (except how the game might impede learning).Hummel et al. (2011) used a game scenario through the EMERGO technique, which is a toolkit for building learning scenarios around some topic. Students were asked to analyze the feasibility and best location for a new shellfish production plant and then write a report to their virtual "contractor." This study was quantitative and used a scoring rubric for an early and later report (after going through part of the scenario and then the full scenario). They also had a satisfaction questionnaire for students who went through the scenario. The researchers found students' scores increased from the early to later report. The improved scores are unsurprising given that students were unlikely to have been able to write a complete report when they had only gone through part of the scenario. Hummel et al. (2011) reported students expressed low to middle satisfaction with the platform. Furthermore, attitudinal research, like satisfaction questionnaires, have been noted to be highly problematic and unreliable unless connected to other constructs, such as intention (Azjen & Fishbein 1980).

A more sophisticated methodology was employed by Svarovsky (2011, 2009) who used a web-based platform, Soda Constructor, to teach students about engineering design. In Soda Constructor students built models of virtual characters, with particular emphasis on the mechanics and structure needed for movement. The activities were designed to have the students engage in engineering professional practices. Svarovsky (2011, 2009) collected numerous forms of data, from interviews, recordings of team meetings, pictures of students’ design, design journals kept by students and others forms of data. These sources were analyzed with a mixed methods approach where the material was initially analyzed and coded through a grounded theory approach (Corbin & Strauss 1998) and then later codes were used in a new technique called epistemic network analysis (Shaffer et al. 2009; Shaffer 2005) that is similar to social network analysis (i.e., a quantitative technique that analyzes connections between 'nodes'). However, methodologically sophisticated studies like this are less common.

Before delving into methodological considerations, it is important to situate this research within the larger field of gaming research. I will cover three major areas in the gaming literature: commercial games, commercial games used for purposes other than pure entertainment, and serious games. All of these subareas contribute to the formation of this study. One area of the gaming literature I will *not* review is using programming games (Li & Watson 2011) for learning objectives, as this is too distant from the focus of my study. It is also important to give a broad definition of gaming for the purposes of this study. Here I use the term “gaming” to refer specifically to electronic or digital games, played on a console or a computer that are traditionally created and played for entertainment purposes. I will expand upon this definition below in the serious gaming portion of the literature review.

### 2.2.1 Commercial Games

Every year thousands of commercial games are released into the market either through brick and mortar stores or online distribution channels such as Steam (a digital platform where one can buy and play games) and the iOS and Android marketplaces. While there are a range of studies on commercial games (e.g. Chess 2014, 2012; Bartle 2003), here I am focused on studies that examine learning in commercial games (e.g. Steinkuehler & Duncan 2008; Steinkuehler 2007, 2005; Squires 2005, 2003).

As an example of this work, Steinkuehler and Duncan (2008) explore the scientific discourse patterns of players of the wildly popular *World of Warcraft* (a

Massively Multiplayer Role Playing Game, or MMORPG), that exists as a virtual world with multiple continents where players create custom fantasy characters that travel the world and battle foes, work with other players and take on other tasks. The researchers examined players' posts on discussion forums related to the game, and found they contained evidence of the social construction of knowledge (86%) and systems based reasoning (over 50%), while one third (37%) expanded on previous users posts and another (37%) rebutted a previous post. From this, the authors argue that these gamers often engage in scientific habits of mind based around their shared interest, without any external motivation to do so.

One of the major contributors to this research space is James Paul Gee (referenced previously as Gee 2010; 2002).In this section I will summarize some of the main findings from Gee and compare and contrast his findings with the structure of my proposed use of *Minecraft* in the classroom. I focus on Gee for a number of reasons. First, his work is one of the most expansive treatments of everyday learning in videogames, spanning multiple books and articles (Gee 2013, 2010, 2007, 2004, 2002; Shaffer & Gee 2005). Second, much of this, especially his book *What Videogames have to Teach us about Learning and Literacy* (2002) and his book chapter in *Serious Games* (2010), specifically examine how everyday learning that happens through games can inform learning principles for classroom learning. Third, while there are strong similarities between Gee's work and that of Shaffer (2007, 2006), Gee is less explicitly focused on learning through gaming for children and/or K-12 learning than Shaffer is; so Gee's points are more in line with this study. Shaffer's work will be more relevant for (and therefore addressed in more detail in the serious gaming section of the literature review).

Gee is studying games for learning principles contained within them. These learning principles assist or scaffold the game player's learning so that they can succeed at and/or complete the game. In my proposed study, completing or being successful at the game is not an end in and of itself. Instead, the game is a means toward the larger educational goal of improving design skills, developing professional identity and ways of thinking as an engineer. Secondly, I argue most of the points below would hold to some degree if the students did the design project without the supplement of the game. What the game offers is a way to scaffold some professional practices as well as engage in some activities that would be difficult to undertake without a gaming platform (e.g., collaboratively building a 3D idea/model synchronously).

In *What Videogames have to Teach us about Learning and Literacy* (2002), Gee begins his analysis of the learning principles embodied in commercial games by introducing the concept of semiotic domains. Semiotic domains (SD) are the specialized language and ways of thinking about a particular "area"—here, for Gee, games. This has similarities with Dall'Alba's (2009; Dall'Alba & Barnacle 2005) discussion of professionals and professional education, where professional education is not just mastery of skills and knowledge, but involves being and becoming a professional in the world (drawing from Heidegger (1962)).Gee says that a player learns the SD of a game by playing it, similar to how professional learning happens through engaging in professional practices of that field. Of course, becoming a master of a game is not quite comparable to becoming a professional such as an engineer or lawyer. Nonetheless Gee mentions that many SD may be interconnected; thus what a player is "becoming" is a certain type of gamer, rather than a master of a solitary game.

Gee's second major principle deals with identities more specifically. Gee talks about three kinds of identities that are activated in game-play; however only two of them concern us here. The other one is the players' identity as controlling a character or aspect of the game world. Much of this identity originates from the stronger narrative of a virtual world (Montola 2012; Duncan 2010) as well as the separate identity of the virtual character one plays as. For instance, in the videogame series *Metroid* the player controls the actions of female bounty hunter Samus Aran as she fights against a vicious army of Space Pirates who destroyed her home planet. This kind of narrative for the game-world and controllable characters may not as easily translate into game-based learning where the game is being used for more than entertainment.

Turning to the other more relevant identities activated during game-play, one is the player's "real life" identity as someone playing a game. This is important for game-based learning as it does not just involve expanding skills or thinking but also has been argued to affect identities as particular kinds of people or professions (Ballance 2013; Barab 2008; Strauss 2006; Gee 2002). The other kind of identity activated is the "projective" identity, which means both the identity the player projects onto the virtual character as well as the "project" or entire task of playing the game. In other words, it is their connection to the virtual world and what they hope to accomplish in it. This is important for game-based learning because how they engage with the world will be different if players see the game as a poor (or good) use of their time

Gee's third major point concerns how people learn. Gee argues that games encourage experiential learning from direct experiences in the game that eventually lead to enhanced skills in that domain. He notes a shift in education research away from viewing learning as acquiring abstract rules that are applied to something, toward building up understanding through experiences that are then abstracted out at some point. Gee talks about experiencing a game through something like an inquiry learning approach (van Joolingen, de Jong & Dimitrakopoulou 2007; Ingerman et al 2004; de Jong & van Joolingen 1998) where the player explores the virtual space, makes a hypothesis ("if I push this block, I'll be able to advance"), tests it and then modifies again accordingly. However, a completely unstructured inquiry learning approach may be problematic for novices because it may be too open-ended. Deep immersion with little scaffolding is problematic for students who have little experience in a domain as it provides too little direction (Salmani-Nodoushan 2009).

One counterintuitive way of scaffolding a learning experience through a digital platform is through the constraints of the digital platform itself.Digital platforms are structured through code in ways that constrain how people use them (Song 2009; Selfe & Selfe 1994; Hawisher & Selfe 1991). While this might be helpful for educational settings in at least reducing the tool from being used in myriad ways, these limitations may also conflict with pedagogical goals an instructor has for the digital platform or game-based learning. Instructors may also shape how the platform is used, which may be able to address platform constraints, as well as scaffold topics for students with little familiarity. Instructors or researchers can strike a balance between total immersion and pure instruction by combining affordances and constraints of the platform as well as pedagogically scaffolding the platform (Salmani-Nodoushan 2009).

Gee's other points about experiential learning include the need for goals to structure the experience (Gee 2010), which relates to the scaffolding mentioned previously. Gee also brings up Schön's (1984) reflection in-and-on action, which the game encouragesas students interact with the game and it's changing states or information. Additionally, Gee (2010) mentions how games give opportunities to apply past learning, such as introducing new challenges that incorporate acts or insights from past challenges.

The next major principle Gee discusses relates to a point I brought up before: the need to balance immersion and instruction in learning. Gee argues that one of the benefits of games is that it gives the player agency or control over part or all of a virtual world in ways not easily mimicked in the real world (Gee 2010). For instance, a game player may be able to intervene, redirect, and/or initiate processes in the virtual world like the establishment and direction of a city's development, which would not be feasible to enact in the real world.

Giving students agency over a virtual world is important for another reason. As I discussed earlier, one of the identities Gee talks about is the projective identity, the identity that the gamer wants to make. In his book chapter, Gee (2010) expands upon this theme, noting that while there is a narrative and goals from the game designers, because of the interactive nature of games, students can also create their own additions to the narrative and/or goals of the game. Some researchers have said this potentially confounds games as an educational “intervention,” as the treatment across students may vary depending on their experience and supplemental goals or narratives (Ennemoser 2010).However, drawing on the informal learning literature, this supposed drawback can be seen as an asset. By giving students a platform where they can develop a projective identity and have the agency to do so, students may become more engaged with the material. Here, informal learning means students engaging in learning activities beyond the formal assignments or parameters of instructor created learning activities (Hung, Lee & Lim 2012; NRC 2009; Marsick & Watson 1997). While it is hard to say *a priori* whether this will happen or to what degree it may happen without being explicitly researched, games certainly open the doorway for students to explore and learn beyond formal instruction/guidance by providing a virtual world within which to act.

Fifth, Gee talks about how games can provide an opportunity to act as people or in places that might challenge previously held beliefs or understandings of the world. For example, for a person who is relatively pro-war or pro-military aggression in response to international conflicts, playing through a first person shooter where one encounters the terror and hardship of armed conflict as well providing a glimpse into the life of the "enemy" might bring to the surface taken-for-granted assumptions about war. (Note many first person shooters glorify violence and likely would not challenge a pro-military person's view of war; however a smaller set of games, like *Spec Ops The Line* intertwine moral ambiguity, psychological trauma and other dimensions of war into their narrative and may challenge said persons' assumptions.) Gee notes that gamers may opt not to play games that challenge their beliefs or values; however opposing views or alternate perspectives may also be more discretely embedded throughout a game and suddenly force players to confront alternative perspectives.

Finally, Gee argues that games are typically social, even if they are single player games. Playing games, like learning a professional field, involves becoming part of a larger community. This argument, along with earlier points on experiential learning and mastering semantic domains, aligns well with the situative cognition framework used in this study (Johri & Olds 2011; Greeno 1997; Choi & Hannafin 1995). Gamers regularly share their strategies and insights with each other, argue and debate about games on forums (Steinkuehler & Duncan 2008), create websites dedicated to games (Milner 2011), or outright play games together.

In other work, Gee has also explicitly written about situative cognition (Gee 2004).Here, Gee introduced the concept of affinity space, which is a physical or virtual location where people can go to interact with others around some shared interest (Hayes & Duncan 2012; Gee 2004).Affinity spaces have two important components called portals and generators: Portals are the means through which someone accesses an affinity space, and generators are the means that create or organize the content for that space. A game may serve as both a portal and generator for an affinity space. By logging onto the game you get access to its content and the game (and perhaps its backend servers) "generates" and organizes that content. For a given interest, there may be many affinity spaces; for instance, there may be official and fan sites for a game that operate in connection with an online game (Gee 2004). Gee developed this concept in part to work around the limitations of defining a community around a topic. Trying to define the boundaries of a community and who is or is not included, particularly for online spaces (Song 2009), proves difficult as people regularly enter and exit the space. Thus Gee (2004) created the concept of affinity spaces to focus on the space without having to define the community of that space. This, however, does not preclude those who are involved in a space from seeing it as a community. By interacting in a space or contributing content to a space (e.g. user created video of a game), affinity spaces show another avenue through which people interact around games (or other affinities). Such social uses of games may also manifest in game-based learning.

### 2.2.2 Commercial Games for Learning

Another related vein of gaming research is the use of commercial games for the purposes of learning (or other non-entertainment ends). Commercial games require a tremendous amount of time, human power and money to create; thus leveraging a commercial game toward another end allows an educator to take advantage of the functionality and affordances of the game without the overwhelming resources needed for its development. Some examples of commercial games used for learning include *SimCity*, a game where players develop and maintain a modern city (Nilsson & Jacobsson 2011; Tanes & Cemalcilar 2010; Gaber 2007; Lauwaert 2007); *Civilization*, where players develop, maintain and compete with other “civilizations” over several millennia (Pagnotti & Russell 2012; Squire 2003); and *Second Life*, an open-ended massive world with content primarily developed by users, including educational institutions and teachers (Bulu 2012; Eckelman et al. 2011; Wankel & Kingsley 2009).*Minecraft* has also received some attention with one scholar (Short 2012) arguing for its potential use in the study of many science domains (e.g. chemistry, physics, biology, geology) and another set of scholars developing physics for the game (Wingrave et al. 2012). And as was mentioned in the introduction, Minecraftedu has emerged to support and promote the use of Minecraft in classrooms in the United States and Finland.

Importantly, these games cannot be used directly as they were developed for entertainment purposes, not educational ones. Thus immersion into the game without any scaffolding or structure would likely produce little success (Salmani-Noudoushan 2009). Studies in this area therefore structure the commercial game in a way to link it to the educational goals of the instructor. For instance, Gu et al. (2010) used *Second Life* to create a virtual design studio for an international group of architects. The learning goals for the students were "(1) understanding collaborative design in 3D virtual worlds and (2) developing the essential skills for collaborative design in 3D virtual worlds" (Gu et al. 2010, pp 165). Students were split into groups of 3-4, provided a tutorial in *Second Life* and asked to design a virtual home. The project lasted five weeks, with one hour of instruction and 2 hours of design/discussion per week. Students successfully created a wide variety of homes from more fantastical to more realistic. In this way, the commercial game was refashioned as a virtual design studio.

However, there is another important consideration when using commercial games for alternative ends. These games are embedded with the views and values of the original designers that may conflict with their educational use. As mentioned earlier, Nilsson and Jacobsson (2011) had students using *SimCity* to build sustainable cities within the game. The authors discussed how students felt *SimCity* was embedded with Western, particularly American, views of economic growth and social welfare. For instance one student commented on how renewable energy was only affordable after high levels of economic success, and that subsidizing such energy sources was not a possible move in the game.

Song (2009), in her study of Web 2.0 technology, reported on constraining influence of technology on actions or perceptions. In the case of *Minecraft* specifically, the game was designed as an exploration and building game. The blocks in the game constraint what can be built as they come in predetermined shapes. Additionally, given their predetermined shapes they push users toward the construction of buildings more so than smaller objects. Smaller objects can still be made, but they will be out of scale to their “normal” size. For example, trying to build a hammer in the game, relying on preset block sizes will result in a hammer much “bigger” in the virtual world than the avatar's hand could hold. Taking note of limitations or constraints of an originally commercial game is important when using them for game-based learning activities.

### 2.2.3 Serious Games

Serious games are distinct in some ways from commercial games, but there is ongoing debate over what “serious games” are. Many define serious games as a game put to a different purpose than entertainment (Ritterfield, Cody & Vorderer 2009; Susi et al 2007; Corti 2006; Michael & Chen 2006). These other purposes can include awareness about health and disease, military or corporate training, political or social activism, marketing, education or others (Ritterfield, Cody & Vorderer 2009; Wankel & Kingsley 2009; Michael & Chen 2006). Some scholars, such as Zyda (2007) and Prensky (2001), suggest that fun or the entertainment of serious games cannot be secondary to its other purposes. In contrast, Shaffer (2007) and Michael and Chen (2006) argue that fun is secondary to the games, although both these groups of authors admit a serious game can be fun, i.e., being a “serious” game does not preclude it from also being fun.

One issue raised by Shaffer (2007) and Michael and Chen (2006) in their work on serious games is the boundary of “game.” To expand upon my earlier definition of a videogame to specifically serious games, I use Shaffer’s definition of games as a contrast point. In his book *How Computer Games help Children Learn*, Shaffer (2007, pp 23) states that games are composed of rules a player must follow, which stem from roles players take in the game. This definition of a "game" is so vast that it could incorporate a good deal of the everyday social organization of a given society or global civilization. Indeed Shaffer himself says that his definition of a game can be extended to students' attendance of and participation in the entirety of schooling. Difficulties with this definition of a game arise not only from how widely it may be applied, but also because the definition only incorporates social rules and not machine-coded rules that also affect how a game is used for learning.

I argue that videogames are distinct from social games, like red-rover, as the former incorporates both machine-coded and social rules. To put this into perspective, I take as an example the work of sociologist Anthony Giddens (1986, 1979) who defines structures in a society as the patterned rules and principles that shape social practices. For Shaffer, the "roles" in games are roles given to players by the rules. Similarly, Giddens argues that structures have relations embedded in them that position people relative to each other. Thus, unexpectedly, we arrive at a position where all social practices (such as running a senate meeting, driving to the hospital, or opening the door for a stranger who is nearby) are transmogrified[1] into "games," as they all involve rules and roles. Extrapolating from Shaffer's definition leads us to viewing the world from a perspective of game theory (Schelling 1980). Game theory is a school of thought and research that studies the optimizing actions people take to achieve greater outcomes when interacting

[1] I use the term transmogrify, a "monstrous" transformation, to emphasize the point that Shaffer likely did not intend for his definition of games to apply to most of social reality.

with actors while having bounded rationality (Simon 1959) in an uncertain, noisy environment (Schelling 1980; von Neumann & Morgenstern 1944). In other words, social interaction is seen as a "game" where people try to maximize their "gains" or minimize their "losses." I believe this is the logical extension from Shaffer's (2007) definition of games as rules and roles and exemplifies its limitations as a definition for games (*qua* serious games) but is likely not what Shaffer intended with his definition.

However, it is not enough to define games in terms of what they are not—as not being the overly broad definition Shaffer uses. Shaffer gives a second example that is illustrative, the "debate" game. Here students debated positions on an historical issue about the U.S. The 1) competitive, 2) goal-oriented, and 3) structured nature of a debate competition makes it seem more like a game than many other social practices, such as Shaffer's example of school attendance.

I argue this kind of game is not the same as a videogame. Different researchers of digital technology have argued that technological artifacts place constraints on their users—such as only being able to communicate through text in early internet Multi-User Domains (MUDs), to take an extreme example (Kolko, Nakamura & Rodman 2000; Markham 1998). While it would require a certain catalyst of social dynamics, it is not very difficult to turn the social rules guiding a debate game into a wholly different game such as the Chinese folk game *Killer* (Lindtner & Dourish 2011) where people sit in a circle and try to identify the person who is the "killer" and take roles such as cop, judge, and bystander. The social rules shaping the debate "game," given the will and some social discord, are easily transformed into other "games." Digital games, however, have assumptions built into their machine-coded game-play mechanics. While it is possible, as

Gee (2010) suggests, for gamers to develop alternative goals that are personally meaningful or play the game in ways that would not lead to "winning" it, the core mechanics of a game cannot be as easily changed as social rules: they are more rigid and literally codified. Thus while serious games are a subset of other types of games, they cannot be reduced to games like the debate game. Serious games, defined here, are not only games with a primary means that is not fun or entertainment (although, as others argue fun may still be derived secondarily from them), they are also digital platforms that have more rigid constraints than a purely social game or social interaction, while still being malleable enough to allow for the creation of meaning and goals by players.

Within serious gaming research, there appear to be fewer projects and studies that have college students or adults as their research population. In a survey of existing serious games Ratan and Ritterfield (2009) found that only 16% of the 600 identified games were for college students or adults. Indeed, Shaffer and his colleagues' work on epistemic games aimed to help students learn about the knowledge, skills values, identity and epistemology of a profession or field has its primary target as the first of K-12 children (Shaffer 2009, 2007, 2006; Svarovsky 2011, 2009). Yasmin Kafai, another researcher who has published extensively in this area, focuses mostly on "tweens" (Searle & Kafai 2012; Fields & Kafai 2010; Kafai 2009; Kafai et al. 2008).

There have been some preliminary findings that games help students learn about a particular field or skills/knowledge in that field, in particular as it relates to science and engineering (Nilsson & Jacobsson 2011; Joiner et al. 2011; Lang & Chen 2010; Barab 2007).While many of these studies focus on K-12, a few study other populations. For example, Joiner et al. (2011) found that first year mechanical engineering students who played *Racing Academy*, a serious game where students could customize many aspects of cars (tires, gears ratio, etc.) to advance through stages, had pre/post-test increases in their knowledge of physics, tires, gear boxes and overall (car) performance. They did not find any difference in gains for men and women, although the actual number of women in the study (15) was dwarfed by the number of men (143).They controlled for this through non-parametric statistical techniques; nonetheless the small number of women limits some of their findings. As was discussed in section 2.2, of the approximately 8,000 papers that researched game-based learning, only 130 had empirical results for the population aged 14 and older. This includes high school students, however, so the number of games for college students' and adults' learning is likely lower. Thus when combined with Ratan and Ritterfield's (2009) results, it seems probable that there are even fewer empirical serious gaming research studies on these populations.

One final consideration for serious games is their connection to "edutainment." Edutainment games were popularized in the '90s as a way to make learning fun and more engaging. Edutainment games are best understood as "games" with two non-overlapping components: a learning component which tends to border on drill practices, and then an often unrelated game or "fun" component (Ritterfield, Cody Vorderer 2009; Habgood & Ainsworth 2011; Habgood, Ainsworth, Benford 2005; Kerawalla & Crook 2005). For example, a student may be asked to solve a set of multiplication questions, and then upon their successful completion students will be able to play a fun game for a short time before returning to the multiplication sets. While there might be different degrees of separation between learning and game components, in edutainment games there is a weak or absent integration of the core mechanics of the game (how one plays or can act in the virtual world) and the learning content (Ritterfield, Cody, & Vorner 2009; Habgood & Ainsworth 2011).

Edutainment is problematic, as the potential gains of integrating gaming with learning are diminished by the separation of the learning process and game mechanics. However, a good example of their integration can be seen in Habgood & Ainworth's (2011) study. *Zombie Division* is a game for young children (7-11) learning division and multiplication. In *Zombie Division* students play as the hero "Matrices" who must defeat skeletons with numbers on their chests by using the appropriate divisor. Here, students are tasked to learn about division, and the core game-play involves using different weapons or combinations of weapons to take on increasingly difficult tasks, represented by increasingly large numbers and more aggressive skeletons with numbers on their chests. Divisors in the game are represented by different weapons. For instance, swinging a sword cuts something in two, hence divides by 2, and a five-fingered punching glove is used for dividing by five. Better integration between the learning content and game-mechanics in game-based learning promotes deeper immersion into the game and ideally greater learning gains (Habgood & Ainsworth 2011; Ritterfield, Cody, & Vorner 2009).

### 2.2.4 Implementation Strategy

In the this section I discuss my implementation strategy for game-based learning in engineering 1 with *Minecraft* as it relates to Gee's (2010, 2002) research on commercial games, a brief point on commercial games used for learning and research on serious games. As some of Gee's points are straightforward in their implications, I only discuss a subset of the points reviewed above.

Returning to Gee's (2002) point about learning semiotic domains through games, for this project, the game *Minecraft* is situated within the larger context of developing design thinking and skills, as well as professional being as a (engineering) designer. That is, learning through the game is aligned with engineering 1 as an introductory engineering class with a heavy emphasis on professional skills and design.

To balance game affordances, constraints and instructor scaffolding, I: a) provide some guidance (through activities) for engaging in design practices and b) use a platform which reduces but does not eliminate the kinds of representations a person can make compared with free hand sketching (Goldschimdt 2003, 1992). In this way the constraints in *Minecraft* may actually work as scaffolds for novice designers.

Gee discusses that one of games' affordances is that games are often designed such that past learning experiences can be applied to new challenges later in the game. For the game-based learning activities, this affordance is complicated by the students working on one long design project with unique stages. These unique stages may not offer opportunities to apply past learning; however design also involves iterating within or between stages (Jin & Chuslip 2006; Adams & Atman 2000).I work iteration into the project to provide students an avenue to apply past learning.

Virtual worlds often bestow players with abilities that are infeasible in the real world. In *Minecraft*, students can rapidly build, deconstruct and transform structures alone or collaboratively. While Lego bricks (a commercial toy used in formal and informal learning environments) can act as a similar manner, they cannot be as quickly constructed because of physical limitations and simplification of operations in *Minecraft*.

Furthermore, *Minecraft* representations are easier than physical models to store, generate and access at a later time due to their digital form.

Gee also discusses how games can expose people to perspectives or people that might challenge past beliefs or understanding of some topic. The possibility for this study is that by playing the game scenarios and leaving it open for students to take on projective identities, the game-based learning activities might confront the students with a different view of engineering and design than the stereotypical and novice impressions some researchers have found new engineering students hold (Chong et al 2013; Zemke 2010; Margolis &Fisher 2003; Yurtseven 2002). While some segment of students might dismiss games used in the classroom as an inaccurate representation of engineering, all were nonetheless be required to use it, aiding the possibility that it gave them a new perspective on engineering and design.

In terms of the social dimensions of games, the activities for this study were team-based and involve considerable interaction and collaboration. Furthermore, students played on a single server dedicated to the class alone and interacted with other members of the class in the virtual world.

In the section on studying learning in commercial games, I mentioned how important it is to take note of limitations or constraints of an originally commercial game when using games for game-based learning activities. In the design section, specifically the implementation strategy subsection, I will argue in detail that there are positive aspects to the constraints of *Minecraft* that make it a viable platform for design learning.

Finally, on the topic of integrating game play mechanics and learning, the core game-play mechanics of building and “sketching” or concept generation were integrated with the intended learning outcomes of the game. I discuss the particulars of this integration in the methods chapter in the subsection that outlines the gaming activities.

## 2.3 Research on Engineering Design Practices

Vincenti and others have argued that design knowledge and skills—in Vincenti's words, “design instrumentalities”—are a core component of engineering competency (Gainsburg, Rodriguez-Lluesma & Bailey 2010). Vincenti states: “Design instrumentalities comprise the knowledge of procedures, ways of thinking and judgmental skills required to carry out the work of engineering design” (Vincenti 1990, pp 219). Thus design skills, knowledge, and ways of thinking are an integral part of becoming an engineer, and in part separate engineers from those in other technical fields (Bucciarelli 2003; Vincenti 1990).

One design technique that I argue is similar to my use of *Minecraft* in this study is sketching. Sketching is a technique where a designer makes rough, initial, conceptual drafts of a design idea/project. Sketching has many affordances, such as encouraging “backtalk” from the sketch (that is, the creator can read things into their sketch after drawing it; Goldschimdt 2003, 1992), reducing cognitive load (Fish & Scrivner 1994), supporting the generation of many ideas (Dorta, Pérez & Lesage 2007; Shah et al. 2001), and developing ideas iteratively (Prats et al. 2009; Goldschimdt 2003), among others. While sketching may happen throughout the design process, it is prominently used in the concept generation stage of design. A related design practice is low-fidelity prototypes (Herring, Jones & Bailey 2009), where a rough model of an idea is built to facilitate concept generation. While building on *Minecraft* may more closely resemble low-fidelity prototyping, this practice has received less research attention than sketching. Therefore I mostly review sketching research in what follows.

In research on sketching, there is ongoing debate about the use of computational tools to assist in the conceptual design stage (Alcaide-Marzal et al. 2012; Cassidy & Stone 2010; Jonson 2005; Won 2001; Black 1990). In a survey of professional engineers, Robertson and Radcliffe (2009) found participants' self-reported enhanced visualization and communication (a positive attribute), premature fixation, and circumscribed thinking (where the most commonly reported response was trying to perfect the design within CAD). Premature fixation, where designers select a solution too early, was reported on a low level, 5%; however, their survey relied on self-reporting, so this item may be underreported. Goel (1995) found that sketchers only reinterpreted hand sketching and not digital sketching. Later Cassidy and Stone (2010) found students could reinterpret digital sketching. However, Cassidy and Stone also reported that students who used the digital platform (Corel Draw) did not use those reinterpretations to transform their final design; instead reinterpretations were made about what the design should *not* look like (that is, they judged a reinterpretation as negative and rejected it) and thus these did not lead to transformation of the final solution.

On the other side of this debate, Rahimian and Ibrahim (2011) report that students using a digital platform, specifically a 3D modeling platform with haptic interface, created more efficient (more quickly completed) designs with more ideas generated therein, compared to non-digital hand sketching. Alcaide-Marzal et al. (2012) found slower performance and fewer ideas generated with a digital platform, a sculpting software meant to mimic sculpting with pliable material, yet still found comparable drawings and reinterpretation in the platform. Thus the debate on using digital platforms versus hand sketching remains unresolved. Indeed, as the debate continues, new proposals for making CAD more game-like have recently emerged (Kosmadoudi et al. 2013, 2012). Researchers or instructors seeking to use digital platforms for the concept generation stage of design will need to situate their work in relation to this debate.

Many other techniques have been employed to teach students about concept generation or as practices professional designers use to generate concepts. One of the most established techniques is brainstorming (Gonclaves, Cardoso & Badke-Schaub 2014) which involves individually or collectively generating many ideas and withholding judgment on their viability. Other techniques include information searches (Herring, Jones & Bailey 2009), role-playing users (Herring, Jones & Bailey 2009), analogies (Ball & Christensen 2009), function analysis (Gonclaves, Cardoso & Badke-Schaub 2014), sketching (Goldschmidt 2003, 1991), design heuristics (Daly, Yilmaz, Christian, Seifert & Gonzalez 2012) and many others.

Information searches include accessing useful information for the design or prior/related work whereas role playing involves designers acting out the roles or actions of users to generate possible solutions (Herring, Jones & Bailey 2009). Analogies involve drawing on knowledge of objects, processes or functions, often from a different domain, to develop concepts or ideas for the domain of interest (Ball & Christensen 2009). Function analysis involves identifying the functions a design should meet (Gonclaves, Cardoso & Badke-Schaub 2014), sketching has already been discussed and design heuristics involve cognitive prompts that suggest new actions for a design to take to explore more of the design space (Daly et al. 2012). While some of these conception generation techniques have been studied for their efficacy (e.g. see Daly et al. 2012), few of these techniques offer a steady access digital platform that dynamically captures designs in one location for revisiting or revising for students, teams and an entire class. The aim of this study is to investigate the use of such a platform for concept generation.

Next I will discuss the main design skills that are related to the concept generation stage (including the more specific process of sketching) of design: ideation, reflection, and iteration. Another important skill involved with concept generation is collaboration, which I also discuss below. While other skills may be invoked or developed during concept generation, these four are critical for generating a variety of design ideas on a team.

One of the design skills invoked by sketching is “ideation” (Vargas-Hernandez, Shah & Smith 2010; Dorta, Pérez & Lesage 2007; Goldschmidt 2003, 1992; Shah et al. 2001).Ideation is the process of coming up with many initial, often rough, ideas or solutions for a design task/problem at the early conceptual stage of the design project. Ideation involves both divergence (or creating many ideas; Dym et al. 2005) as well as convergence (or selecting a subset of appropriate ideas; Toh & Miller 2015). Studies on how novice engineering students spend their time on design projects suggest they do not spend as much time on ideation as compared to experts (Crismond & Adams 2012; Atman et al. 2007; Atman et al. 2005).Designers or design students can employ ideation strategies to explore more of the problem space (Simon 1969), building on or going beyond more obvious solutions, thereby increasing the novelty of the designers' eventual solution downstream (Daly et al. 2012; Vargas-Hernandez, Shah & Smith 2010; Dorta, Pérez & Lesage 2007).In sketching, ideation is accomplished by quickly creating multiple rough drawings that represent small or larger deviations from underlying ideas, in traditional pen and paper formats (Prats et al. 2009; Goldschmidt 2003) or digital formats (Rahimian & Ibrahim 2011; Alcaide-Marzal et al. 2012).

"Reflection" is another key ability that can be developed through sketching or broader concept generation practices.Donald Schön's (1984) work on reflection in professional practice, including reflection-in-action and reflection-on-action, has been highly influential on notions of reflection in design (Gerlick et al 2010; Adams, Turns & Atman 2003; Valkenburg & Dorst 1998). Reflection-in-action (RiA) is a process of being aware of, responding to, and interrogating cues while one is performing some action (Schön 1984). In sketching, Schön and later Goldschmidt refer to this reflecting as the "backtalk" of a sketch (Goldschmidt 1991). Reflection-on-action (RoA) occurs when someone returns to and interrogates a completed action or decision. For example, RiA might happen as someone sketches and notices a missing element in their ongoing sketching, whereas RoA might happen when a designer moves onto another step of the design process (such as modeling) but then returns to a part of sketching they had discarded previously.

Novice designers tend to operate in a tacit mode, failing to reflect on their decisions, progress on the project, or assumptions/values of the project or decisions (Crismond & Adams 2012). Researchers and teachers have developed different tools and techniques for encouraging RoA/RiA including design-stage specific or after-design project questions/brief reflection papers (Siewiorek et al. 2010; Hamilton et al. 2007), design diaries (Crismond & Adams 2012; Svarovsky 2011, 2009) and exercises where students compare their design process to that of others(Crismond & Adams 2012).For example, students may be asked to answer questions at the “close” of different design stages (design-stage specific), which more closely resembles RiA, or they may be asked to write a reflection brief at the close of an entire design project (after design project), which more closely resembles RoA. Digital tools can also be used for reflection (Bateman, Teevan & White 2012; Turn et al. 1997).

A closely-related design skill/strategy is “iteration.” Iteration refers to the systematic or intentional repeating of stages of the design process or looping across/back multiple stages of design such as from modeling to problem definition (Crismond & Adams 2012; Jin & Chuslip 2006). Novice designers are less likely to make these transitions or to do so in a haphazard, less intentional manner (Crismond & Adams 2012; Atman et al. 2005; Adams & Atman 2000; Atman et al 1999). Atman et al. (2005, 1999) found in a comparison of freshman and senior design students that senior students made considerably more transitions. In another study Atman et al. (2007), found that senior students and experts made similar levels of transitions, suggesting senior students have moved closer to expert behavioral patterns. Adams and Atman (2000) argue that these transitions are correlated with higher quality final designs.

Iteration is closely related to reflection; indeed, what sparks a designer to iterate is often reflection after running into a difficultly or self-monitoring of their design process (Crismond & Adams 2012; Adams & Atman 2000). Similar to reflection, iteration on a decision step may be initiated by examination of externalized thoughts during or after action.

The final design skill related to concept generation is collaboration. While concept generation could be conducted individually, the majority of engineering design in industry is a social, team-based effort (Bucciarelli 2003, 1996; Vincenti 1990). Sketching itself can directly promote collaboration--a sketch visualizes a concept or idea in one team members' head that can then be shared with other team members to convey an idea beyond linguistic dimensions (Rahimian & Ibrahim 2010). As discussed above, sketches are often rough or ambiguous in their details, which can also make a sketch generative for new thoughts by reading the ambiguity in different ways (Stones & Cassidy 2010; Goldschimdt 2003). This trait of sketches may encourage collaboration when one student is able to generate an idea or particular interpretation from another student's sketch.

Returning to collaboration more broadly, there is a tendency for engineering design projects in education to be broken into discrete blocks and later reassembled into a whole, with limited collaboration between teammates (Rowan-Kenyon et al. 2012; Zemke 2010; Leonardi, Jackson & Diwan 2009). Other research has found that women are sometimes marginalized by other teammates, or their work is undervalued on design teams (Tonso 2007; Tonso 2006). In light of these difficulties, much work remains on how to better promote team collaboration. One promising means to encourage collaboration is through platforms such as Web 2.0 applications and virtual worlds that can offer a means for collaborative knowledge building (Kimmerle et al 2013; Moskaliuk, Kimmerle& Cress 2012; Moskaliuk et al. 2011; Kimerlee, Cress & Held 2010). This is similar in principle to collaboration through sketching. However, digital platforms, particularly games, bring associated challenges in addition to opportunities for collaborative knowledge building. These challenges are discussed in more detail in section 2.4

I now turn to my implementation strategy for *Minecraft* and associated pedagogical structure as it relates to design platforms and design skills.

### 2.3.1 Implementation Strategy: Design Studies

In this section, I first situate *Minecraft* in association with the ongoing debate over digital and more traditional concept generation means. Next I discuss how *Minecraft* and the activities I designed for it can help students develop design skills associated with the concept generation stage of design.

To address the debate over concept generation platforms I propose using a different approach by having students play a 3D videogame to engage in the conceptual stage of design, as well as some related design steps or moves. I argue that *Minecraft* can be used as a somewhat simplified but collaborative platform for engineering students to engage in "sketching" or building rough models of early design ideas. Similarities and differences from sketching open the possibility that *Minecraft* may grant several affordances for the conceptual/ideation stage in design.

First, *Minecraft* is more constrained than sketching or some computer platforms like *Photoshop* or some CAD programs in terms of construction of an idea: it has pre-shaped blocks and other units that must be used. However, some researchers have reported that the people who benefit the most from sketching are those with considerable experience with it (Prats et al. 2009; Goldschmidt 2003, 1991). By simplifying how one goes about "sketching" by constraining forms and using a system that requires no drawing ability, this limitation of *Minecraft* could potentially serve as scaffolding for early design students (who may not have experience with sketching). Another limitation comes from the 3D environment of *Minecraft* in contrast with the 2D environment of sketching. Such a 3D environment is more like a “finished” design project and this may be likely to induce fixation, or a sense that the project is more complete than it is (Crilly 2015; Alcaide-Marzal et al 2012; Roberstson & Radcliffe 2009). This issue must be dealt with carefully, as the more fixed form of shapes in *Minecraft* may push students to fixate. I attempted to minimize this affect by taking advantage of *Minecraft's* collaborative nature and having “pause” periods between uses of the platform (i.e., gaps between the game-based learning activities), which can reduce fixation (Kohn & Smith 2009; Sio & Ormerod 2009; Smith & Blankenship 1991).

Additionally, unlike platforms where a student can generate a fixed shape and then scale it appropriately, in *Minecraft* all shapes/forms must be built from the stock units of a set size. This potentially gives a student more “backtalk” than creating a shape and scaling it up and down as needed because they have to build the shape and then briefly reflect as to whether or not it is what they are attempting to create. This process should occur naturally when students build on the platform.

In terms of specific design skills related to the concept stage of design, ideation is easily accomplished on *Minecraft*. The virtual world in *Minecraft* is large and students were given access to all building materials when they log onto the platform. Furthermore, teams were given a sizeable dedicated area for building concepts. Perhaps less obvious than ideation, reflection can also be promoted through *Minecraft*. I theorize that *Minecraft* can be used for both RiA and RoA. In *Minecraft*, RiA comes directly out of the ability to build in the virtual world, with immediate feedback as well as synchronous chat with team members. RoA can also be supported by the synchronous chat (after “building” is complete) as well as through a notation system ("signs" with brief descriptions or explanations that can be placed in the virtual world). Additionally, the things students build can be a source for future RoA as an externalization of their thoughts in a digital, semi-permanent form. Creations on *Minecraft* are not fixed, they can be modified, altered or replaced. Since student teams each have a large dedicated space, they had ample room to modify existing designs or build new iterations.

Finally, *Minecraft* is inherently collaborative. Researchers have argued that some digital platforms allow for knowledge building through the collaborative creation of media/data (Kimmerle et al 2013; Moskaliuk, Kimmerle & Cress 2012; Kimmerle, Cress & Held 2010).Additionally, Moskaliuk et al. (2011) argue that this principle applies to virtual worlds as well, and compare virtual worlds with other user-generated content platforms like Web 2.0 technologies (Song 2010, 2009; Wang et al. 2007). In a collaborative environment like *Minecraft*, players not only experience "backtalk" from what they built, they may experience a similar feedback mechanism from moves from their teammates. This is accomplished in *Minecraft* by allowing players to collaboratively externalize their ideas so that other players can interact with, question, critique and modify. Critically, *Minecraft* has both synchronous team chat (Giesbers et al. 2013) and asynchronous communication (in the form of signs or artifacts); (Garrison, Anderson, & Archer 2010; Rouke et al. 2001) to facilitate many of these processes. The ability for players to synchronously collaborate in the same platform is one of the unique aspects of *Minecraft* when compared to typical sketching platforms, whether analog (Goldschmidt 2003, 1991) or digital like CAD (Robertson & Radcliffe 2009), 3D rendering software (Rahamian & Ibrahim 2011; Ibrahim & Rahamian 2010) or 2D drawing platforms

(Cassidy & Stone 2010). Thus *Minecraft* has the potential to scaffold a number of design skills/modes of design thinking that are part of the ideation process, including the generation of ideas itself, reflection on ongoing or past ideas, iteration through the idea development stages and collaboration with one's design team.

## 2.4 Gaming Culture and the Digital Divide

In this final section of the literature review, I discuss some challenges associated with using game-based learning in the classroom. Gaming culture is a male-dominated domain (Jenkins & Cassell 2008; Kafai et al. 2008; Lazzaro 2008; Lucas & Sherry 2004) that may indirectly affect game-based learning activities through their connection to the broader gaming culture. I thus review four ways in which gaming culture remains male-dominated to situate this research. Furthermore, experience with digital platforms like games is not evenly distributed across different demographic groups. This is often referred to as the "digital divide" (van Dijk 2006; Yu 2006). I briefly discuss variation in experience with digital platforms. Lastly I discuss my implementation strategy to reduce the risks of pernicious aspects of gaming culture from affecting the class and how I will address unequal levels of experience with digital platforms like games.

### 2.4.1 Gaming Culture and Depictions of Gender and Race

Videogames and gaming as a cultural domain have historically and continues to be male-dominated (Jenkins & Cassell 2008; Kafai et al. 2008; Lazzaro 2008; Lucas & Sherry 2004). Although research on gender in gaming culture is somewhat fragmented, four related topics have received some attention: the gaming interests of men/boys and women/girls and the relative value different kinds of games have been given within gaming culture (Juul 2010; Lazzarro 2008); controversial events that highlight gender disparities in gaming (Chess & Shire 2015; Salter & Blodgett 2012); the representation and retention of women in the gaming industry (Prescott & Bogg 2010; Consalvo 2008); and women's representation or depiction in videogames (Martins et al. 2009; Burgess, Stermer & Burgess 2007; Labre & Duke 2004; Dietz 1996). These deal respectively with what is valued (in terms of games), gender differentiated interaction norms, who produces media, and how that media depicts groups in gaming culture. All of these reveal different ways in which gaming culture remains male-dominated. I address each of these in turn. There is even less research on minorities in gaming, however, I also discuss the limited work on minorities' underrepresentation and depiction in videogames (Brock 2011; Burgess et al. 2011; Everitt & Watkins 2008).

Some researchers have focused on the differences in gaming interests between girls/women and boys/men (Lucas & Sherry 2004; Kafai 1998), while others have examined (Suden & Svengsson 2011; Thornham 2008; Cassell & Jenkins 1998) or advocated for (Bertozzi 2012) girls/women who do or should play games similar to boys/men and yet still others have examined fluidity in gaming interests for girls/women and boys/men (Carr 2005; Jenkins 1998). While this debate continues, researchers have found that one broad set of games—often called "casual games"—are played predominantly by women (Kafai et al. 2008; Consalvo 2007). So-called "casual" games are often defined as having less complicated game-play mechanics (Bogost 2007) and rely less on or use of game-play conventions (Juul 2010).Game-play conventions are mechanics that are shared across several games. Since they are shared across several games (often of similar genres), conventions may not be explicitly stated or addressed within the game. It is often up to the player to adapt them from past experience or learn them through trial and error if they never encountered them before (Juul 2010). These two conditions—complex or additive mechanics (Gee 2002) and unspoken conventions—make the learning curve for non-casual games steeper than for "casual" games.

Despite being grounded in the mechanics of the games, the label "casual" is problematic for many reasons, including that it implies mild or fleeting interest. Indeed, many game developers use the label to refer to a demographic who are not interested in investing a large amount of time in games; instead, “casual game players” are thought to seek brief game-play sessions as a distraction or escape from other concerns (Juul 2010; Bogost 2007). Furthermore, casual game players are often construed as preferring easier games, which coincides with lower time investment in games. From this description, it would seem casual game players are not highly involved in gaming culture.

Emerging research on those who play casual games, however, suggests "casual" is a poor descriptor of many of the game-players. Juul (2010) conducted a survey with 82 active casual gamers (recruited from a casual game website; 93% were women) and found that many attributes they are thought to have proved inaccurate for his respondents. Over a third of the respondents reported playing at least an hour daily and another 14% reported playing for at least 3 hours daily. In a qualitative study of women who played casual games, Lewis and Griffiths (2011) likewise found some of their interviewees played regularly. Juul (2010) also found that around half of his respondents preferred games that were challenging—neither too easy nor too difficult—and another third said it would be worse if games were too easy. Similarly, Lewis and Griffiths (2011) found women in their study enjoy competing against friends (for example, in the tile matching game *Bejeweled*) or against their own past performance. Consalvo (2007) was able to identify and study affinity spaces around the popular hidden object game *Return to Ravenhearst*, where casual game-players shared tips, reflections and reviews on the game. An affinity space seems unlikely to arise around a topic people have only casual or fleeting interest in. Although Juul's (2010) respondents were likely more dedicated casual game-players who have accessed the casual game websites where his survey was posted, these dedicated gamers show that at least some “casual” game players enjoy challenging games and spend considerable amounts of time playing them. Lewis and Griffiths (2011) study back up these findings. Their interests and investment are far from casual; nevertheless, these types of games are often marginalized or contrasted with "hardcore" games that often have a larger male demographic of players (Juul 2010; Lazzarro 2008). In this way, "casual" games, and the women who play them, are left at the periphery of gaming culture.

A second aspect of gaming culture that reflects the ongoing domination of males concerns a set of controversies in gaming culture. These controversies reveal ways in which women's voices and work within gaming are ridiculed or minimized, often in hostile ways. Here I briefly cover two recent controversies including the "Dickwolves" incident (Salter & Blodgett 2012) and GamerGate (Chess & Shire 2015).

Penny Arcade is a well-established web-comic and blog about games (http://www.penny-arcade.com/). Over the years, Penny Arcade has expanded, publishing a series of games, creating podcasts, working with charitable organizations to get gamers involved with social causes and establishing their own convention, the Penny Arcade Expo or PAX. In 2010 one of the comics published on Penny Arcade depicted fictional creatures called "dickwolves" that raped a non-playable character (NPC)while the hero completed other quests. The comic was commentary on games' narrative structure where the player helps a NPC only to ignore them for the remainder of the game. The use of rape as a joke in the comic drew attention from many commentators, particularly women who had dealt with the colloquial use of "rape" as slang in gaming to mean a decisive victory over opponents or to be decisively defeated. The comic served as a symbol for how sexual violence is trivialized in gaming culture and often turned into a threat between gamers. The comic creators dismissed concerns over the content of the comic and later turned the dickwolf creatures into a t-shirt sold on the site. Furthermore, many male gamers rallied in support of Penny Arcade and the use of dickwolves and rape as mere humor and ridiculed those who sought to challenge the ways rape is used in gaming slang. Salter and Blodgett (2012) argue that the event shows gaming culture is hypermasculinized and male gamers are resistant to critique or discussion of problematic aspects of gaming culture. Penny Arcade's creators, who have tried to change how gaming is viewed in the wider culture (such as through collaboration with charitable organizations) and who stand as an authority in gaming, did little to change the site, and in fact exacerbated gaming's hypermasculization through the promotion and sale of dickwolf shirts and encouragement of male gamers who view critiques of gaming culture as illegitimate (Salter & Blodgett 2012).

A more recent event, starting in 2014, called GamerGate shows little has changed in gaming culture. The GamerGate controversy involves accusations that feminist and social commentators and women in the games industry are attempting to undermine or exert undue influence over games. Feminist critics such as Anita Sarkeesian and game developer Brianna Wu, among others, have received numerous death and rape threats for purportedly undermining gaming culture. In a particularly bizarre incident, feminist media researchers Chess and Shaw (2015) discuss how a fishbowl discussion about diversity in games at the 2014 Digital Games Research Association (DiGRA) was construed as feminist conspiracy involving the government, DiGRA and researchers who all sought to transform gaming through propagandist social control. Chess and Shaw (2015) argue part of the reason for the emergence of this conspiracy is the opaqueness of academia, but also note that those identifying the supposed "conspiracy" are also acting as agents to reinforce the current, highly gendered power structure of gaming. Unlike the dickwolves incident, GamerGate has no clear figurehead; nonetheless the coordinated attack, threats, and dismissal of women seeking to change discourses in gaming or developing games reveals gaming culture remains closed to much critique. Tellingly, these particularly egregious events happen at a time when women now constitute nearly half of those who self-identify as gamers (ESA 2013). So, while more women and girls may play games, their voices and work in gaming are still often trivialized, ridiculed or dismissed, effectively silencing or ostracizing them.

A third point of contention for women in gaming involves the actual game developers. Women are underrepresented in the gaming industry (Prescott & Bogg 2010; IGDA 2004). In a survey of UK game developers, Prescott and Bogg (2010) find that women in the gaming industry are often in positions such as human resources and have lower representation in positions that involve game design, like programmers, audio engineers, and writers. It may be that women's lower representation in roles directly tied to game creation may indirectly perpetuate problematic or stereotypical depictions of women in gaming, as discussed below. Furthermore, the International Game Developers Association (2004) survey of game professionals found that 49% of men reported that they plan to stay in the games industry for their entire career, whereas only 34% of women reported the same plan. This suggests women may leave at a higher rate than men in the gaming industry. Consalvo (2008) reports that gaming companies often expect their employees to work through crunch periods that may constitute 60-80+ hours of work per week. Consalvo interviewed women who reported that this pressure, often combined with family obligations, made gaming careers untenable for them. It appears then, at least for the near future, game production will largely be conducted by men who may not be likely to challenge the dominance of males and hypermasculinization in gaming.

Fourthly, in an early study of women's representation in games, Dietz (1996) found very few women characters are included in games. Later studies indicate there are considerably more female characters in games (Martins et al. 2009; Jansz & Martis 2007) but their physical portrayal as hyper-sexualized (Martins et al. 2009; Burgess, Stermer & Burgess 2007; Jansz & Martis 2007) or their inclusion in sometimes limited ancillary roles (Dietz 1996; Gailey 1993) remains problematic. Jansz and Martis (2007) note that as games have become increasingly popular, there has been an increase in strong, brave heroines in videogames such as Lara Croft, Aya Brea, Samus Aran, Jade (Shauni) and Lightning. Nonetheless, physical portrayals are often sexualized even if their roles are not trivialized. Thus, across gaming interests, responses to controversial topics, the demographics of game producers and representation of women in games, gaming remains a highly masculine space.

Game-based learning moves games into an educational setting and therefore is not centered within gaming culture; however gaming culture may indirectly affect games in other settings. Keeping the contours of gaming culture in mind when designing game-based learning activities may at least help reduce the chances of noxious elements of gaming culture affecting game-based learning. For example, one study of games in education settings, a virtual classroom for a computer science course, found that female students indicated more interest for the class when elements associated with traditional computer science culture (e.g. science fiction, Star Trek, some video games' paraphernalia like game systems) were removed and replaced with more “neutral” objects such as art (Cheryan, Meltzoff & Kim 2011). Male students responded the same in both environments. This suggest when games are used in a class, what objects are included in the virtual classroom or learning environment may be viewed less positively depending on how they are introduced or what they are related to.

Beyond gender, an earlier study by Kolko (2000) described how people in early gaming platforms such as multi-user dungeon (MUDs) or MUD object-oriented (MOOs) users presented or discussed race. As these were text-based, there were no “avatars” or virtual embodiments for others to see. Many users at the time argued that in these games race no longer mattered as it could be “transcended” within the platform. However for non-white players, simply using a game did not change their day-to-day lives. As Kolko (2000) points out, the argument by some game players that race no longer mattered trivialized their real life experiences. The technical issue of not displaying any race is less of a problem now with technological advances but studies into video game content also find major underrepresentation for people of color (Burgess et al 2011; Everitt & Watkins 2008; Jansz & Martis 2007; Dietz 1996).

Burgess et al. (2011) report that people of color are more often portrayed in ancillary roles in games, or as overly aggressive characters. However, a limitation of Burgess et al. (2011)'s study and some other studies (such as Burgess, Stermer, & Burgess 2007) is that they only analyze cover or related game art, not the game itself. Essentially they truncate the majority of the game to a limited interpretation. So, for example, a character could appear aggressive on a cover but have a more dynamic personality within the game, or, worse, the characters' portrayal within the game may exacerbate or reinforce the stereotypical cover images. While a deeper examination is time-consuming, it would also shed more light on the complexities of how women and minorities are depicted in games. Nonetheless, issues of under-representation and stereotypical representation, like those found in other media platforms, abound in games (Martins et al. 2009; Everitt & Watkins 2008; Jansz & Martis 2007). Work by Brock (2011) also explores gamers' discourse around a particular game, *Resident Evil 5*, where a white male protagonist is sent to Africa to battle a zombie outbreak. The portrayal of a white male killing numerous Africans (who had been infected) raised questions about the racial messages the game sent. As Brock (2011) reports in an analysis of an article and user comments on the game, many users dismissed concerns as "race-baiting" and did not acknowledge or see any possible connection between the game's narrative and other racialized confrontations, such as European colonization of Africa (Steinmetz 2008). While there have been few studies along racial dimensions of gaming culture, Brock's

(2011) work and the depiction of people of color in games raise concern about the openness of the community about issues of race and history.

Moving beyond stereotypical or marginalizing portrayals for women and people of color in media, there are also many studies that report on the gap in knowledge, skill and familiarity with digital platforms by gender (Huang, Hood & Yoo 2013; Foteinou 2010), class (Schradie 2011) and race/ethnicity (Straubhaar et al. 2012; Kvasny 2005; Monroe 2004). For instance Schradie (2011) found that people in higher socioeconomic classes were more likely to use many web 2.0 applications like blogs, compared to those in lower socioeconomic classes. Schradie (2011) finds those with more higher education are more likely to use different web 2.0 applications, and that those from higher socioeconomic classes have more regular access to the internet to use web 2.0 applications. The digital divide is particularly relevant in an information age (Bell 1976) that increasingly requires high levels of information and technical capabilities to find decent employment (Stalder 2006; Castells 2000).Those who grow up in communities or backgrounds that experience a digital divide will likely enter college behind their higher socioeconomic classed peers who have spent more time and are more familiar and capable with information and communication technology. This disproportionately affects people in lower social classes, minorities and women (Huang, Hood & Yoo 2013; Schradie 2011; Monroe 2004), and thereby recreates or reinforces existing inequalities (Straubhaar et al. 2012; Kvasny 2005).

Taken together, these limitations and issues with digital platforms and video-game culture need to be considered when designing an educational study based on games. While complete mitigation may be beyond reach, much can be done to lessen their effect.

In what follows, I discuss some strategies I used in the game-based learning activities to try to address these points.

### 2.4.2 Implementation Strategy: Gaming Culture and the Digital Divide

The past experiences or any internalized views students may have from any prior involvement they had in gaming culture are not topics an instructor can easily change. However, for the game-based learning activities and the game itself, it is possible to set some boundaries on how the game is used. For instance, *Minecraft* usually is populated by "enemies," monsters who appear in its world and may be hostile to players. Furthermore, the game has a “health” system that would allow students to harm other students' avatars, although the game is not principally about fighting other players. In my study’s intervention, I disabled monsters as well as the health system to discourage disruptive practices either from the game (monsters) or other students. Since several students were unable to follow the lighter restriction that dynamite not be used on other students' artifacts after the activities had started, as an intermediary measure I also disabled this in-game item. In terms of images and portrayal of different groups, the creator of *Minecraft* made the unfortunate choice of making default characters in *Minecraft* “genderless.” However, as researchers have found in other domains, purportedly genderless characters are often interpreted as some gender given the context. As “builders” and “doers” *Minecraft* avatars will likely be interpreted as males (Kolko 2000).Fortunately there are “skins” in *Minecraft* that can be applied to avatars to change their appearance. These alternative appearances include different gender, racial and ethnic models for students' in-game avatars. They are primarily fan-made and thus do not conform to the creators' original design vision. Instructions for how to play also contained instructions on how to change their in-game avatars appearance. This did not entirely mitigate how individuals or groups are regularly marginalized in gaming culture, but it will hopefully make the use of *Minecraft* in the classroom less alienating because, as many argue, there is a distinct identity connection between players and their avatars (Li, Liau & Khoo 2013; Rigby & Przybylski 2009; Ryan, Rigby & Przybyski 2006; Gee 2002).

In order to address students entering the game-based learning activities with different levels of familiarity with digital platforms, the first activity of the intervention, "activity 0," is an opened-ended activity to give students an opportunity to familiarize themselves with the game and to introduce core game-play mechanics. I developed a specific tutorial area in a different virtual location from where students were asked to build artifacts. In this area, I made several stations or in-game signs that explained controls, such as the walking system, inventory system and the flight system.

In the next chapter I discuss the data collection procedures and context of the study, the analytical methods I used and the class activities.

# CHAPTER 3. METHODS

The methods chapter is composed of three major sections: context and data collection procedures, research methods, and pedagogical methods. In the first section, I discuss the context of game-based learning intervention as well as the students in the intervention and comparison courses, and the data collection procedures.

In the second section of the methods section I discuss the mixed methods design of this study and provide a diagrammatic view (Ivankova, Creswell & Stick 2007) of the data collection, research methods and research products for each component of the analyses. I then describe the research methods I used, and any relevant methodological considerations and procedures I followed for the analysis.

For the third section of the methods I begin by discussing the pedagogical method employed in this paper, the Content Assessment and Pedagogy (CAP) framework (Wertz 2013; Streveler, Smith & Pilotte 2012). I then apply the CAP model to the instructional methods I proposed and evaluate their fit.

Finally, I conclude the methods chapter with an in-depth discussion on the instructional procedures I used in the game-based learning activities for this study. I begin with the discussion of context and data collection procedures.

## 3.1 Context and Data Collection Procedures

In this section, I describe the context of the game-based learning activity and comparison class, briefly report on the participants in the study and describe the data collection procedures.

### 3.1.1 Context: Engineering 1

In this subsection, I broadly outline the intervention and comparison class contexts. I provide a more detailed discussion of the game-based learning activities for the intervention class in subsection 3.3.5.

This study utilizes a design-based research approach, which has markedly different assumptions than traditional experimental design (Barab & Squire 2004; Collins, Joseph & Bielaczyc 2004). Two differences are particularly important when comparing across contexts through these two methods. First, design-based research embraces the "messiness" of learning in a context, such as in a classroom, whereas experimental design aims for controlled laboratory studies where context variation is minimized (Collins, Joseph & Bielaczyc 2004). Second, design-based research seeks to characterize the situation or context in which the intervention happens whereas experimental design seeks to manipulate a (typically) small set of variables while holding others “constant.” Under experimental design, a control study should be as similar to the intervention study (with the exception of the variables researchers wish to test) as possible. However, in design-based research, the comparison study (or in this case, comparison class section) can vary from the intervention study as long as the researchers capture the differences across contexts. A comparison class section can serve as an external contrast point, to better understand the ways in which an intervention in the target class did and/or did not work. In this case the comparison class serves as a contrast to distinguish whether the gaming intervention had any effect above other instruction on design, which existed in both the intervention and comparison class. I call the contrast section in this study a comparison to help clarify that it is different than a control in traditional experimental design. In light of these methodological differences I present both contexts here.

The game-based learning intervention was conducted in a first year engineering course at a university in the Midwestern United States. There are two primary courses in first year engineering, what I will call engineering 1 and 2 for anonymity purposes. Students admitted to the College of Engineering at this university are all required to take both of these courses, typically in their first and second semester pursuing an engineering degree. However, engineering 1 is also taught with fewer sections in the spring semester, for students who were admitted in spring or had a conflict with taking it in the fall. This study was conducted in the "off" semester of engineering 1, spring of 2014. In fall semesters, there are typically 15 sections of engineering 1 taught; however in this “off” spring semester, only 2 sections of the class were taught. One section was used as the intervention section and the other as the comparison, with permission from instructors of both classes.

As a course, engineering 1 is intended to introduce students to the profession of engineering, and it focuses on many professional skills, such as information literacy, teamwork, communication and most critically for this study, design. One of the major projects lasting half the semester is a team-based design project where students work in the same teams of 3-4 students to design a product or process for a topic set by the instructor. The game-based learning activities for this study were situated within the early-to-middle stages of the project. I discuss the activities in depth in section 3.3.5.

The intervention course was the section of engineering 1 where the game-based learning activities happened. Within the course the design project followed the typical structure of the engineering 1 class, described previously. The teams students were assigned to were permanent.  The design scenario for the project asked teams of students to design a product or process for an alien student who had recently come to their school integrate with campus life. The game-based learning activities started after students had been introduced to the focus of the design scenario and had some opportunity to seek out information and scope the problem to some degree. In particular, activity 1 and 2 happened during the design ideation stage of the project where students were expected to generate many concepts (divergence) and then evaluate and select a smaller set of concepts (convergence). These two parts of the ideation stage map to activity 1 and 2, respectively (these activities are described in more detail in section 3.3.5). Students in the intervention class were all given full access to *Minecraft* (individual accounts) that allowed them to access the game at any time throughout the semester. Students were instructed to install *Minecraft* on their personal computers to allow for regular access. The game is not free; however Minecraftedu (http://minecraftedu.com/) offers discounted versions of the game for educational purposes.

The comparison course was the other section of the same course as the intervention course. During that semester, I spoke with this section's instructor to understand how he structured the class and to learn contextual details for later analyses.

The instructor in the comparison class divided the entire class into two large teams. Within each of these larger teams, sub-teams were responsible for different components of a sizeable design project (in this case, the task was to remodel, renovate or re-imagine a large building on campus that contains study areas, several restaurants, some stores as well as some university offices). Students were not permanently locked into their sub-team: they could join different sub-teams at different points in the semester and assist with the function of that new sub-team. The two large teams were also in competition with each other, which the instructor felt spurred some students' engagement on each team. The structure of the comparison class's design project and student teams were substantially different from both the intervention class.

### 3.1.2 Participants

Engineering 1 typically has 120-130 students; however since this was an off-cycle semester the class size was somewhat smaller with 109 students. In contrast the comparison class was somewhat smaller with 95 students. Table 3.1 breaks down the students by gender as well as international or U.S. nationality. As table 3.1 shows, 21% of the class were female and nearly 70% of those reporting their nationality were international, which is quite high. This could be because this was an “off-cycle semester” of the course.

Table 3.1
Gender and Nationality Demographics for Engineering1 Intervention

| Female | Male | International | U.S. National |
|---|---|---|---|
| 22 (21%) | 85 (79%) | 71(69%) | 32(31%) |

### 3.1.3 Data Collection Procedures

I collect three forms of data for this study: survey data, game-logged data, and interview data. I describe the collection procedures in turn.

The survey sought to measure students' design process and collaboration procedural understanding. I used *Qualtrics*, a survey creation and distribution software, to generate and propagate a digital version of the survey (the construction of the survey is discussed in section 3.2.2). The survey was first given to students before any of the game-based learning activities (the "pre-survey"). The survey contained nine design process or collaboration questions that are identified in section 4.2. Design process and collaboration questions were all on a 5-point Likert scale from strongly disagree to strongly agree. Due to time constraints, I was unable to coordinate with the instructor of the comparison class to have them administer the pre-survey in their class. After the final activity, students in both the intervention and comparison courses were given the same survey. The order of questions was randomized in order to minimize familiarity with the questions.

The game-logged data came from backing up the *Minecraft* server at key time-points throughout the semester. The server was available at all times of the day throughout the week except for times when I was backing up, modifying or performing maintenance on it. The backed up server preserved the exact state of the server at a given time point. I backed up the server at four time points. First, I backed up the server before students were introduced to *Minecraft*. This was simply to preserve the server's state before any students had used it. Second, I backed up the server after activity 1. Students built many artifacts for this activity so I wanted to capture the server's state for late comparisons across time. Third, I backed up the server after activity 2, for the same reasons as for activity 1. Finally, I left the server up for 3 weeks after activity 2, until nearly the end of the semester. At this point I took the server down for good and preserved the server for one final comparison point. In this study I only examine the second through fourth server states, as the first back up contains no game-logged data of interest.

The final type of data was interview data. Near the end of the semester, after the game-based learning activities were complete, I returned to the classroom to present my plans for the next stage of the study. I distributed an information or recruitment sheet to each student about the follow-up interviews, as well as an index card. After describing the intent of the follow-up study, I asked students who were interested in participating in an interview to write their name and email on the index card I gave them, and I then collected all cards. This was to help students avoid any conflicts or pressure from the instructional staff or classmates to participate/not participate. Twenty-four students wrote their name on an index card and 14 students responded to my email personally inviting them to participate in an interview. I successfully interviewed 11 students, or around 10% of the total class population. I offered a small financial incentive for participating: 10 USD.

I provide a summary of my interview participants (names anonymized) in table 3.2. Several of my interviewees were Chinese nationals. I asked a Chinese colleague for appropriate pseudonyms for male and female Chinese students. Two further students were Americans that I created pseudonyms for. Finally the remaining two students were also international students; however, they hailed from countries no other participants came from. To protect their anonymity I only indicate their continent of origin, and gave them Western names.

Table 3.2
Student Pseudonyms

| **Name (Pseudonym)** | **Gender** | **Nationality** |
|---|---|---|
| Cheng | Male | Chinese |
| Collin | Male | American |
| Devlin | Male | American |
| Gang | Male | Chinese |
| Liang | Male | Chinese |
| Jing | Female | Chinese |
| Nicole | Female | European |
| Qian | Female | Chinese |
| Steven | Male | Asian |
| Ying | Female | Chinese |
| Zhi | Male | Chinese |

The interview protocol had three sections: a section on their identification as gamers and past experience with engineering and gaming; a section on their experiences with the game-based activity in class; and a section on their informal uses of the game. The first section intentionally explores past experience with gaming and engineering (outside of the classroom) to better situate their present experience in engineering 1. This part of the protocol most explicitly addresses the sub-research questions about how engineering and gaming discursive practices and identity influenced their use of the game. In the second section, I asked the interviewees to give a narrative of the activities in which they participated. I also prompted students about what other teammates were doing during that time, and asked them to compare game-based activities to other classroom activities (of their choosing). This part of the protocol most explicitly addresses the overarching second research question concerning how students discuss the gaming platform and its constraints or affordances. The third section of the protocol inquires into students' more informal uses of the platform, the motivations behind their use, as well as whether more informal instances of use affected their design project. This final part of the protocol most explicitly addresses the sub-research question about students' informal learning practices. The full protocol can be found in appendix A. Interviews ranged from 15 minutes to 45 minutes in length. I recorded and transcribed all interviews. This study was approved institutional review board (IRB) with the stipulation that students' names remain pseudonymized and the instructional staff in engineering 1 did not have access to any research data until after final grades were posted for the class.

## 3.2 Analytical Methods

In this section I discuss the mixed methods design of the study and justify the inclusion of multiple data types in the study. Next I discuss the five analytical methods I employed to examine the three kinds of data I collected. For each method I describe the method itself, any relevant methodological considerations and the procedures I used for conducting the analysis.

### 3.2.1 Mixed Methods Design

Methodologically, this study employs what is sometimes called a parallel (Teddlie & Tashakkori 2010), concurrent (Teddlie & Yu 2007), or triangulation approach (Borrego, Douglas & Amelink 2009) to mixed methods research. While it sometimes goes under different names, the basic structure remains the same across these authors. In concurrent mixed method designs, qualitative and quantitative data are collected before any analysis is conducted (Teddlie & Yu 2007). Unlike sequential design, where one form of data may be collected, analyzed and used to structure another data collection step with a different data type (Ivankova, Creswell & Stick 2007), in concurrent design, all data is analyzed and reported in the same step. Data for concurrent designs may be selected from different sites or populations or the same population (Teddlie & Yu 2007). For this study, they were all selected from the same population: students in the spring 2014 engineering 1 class. Given that the collection of different forms of data is not dependent on a prior data collection step in concurrent design, all forms of data could be analyzed independently as separate studies. As a mixed methods design, however, data types are analyzed in parallel, complementary or contradictory findings across the forms of analysis are used to triangulate the phenomena under study and integrated in the findings, ideally.

Many mixed methods researchers critique the “incompatibility thesis” (Teddlie & Tashakkori 2012; Niglas 2010; Morgan 2007) which is a claim that quantitative and qualitative research cannot be designed in the same study because their epistemological and ontological assumptions fundamentally conflict. Many mixed method researchers argue that the incompatibility thesis too strongly links research questions, methodology, epistemology and ontology into inseparable, fixed sets (Biesta 2010; Niglas 2010). These authors remind us that quantitative and qualitative refer to types of data that may be used with different methods, epistemologies and ontologies, although not all combinations are feasible. In a similar vein, Abbott (2001) argues that the dichotomous “quantitative vs. qualitative" framing overshadows instances where methods or methodology blur this distinction, such as through quantitizing textual data (Borrego, Douglas & Amelink 2009) or through making multivariate clusters (formed through cluster analysis) that can provide descriptive quantitative profiles of some population (Castellani & Rajaram 2012).

Some constructivist or positivist epistemologies and ontologies may seem to suggest certain appropriate methods or kinds of data and thereby uphold the incompatibility thesis. However, alternate frameworks like pragmatism (Biesta 2010; Morgan 2007) and critical realism (Maxwell & Mittapali 2010; Steinmetz 1998) are flexible for multiple types of data. As I briefly described in section 1.1.2, I adopt a critical realist epistemology/ontology for this work. When comparing and contrasting results from analyses using different types of data, the key requirement is to understand the limitations of data type and method (for example a qualitative analysis may be used to show that something exists in the quantitative analysis, but not "how much" of it exists). Fielding (2012, 2009) calls this kind of integration “analytical density.” The aim of analytical density is not to reinforce the same finding through multiple methods (which would instead be called “convergent validity”), but rather to paint a wider and deeper picture of the phenomenon or phenomena researchers are studying. Fielding (2009) further argues that analytical density forces a researcher to stay alert to the weaknesses of methods and to negotiate the inferences of any findings in light of multiple methods. Thus, keeping analyses' limitations in mind, these methods can be used to inform and qualify each other. I present integrated results between some of the methods after presenting the findings and discussion for each method. Later I also integrate across several methods in the recommendations section of this manuscript.

Table 3.3
Concurrent Mixed Methods Design Data Collection and Analysis Stages

| Phase | Procedure | Product |
|---|---|---|
| Quantitative Data Collection | • Pre-survey intervention class | • Pre-survey responses |
| Qualitative Data Collection | • Minecraft server-state at preserved at 3 time-points | • Student built artifacts at 3 time-points |
| Qualitative Data Analysis | • Inductive Visual Content Analysis<br>• Logic-tree development and application | • Logic-tree<br>• Visualization of artifacts across "map" of virtual world |
| Qualitative Data Collection | • Interviews with Students | • Text data (transcripts) |
| Qualitative Data Analysis | • Fairclough Discourse Analysis<br>• Miles & Huberman Data Displays<br>• Thematic Analysis<br>• Taxonomy development | • Students engineering and gaming discourses and gaming identities<br>• Group Outcomes Matrix<br>• Informal use Taxonomy |
| Quantitative Data Collection | • Post-survey intervention and comparison class | • Post-survey responses |
| Quantitative Data Analysis | • Factor Analysis & Cronbach's Alpha<br>• Scale Correlations<br>• One-way ANOVA tests<br>• Cohen's d | • Factor loadings<br>• Internal reliability measures<br>• Inter-scale correlations<br>• Test of mean differences<br>• Effect sizes of statistical differences |

Table 3.3 depicts the mixed methods design of this study in a diagrammatic form that displays each data collection step (described in section 3.1.3), the analysis used on each type of data, and the outcome of those analyses (described in Chapter 4, below). This diagram was created using the guidelines Ivankova, Creswell and Stick (2007) recommend for diagramming mixed methods designs. I now turn to describe the methods used in this study.

Before turning to a discussion of each of the methods used in this paper, I present two reference tables. Table 3.4 depicts the associations between the methods I used and research questions I am studying. I do not discuss either figure or table in detail, but leave them here as a quick reference given the complexity of the mixed methods design in this study. In the diagram for the mixed methods design, the timing of data collection proceeds chronologically starting at the top and working downward.

Table 3.4
Data and Methods Association with Research Questions

| **Research Question** | **Analysis(es) method(s) and data used** |
|---|---|
| 1 | ANOVA of pre/post intervention class and intervention/comparison |
| 2 | This question is analyzed through the following 4 sub-questions |
| 2A | Discourse analysis of students' discussion of engineering discourses |
| 2B | Discourse analysis of students' gaming identity and discourses |
| 2C | Thematic analysis of students' responses to informal use questions |
| 2D | Visual content analysis of artifacts built on the server at 3 time-points |
| 3 | Synthesized from results and discussions of all previous questions |

### 3.2.2 Scale Construction

Scale construction involves generating, testing and modifying a series of questions intended to measure a single (or set) of underlying concepts as a scale(s) (Spector 1992). A scale is composed of multiple questions that address aspects or components of some latent (i.e. unmeasured) concept. Multiple questions serve two functions: they can be used to measure concepts that are not easily captured in a single question; and they can stabilize the measure (i.e. reduce the impact of measurement error, such as when a person replies to questions randomly) by averaging the responses over the *n* questions that compose the scale (Spector 1992).

Given that the design process and collaboration are multifaceted concepts and the limited availability of instruments to measure these, I created scales to measure each of them. These scales aim to assess students' development from novice to more informed designers (Crismond & Adams 2012). I sought to create scales for each element of the design process discussed in the literature review (2.3)--ideation, iteration, and reflection--as well as collaboration. These measures attempt to capture students' procedural understanding of the design process (Anderson & Krathwohl 2001); that is, they attempt to measure their understanding of the design or collaboration within the design process. Below I discuss the process of developing the design process and collaboration scales through a pilot phase.

The design literature was my starting point for developing design process and collaboration questions. I first immersed myself in this literature. Drawing on the theoretical and empirical work in the design literature I generated a set of questions for ideation, iteration, reflection and collaboration. I used a 5-point Likert scale (strongly disagree, disagree, neither agree nor disagree, agree strongly agree) for each question. I then sought out design experts with whom to conduct cognitive interviews (Sirken et al. 1999) on the questions. Cognitive interviews involve asking a respondent or expert to go through survey items and state aloud their thinking about the questions, such as what they think it is asking, how they would answer, difficulties conceptually or grammatically with the question and other feedback. I conducted cognitive interviews with 3 design experts in engineering education and 2 outside of engineering education. After incorporating recommendations from these design experts, I created a survey on *Qualtrics* survey software with several questions (4-6) for each of the design process scales and the collaboration scale. There were also variants of many questions, or alternative phrasing and word choices. There were forty-seven total number of questions in the pilot instrument. Importantly, many of these questions were minor variations on a smaller set of questions. Variants were included to test if some were clearer to the pilot population than others.

During the spring only 2 sections of engineering 1 were running and both were part of my study, so I could not pilot the survey in that course. I did not want to prematurely expose these classes to the survey instrument. Instead, I used engineering 2, the first year engineering class that students take in the semester after completing engineering 1. While these students were more advanced than engineering 1students, engineering 2 students were the most similar available population for piloting the survey on. Across several classes I collected approximately 150 usable results. Several questions had extreme response patterns (for example, heavily skewed toward the positive or negative side of the Likert scale) and were therefore dropped from further analysis.

Next I used exploratory factor analysis in the *SAS* statistical package to try to identify underlying factors in the questions. Factors are essentially latent or unmeasured variables, and factor analysis attempts to assess whether the data you have contains such factors (Kim & Mueller 1978). I used exploratory factor analysis (as opposed to confirmatory factor analysis) as these questions have never been tested. Generally, researchers recommend collecting at least 10 data points for every question used in a factor analysis (Kim & Mueller 1978). Therefore, after removing questions with extreme responses, I used experts' preferences for question variants (i.e. variations on the same question with different phrasing) to select a final subset to put into the factor analysis. The factor analysis identified 2 factors: one comprised of design process questions (primarily ideation and iteration) and one factor comprised of collaboration questions. I report the factor loadings and Cronbach's alpha for the pilot and class intervention in my findings, section 4.2.

### 3.2.3 Analysis of Variance

Analysis of variances (ANOVA) tests if there is a difference between the means of two or more groups (Iversen 1987). I used one-way (pre/post) ANOVA to test if students show differences in their responses to the design process and collaboration scales. I was unable to collect pre data from the comparison class; however I was able to collect the post survey in both classes on the same day of the semester. Given this, I also conducted a one-way ANOVA on the intervention and comparison classes post responses. The analysis of changes in the intervention and comparison group through ANOVA is a quasi-experimental research design as students are not randomly assigned to the classes (Olds, Moskal & Miller 2005; Light, Singer & Willet 1998). I report Cohen's d (effect size) for any statistical differences. I considered using multiple analysis of variance, which can test two or more dependent variables (e.g. the design process scale and collaboration scale); however, as I report in the results, there was little evidence for conducting a MANOVA over an ANOVA. Since the activities are meant to increase students' design thinking skills and practices, I anticipate that students in the intervention section post-intervention would have higher scores than pre-intervention and I anticipate the intervention class will have higher scores than the comparison class. I anticipate these results for both design process and collaboration.

### 3.2.4 Discourse Analysis

Discourse analysis is a qualitative technique that takes as its focus the way people frame social realities, people or other topics through "texts" (Gee 2008; Fairclough 1989). Here, "text" has a broad meaning, including transcribed speech (Rogers 2011; Fairclough 2003), written publications (Krippendorf 1980) and visual artifacts (Rose 2008). A core concept for discourse analysis is "discourse," which constitutes different ways of textually representing the world and its components (Luke 2000). These representations allow people to highlight certain aspects of the social world while obscuring or diminishing others (Fairclough 2003). Discourses also imply particular identities for those speaking the discourse (Fairclough 2003; Lave & Wenger 1990) or for those who are spoken of through a discourse (Harre & Van Langenhove 1991). Discourses, at least more prominent ones, are present across many texts, a condition sometimes called "intertexuality" (Campbell & Gregor 2004). Following this, a discourse's influence may be local (in that it is connected to only a few other texts) or extend several other locations, or even to an entire nation or broader (Campbell & Gregor 2004; Fairclough 2003).

There are several forms of discourse analysis (Gee 2008, Fairclough 2003, Luke 2000; Foucault 1972). In this analysis I drew on Fairclough's approach to discourse analysis (Fairclough 2003, 1992; Chouliaraki & Fairclough 1999) because it takes a unique position in contrast to many other forms of discourse analysis. In social science and education research discourse analysis has been heavily influenced by Foucault's work (1984, 1980, 1972) and focuses heavily on the social dimensions of language (e.g. discourses may obfuscate the agency of powerful actors to "hide" their actions that are against the interests of other groups and therefore perpetuate the social influence of powerful actors). Other forms of discourse analysis from linguistics expend more focus on the structure and function of language with less attention to its social implications (Fairclough 2003, 1992). Fairclough's work, building on research from Halliday (1994), seeks to merge close analysis of language structure and function with an analysis of the social impact of language. In so doing, Fairclough combines the strengths of the linguistic school's grounding in language functions (inferred from their structure) and the strengths of the social science school's emphasis on social ramifications of language (on thinking, practices, continuity and change).

For example, more on the linguistic side of Fairclough's discourse analysis is the study of semantic relations between sentences and clauses. Essentially, this analysis tries to identify the functional relationship between a sentence and a clause. There are many types of relationships (such as causal, conditional, temporal, additive, elaborative, contrastive/concessive and other relationships) and identifying the relationship in a given sentence reveals what "work" that sentence (and attached clause) does. In other words, what is the function or action a particular sentence and its attached clause accomplishes?

There may be several clauses attached to a main sentence through different relationships. An example from one of my interviews (with the type of relationship written in capital letters was as follows:" I saw that we're going to use Minecraft CONSEQUENCE so I start playing it REASON cuz I never played before." Note that consequence (when something naturally follows the thing that happened before it) and reason (an explanation given for the previously mentioned topic) are both causal relationships. Through analyses like these and other more linguistically-centered analyses I was able to ground my discourse analysis in the functions' clauses, sentences or larger sections of text performed. Some other examples of linguistically-centered analyses include: identifying modalities (words or phrases that mark certain epistemic stances or degrees of commitment to statements); identifying what kinds of statements are there such as facts, predictions, hypotheticals and evaluations; or identifying paratactic or inclusive and hypotactic or exclusive relationships between clauses.

For the more social side of Fairclough's discourse analysis, one example is examining what is included in the description of other people and what is excluded. This gets directly at discourse's ability to simultaneously highlight and obfuscate representations of people (or other parts of the social world) when they are invoked. Within my analysis of first year engineering students, many invoked different aspects of what engineers do, but tended to speak very little about aspects of engineering work that involved speaking with others, coordinating with others or about the social impact of engineers work. Through analyses like this and other more socially-centered analyses (some examples include: identifying discourses invoked; identifying what dimensions of events were included and excluded; identifying the identities invoked through discourses)

I was able to connect students' interviews with other discourses about gaming, engineering and other social relations. Critically, Fairclough (2003, 1992) does not distinguish between more linguistically and socially-centered parts of his analysis scheme; I have categorized them here to briefly demonstrate how his work brings linguistic and social schools of discourse analysis together. Those presented here as more socially-centered were identified through the concrete statements and words students made, while the others I presented as more linguistically-centered directly shape their social implications (e.g. modalizing a discourse to express low commitment to it) or action. At the end of Fairclough's (2003) book, *Analyzing Discourse: Textual analysis for social research*, Fairclough presents a series of questions for interrogating text based on his linguistic and social discourse analysis schema. I used these questions to guide my analysis of students' interviews. The questions I used are reproduced in their entirety in Appendix C, along with some modifications and additions I made specifically for this analysis.

To begin my analysis, I first created an Access database with a column for each of the questions listed in Appendix C. I then segmented each transcript into sections centered on similar topics (primarily either the class, the game, or engineering). I then analyzed each segment from the transcript with the questions in the Access database. During this process I made annotations within the transcripts for things like the relationships between a sentence and its attached clause, as shown in the example text above. Transcripts had anywhere from 6 to 10 segments. After completing this I created two full-page forms based off responses I had recorded in the Access database. I provide a sample of these forms in appendix D. Each segment of an interview required two forms to display answers to all of the questions; however some segments were more detailed than others. To begin to identify discourses (engineering, gaming or otherwise) within each interview, I printed the forms out and analyzed them by hand looking for bits of discourses across the responses I recorded for each question (e.g. what was listed as desirable or undesirable, what things were listed as similar or dissimilar, instances of intertexuality, identities invoked and others) across interviewees segments. I also cross-checked the responses in the forms against the original transcripts to ensure consistency.

Once I completed this for all segments for all interviewees I started to summarize the discourses invoked by each participant. To do this, I drew on the work of Miles and Huberman (1994) who advocate the use of qualitative data displays both as a tool for facilitating analysis and for displaying results. They discuss two main forms of qualitative data displays: networks and matrices. Matrices can display several things including events, conditions and roles. In order to summarize the 100+ pages of forms, I created a role matrix where each interviewee had a row and the rows were sorted by gender. The columns in the matrix were originally engineering and gaming discourses, but after summarizing a few interviewees' responses into a row; I also added a “class discourse” column. In order to be included in one of the columns for a given interviewee, a particular discourse had to be mentioned in two separate instances; instances were counted as separate if they appeared in different sections of the interview or if they invoked different components of a given discourse. I used the forms I had previously marked to identify discourses, and checked for multiple instances of the discourses within the transcripts. I allowed for other discourses to emerge at this point if I had not taken note of them in previous analysis, as well. With each discourse, I also included either paraphrased examples or small chunks of quoted text as an example of that discourse, following Miles and Huberman's suggestion.

I then had a 7-page table that was briefer than sorting over a hundred printed pages of forms. I started a second synthesis/abstraction phrase, where I sorted interviewees into groups and looked for shared discourses within those groups. I used this table as a summary of the results, discussed below in section 4.3. As I am interested in how or whether different discourses relate to different uses of the platform, I sorted students into different "use" groups. These groups were identified by analyzing answers students gave to questions about using the platform for class and informal use of the platform (see Appendix A for the interview protocol). The criteria for each use group and the number of students in each group is summarized in table 3.5. Here, data categorized as "informal use of the platform" constitute any instances where students used the platform when they weren't required to for class. Since all students were compelled to use the platform for the primary required activity (1), students' use during activity 1 was not used to distinguish groups. Instead, any continued use beyond activity 1 was used to define informal use. The “limited-use” group did not use the platform for class purposes beyond the required activity, whereas the “moderate-use” group used the platform toward minor class ends, such testing out different tools on *Minecraft* that could subsequently be used for their designs. In contrast to these two groups, the “high-use” group used the platform to substantially influence their design project, such as using *Minecraft* to visualize their final design for class or iterating on their design. All students fit distinctly into one of the 3 groups.

Table 3.5
Criteria for Informal Use Groups

| Group | Criteria |
|---|---|
| Limited-use (5) | Used for required class activity only. Any informal use was for non-class purposes. |
| Moderate-use (3) | Used for required class activity. Informal use for minor class purposes, such as testing out *Minecraft* functions for their class project but not pursuing them. |
| High-use (3) | Used for required class activity. Informal use for substantial class purposes, such as redesigning a past design or building a new design. |

With the groups completed, I then searched for shared discourses between individuals in each group. I sought shared discourses because I was interested in similarities between individuals in the use outcome groups. In order to count individuals' discourse as a shared discourse, at least two members of the group must have used it. Shared discourses were then placed into a group outcome matrix, with each group as a row and engineering, discourse and class as columns in the matrix (table). I also report on complementary or opposing discourses from individuals in the results section, although they were not included in this summary table. More specifically, these complementary or opposing discourses are related to, but not the same as, the shared discourses of a given group. Thus these individual discourses either bolster the shared discourses or provide qualifications to the shared discourse. In this also captures more of the complexity and heterogeneity within use groups.

Developing the outcome use groups was not something I originally planned as part of the analysis. These groups emerged out of several iterations of the discourse analysis, as detailed above. As such, when I conducted the interviews I did not always ask follow-up questions that would shed light on whether a discourse (or identity, discussed shortly) influenced how they used the platform or vice-versa. I did ask students about discourses around gaming and engineering that extended over long periods of their life (such as engineering experiences before college or when they started gaming; see Appendix A, which can give some sense of the temporal influence of discursive practices, identities and outcomes. Nonetheless, as many researchers have argued, discourses and identities are dynamic and contextual (Rodgers 2005; Lave & Wenger 1991). Therefore, the results of this analysis point to tendencies or potential relationships between discourses, identities and use outcomes, not strict causally ordered relationships. I wrote the results with this caution in mind, and will echo it again before discussing the results of the discourse analysis.

Table 3. 6
Illustrative quotes for Gaming Identities

| **Gaming Identity** | **Example text** |
|---|---|
| Non-Gamer | It was something I did when younger a lot more often than I do now. I almost never play now just because time wise I don't see it as something that's crucial for me... |
| Occasional Game-player | R: Maybe for me it's a pass of time, it's just when I have other things to do I just forget to play the Candy Crush. |
| Gamer | R: Since I was in middle school I think I played at least 2 hours per day.<br>I: ...looking back was there anything in particular that drew you to it or you just kind of bumped into it?<br>R: The biggest thing was my friends, I just had, need to have some common topic, some common interest with [them]. |

The final component of the outcome group matrix was incorporating gaming identities for each student. Originally I had planned to do this for engineering and gaming; however, after reviewing students' framing of engineering and the discourses they invoked, I do not feel I have enough information to try to identify their engineering identities. I therefore only report on engineering discourses in the results.

For gaming, I developed two criteria for labeling students' gaming identity. These criteria were how frequently an interviewee reported playing games as well as how important gaming figured into their lives. Although these are separate criteria, in the data they coexisted in three patterns: those who played games frequently and where gaming performed some important function in their life (such as connecting with friends); those who played games occasionally and where gaming was a side hobby or way to pass time; and those who played games infrequently or never and did not see themselves as a "gamer." These identities were labeled as “gamer” (four total participants), “occasional game-player” (for reasons discussed in section 2.4 concerning the problematic nature of the “casual gamer” label, five total participants) and “non-gamer” (two total participants).

In table 3.6, I provide brief quotes to illustrate each of the identities. While gamers and non-gamers generally labeled themselves with these identities, to distinguish the occasional game-players from gamers I employed these criteria. For the last step of constructing the group outcome matrix, I put the number of individuals who with each gaming identity into the gaming discourse column, below the gaming discourses they invoked. This table is presented and discussed in the results, section 4.3.

### 3.2.5 Thematic Analysis

My goal for the analyzing the ways students used the platform informally was to identify all the different ways students used this platform. Recall that I am defining informal use as any use that was not required as part of a class activity. Ultimately, this became a taxonomy based on how my interviewees used the platform informally. At the beginning, however, I selected thematic analysis to conduct this part of the analysis because it is a flexible, minimally structured qualitative technique (Braun & Clarke 2006). Braun and Clarke (2006) outline some general questions researchers should explicate for their analysis, including: What counts as theme? Is it inductive or theoretically driven? Are the themes semantic or latent? Is it a broad or focused analysis? And What epistemology informs it? These questions help guide an otherwise very open technique. I briefly answer each question for this analysis next.

Here I count unique instances of an activity as themes. These themes do not have to be the most frequent, but they should be conceptually distinct from each other. Given that my analysis is exploratory, the analysis is inductive, although it is broadly guided by past research and theory on informal learning (NRC 2009; Marsick & Watkins 1990). The themes are latent; that is, they are not instances of what people directly said, but abstracted themes based on transcripts. The focus here is fairly narrow, since I am looking at one kind of behavior only. And finally, like the rest of this manuscript, the thematic analysis is framed by a (critical) realist epistemology (Steinmetz 1998; Harvey & Reed 1992; Bhaskar 1975) that assumes both that there is an external world "out there" that effects everyday life but also our social world is an open system that cannot simply be studied to identify objective laws or rules. Research is not capable of capturing all the dynamics active an open system, which itself is constantly evolving (Capra 1996; Cilliers 1996, Buckley 1967). Therefore, how we interpret the phenomenon is important, and has real effects on the development of the system, even though it is still constrained in some senses by the world “out there.” In other words, how the researched and researchers interpret the world is important but constrained in some ways by a material reality. This epistemology frames the entire study, including the thematic analysis here.

From this basis, then, I sought the different ways students informally used the platform. After I had completed the discourse analysis, I cycled back through the transcripts and extracted all instances where students spoke of informal use behaviors. I only included behaviors they actually claimed to take, since I was interested in the ways students had used it, not how they might hypothetically use it. All excerpts were placed in the same document and uploaded to *Dedoose* qualitative software package, which is an web-based analysis tool. I used open coding (Corbin & Strauss 1998) on this amalgam transcript, paying particular attention to the details of the activities undertaken and any motivations students stated or implied. This sometimes required returning to the full transcript to cross-check motivations.

Next, I drew on Miles and Huberman's (1994) qualitative analysis technique called "clustering." Clustering involves grouping similar things, and within the open codes I began to cluster similar activities as well as motivations. From this clustering, two major kinds of motivation for informal activities emerged: "for class purposes" and "for non-class purposes." After identifying this trend, I returned to all the existing activities to see if they could be coded by one of these two motivations. I cross-checked excerpts about use against the full transcripts as needed.

After this, I created Excel documents by exporting data from *Dedoose* that contained each activity quote and its codes. I made a separate document for class and non-class activities. I then manually analyzed the codes in these documents, drawing again on clustering (Miles & Huberman 1994). I first organized the concrete activities into more abstract themes. I then used "splitting" (Miles & Huberman 1994): breaking themes into distinct sub-themes contained within the original theme. I iterated through this process several times, returning to the quotes on the *Excel* sheet to crosscheck. Several iterations through this process led to a list of abstract themes that could be placed under either class or non-class purposes. The splitting process created sub-themes under some themes, in addition to the more abstract theme of "class" or "non-class." To present this, I organized themes into a tree structure with informal use at the top, class and non-class branches from it and the remaining themes under their respective branch. I present this taxonomy visually in the results (section 4.4).

### 3.2.6 Visual Content Analysis

Results from the pre/post ANOVA (see section 4.2.1) scores for this class and the comparison class, as well as ways in which students discursively framed *Minecraft* as part of their design project (see section 4.3-4.3.3) led me to conduct one final additional analysis on the objects student built within the game. This analysis examined whether the objects students created suggest students were able to design artifacts that could inform, develop or be generative for, their projects. Ideally, students would have provided answers to this question through the annotations they were asked to add to each of their designs on the platform. However, not all students annotated their designs, and interviewing all students about their designs at the end of the semester was not feasible. Additionally, students created objects that appear not to be for class on the server; these non-class objects were very infrequently annotated, as students were only asked to annotate class designs. "Not for class" objects reveal important dimensions in the ways students used the platform and may qualify or raise questions about students 'use of the platform for class.

Given that some creations were not annotated, it was not possible to definitively state whether a design was "for class" or "not for class" purposes. It may be possible, however, to establish a set of criteria to identify artifacts that have the greatest probability of being either for class or not for class. My reason for doing so is not to impute the intention of students building the artifacts, but rather to answer the research question (2D) of whether students are both capable and willing, at least in some cases, to use the platform for design. The outcome of this analysis may have critical implications for using gaming platforms for learning.

I also explored how students used the platform within the in-game space and across the time the server was available. My reason for exploring students' artifacts across time and (in-game) space was to begin to better understand student and game interactions. Following Cobb et al. (2004) and other researchers who write about design-based research, I aim to contribute theory or transportable insight from the results of exploring students' artifacts over time and (in-game) space. In other words, design-based research may explore particular contexts in great depth, but a central goal of the methodology is generating theory or insight that might be applied to similar contexts (Barab & Squire 2004).

I used visual content analysis (Rose 2008) to analyze artifacts. Below, I first describe visual content analysis and then I detail the procedure I went through for analyzing the artifacts.

Content analysis is a method for examining typically pre-existing symbolic communication or media, i.e.," content" (Krippendorf 1980). Unlike interviews or surveys where data is collected and then analyzed, content analysis is conducted on "data," such as newspaper articles, that already exist. Krippendorf (1980) emphasizes that content analysis can be used for any material that might have symbolic meaning and Rose (2008) explicitly discusses a visual variation of content analysis. Similar to qualitative coding, a researcher using content analysis can develop categories pertaining to relevant qualities of the media they are examining (Berg 2007).

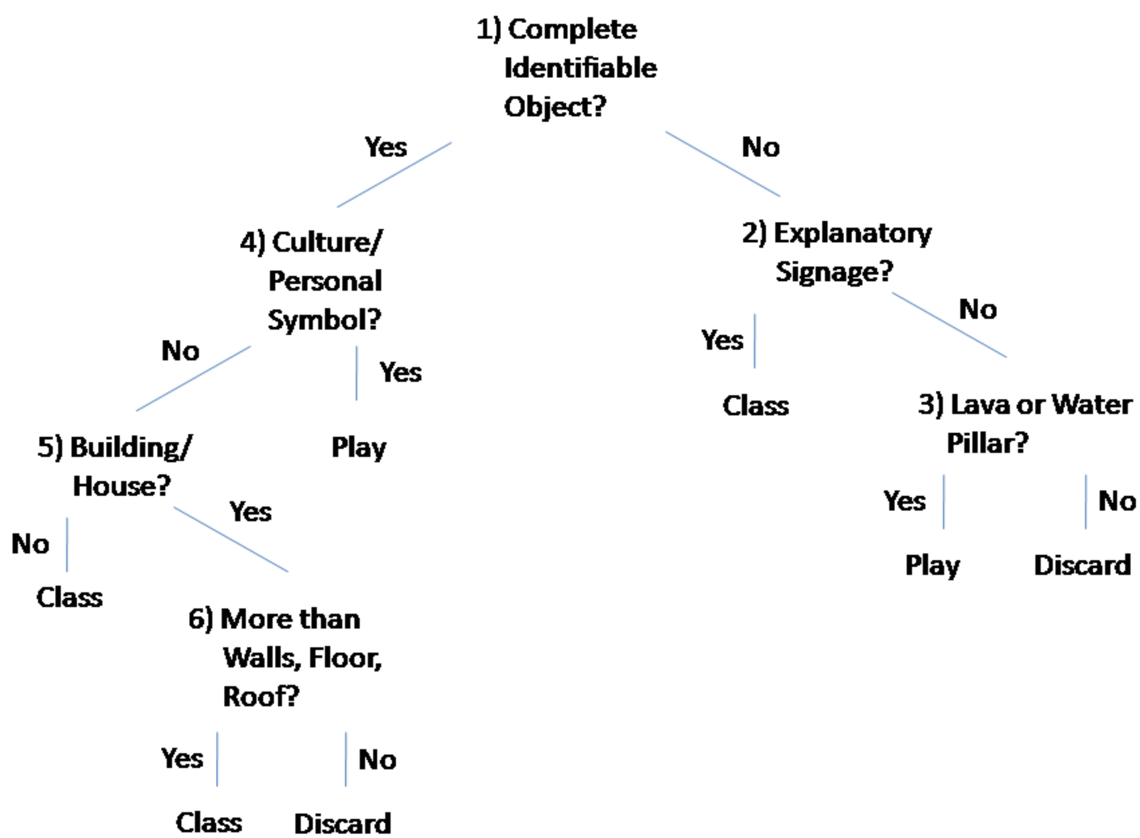



*Figure 3.1 - Logic Tree for Assessing Students' Artifacts*

Krippendorf (1980) lists several reasons to conduct content analyses, including for identification purposes. For this part of the study, I was not aiming to analyze students' artifacts for particular qualities they may have, but rather in order to categorize them as a plausible “class” related artifact or “non-class” artifact. Next I describe the scheme I developed for categorizing artifacts.

I took a more inductive (e.g. see Berg 2007) as opposed to more deductive (e.g. see Weber 1990) approach to developing content analysis categories and some criteria for labeling artifacts. I examined all artifacts on the server at each time point at which I preserved the server (after the first activity, after the second activity at near the end of the class) and searched for commonalities between artifacts. I did not examine the first server state, as this was before students had used the game. From this, I was able to identify two "non-class" categories of artifacts (water/lava masses and several types of symbols) and three “class” categories of artifacts (everyday objects, buildings, and artifacts that had signs). I also developed criteria to maximize the likelihood a given artifact was either “for class” or “not for class.” From these categories and criteria I developed the logic tree displayed in figure 3.1. This tree was developed iteratively by comparing the categories and criteria against the objects on the server. From the logic tree, an artifact could be labeled “for class,” “not for class,” or discarded from the analysis. If any artifacts fell into both of the larger groups (“for class” and “not for class”) or if artifacts that were less clearly “for class” or “not for class" were included in either group via the logic chart, I adjusted the tree through different criteria and tested it again.

I now walk through the components of the logic tree. At the top of figure 3.1, two criteria come into play for evaluating an artifact: is it complete? And, is it an identifiable object? Both criteria must be met to proceed on the "yes" link but if it fails either the artifact will proceed on the "no" link. Here, being “complete” means containing all obvious parts (for instance, a building with walls, a floor, and ceiling or a symmetrical object whose symmetry is intact). The second criteria at this tier required that the artifact be an everyday or recognizable object that required little interpretation to identify. These criteria did not *eliminate* any artifacts from being included, but instead placed those that failed one or both of the criteria on the rightmost path.

The next decision point on the right path asks whether the artifact had signage explaining the artifact. These were some of the objects that were labeled as per my original instructions; all of these were included in the "for class" category. Not all signed artifacts went this way as some were identifiable (and complete) objects, such as a chair and table with signage. The objects that traveled this rightmost path with signage were either entirely new objects (such as magnetic boots and rails) or not clearly identifiable. All objects on the right path with explanatory signage were placed as "class" artifacts. If an artifact lacked signage, it traveled to the final decision point on the rightmost side where the criteria asked whether it was a lava/water mass or not. In *Minecraft*, it is possible to build pillars or masses of water or lava. These aren't really “objects” as such but they are an outcome of playing with the water or lava system in the game. Therefore, if an artifact was a pillar or mass of lava/water it was included in the “not for class” group. If any object that made it this far on the rightmost path was not a lava/water mass, it was discarded. If an object arrived at this criterion, it would have been an incomplete/unclear object, with no signage.

Turning to the leftmost path, if an object was identifiable as an existing object in the world and appeared complete, the next decision point criterion was whether it was a cultural, personal, or religious symbol. Examples that fell into this category included crosses, flags of different nations and "building" one’s name somewhere on the server. These objects were far removed from the design project and thus I felt comfortable labeling them as “not for class”. If the artifact was not one of the above symbols the next decision-point criteria asked whether it was a building or a house. If the answer was no, the artifact was included in the "for class" group. These objects were complete, identifiable and not a symbol of some sort and thus were likely a class-related design (this group included many of the everyday objects). Buildings and houses, however, had a further stipulation: the final criterion. Houses and buildings are perhaps the easiest or most straightforward objects to design in *Minecraft*. Therefore, I wanted to be particularly careful in examining buildings/houses. While a house/building may be for class, if that artifact also has a more detailed interior, including chairs, tables, interior walls, and other components it would suggest a more detailed design, which may be more likely "for class" than for fun or "not for class" purposes. As a final precautionary measure, only those houses/buildings with interior fixtures or walls (such as dividing the interior into rooms) were included as "for class." Cumulatively, this meant objects that arrived at this criterion were identifiable objects that were complete and were houses with detailed interiors. Houses/buildings that had bare interiors were not included as “for class”.

While using the logic tree in figure 3.1 is a conservative measure of the artifacts built on the server, by the final state capture of the server there were over 50, collectively, of either "for class" or "not for class" artifacts. The logic tree still preserves a large amount of creations for assessing research question 2C.

## 3.3 Instructional Framing and Procedures

In this final section of the methods chapter, I first discuss my broader understanding of the design process that shapes the intervention on the concept generation stage studied here. Then I cover the content, assessment and pedagogy (CAP) model and apply it to this study. To close out the methods chapter, I briefly discuss a pilot study that informed this current work and then discuss the game-based learning activities in depth.

### 3.3.1 Perspective on the Design Process

In this study I primarily focus on the concept generation stage of the design process. However, my understanding of the concept generation stage is informed by my broader perspective on the design process in total. Concept generation happens after a stage of formulating the problem, which involves identifying a problem (Lawson & Dorst 2009) information searching (Atman at el. 2007) and problem scoping or changing/framing the problem to be addressable through a design (Lawson & Dorst 2009; Atman et al. 2007). These stage(s) are followed by concept generation, which as mentioned previously, involves the creation of many concepts (Dym et al. 2005) and a subsequent convergence or evaluation step on the previously generated concepts (Toh & Miller 2015). Following concept generation, there is some stage of modeling or prototyping (Atman et al. 2007) and an evaluation stage of the modeled/prototyped concepts (Lawson & Dorst 2009). Importantly, as Lawson and Dorst (2009) argue, evaluation of a design may involve subjective (e.g., stakeholder preference) and objective (e.g., meeting a certain physical, measureable capability) evaluation of both requires some synthesis of what are at first incommensurable evaluations. If the concept that was prototyped and evaluated turns out to well address the problem and the constraints the design process may end here. On the other hand, difficulties or limitations with the evaluated concept may lead to an iteration loop back to an earlier stage of the design. Following Jin and Chuslip (2006) I argue there may be iterations between stages (e.g., problem scoping and evaluation) as well as within a stage (e.g., several models built). One explicit way these iterations may happen across stages is from problem formulation to solution generation, or what Dorst and Cross (2001) call the co-evolution of problem-solution sets. It is within this larger context of problem formulation, information seeking, modeling, evaluation and loops within or across stages I see the concept generation stage of design happening.

### 3.3.2 Content, Assessment and Pedagogy (CAP) Model

The CAP model is a backwards-design approach for developing a course and ensuring that the content seen as most central to the course by the instructor is assessed through means that can reveal whether or not students have learned that content. Following this, a pedagogical approach is used that can appropriately help students develop the desired mastery (Wertz 2013; Streveler, Smith & Pilotte 2012).The underlying theme behind the framework is *aligning* these three elements, so an instructor does not, for instance, expect students to master solving open-ended problems culled from industrial settings only through abstract problem-based assignments and lectures on underlying mathematics.

The CAP model uses an embedded ranking for the centrality of content in a class, originally developed by Wiggins and McTighe (1998) and reproduced in figure 3.2. The centermost circle represents the most important knowledge that the instructor believes students should master within the class and carry beyond the class. It is called the "Enduring Understanding." In the second circle is knowledge, skills or ways of thinking called "Important to Know." This content does not need to be mastered at the level of Enduring Understanding, but is nonetheless important supporting knowledge students should at least be familiar with. The outermost circle is content labeled "Good to be familiar with", which is related knowledge, skills or ways of thinking that are helpful and complimentary, but not necessary to know. Having outlined the CAP model, I now apply it to this study.

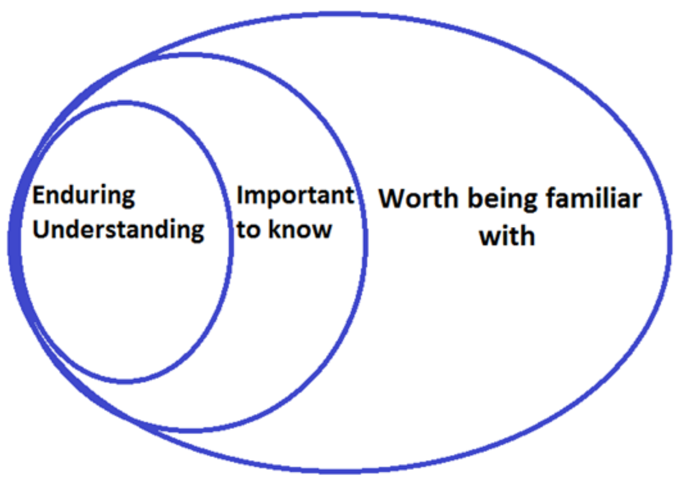



*Figure 3.2 - CAP Content Designations*

### 3.3.3 CAP Applied

I employed the CAP model primarily for the first research question of this study, which sought to assess whether students' learning develops along the axis of novice to informed designer (Crismond & Adams 2012). The second set of research questions, which explore how students discursively frame and use the platform, does not lend itself as well to the CAP method. These questions are more exploratory in nature, making it difficult to define beforehand what kind of mastery is needed. Indeed, the second (overarching) research question is aimed at developing an understanding of how *Minecraft* as a gaming platform constrains and enables students when engaged in early stage design processes. Such knowledge can then be used to generate recommendations for future platforms (research question 3) created for the direct purpose of design learning. More specifically, the sub-questions explored students' framing of engineering as a profession and gaming as an interest and how these activities relate to both of these. Other sub-questions explored informal use practices and the artifacts students build. While these sub-questions were intended to help to unveil students'(possibly changing) notions of engineering and gaming and the kinds of activities they engaged in beyond formalized instruction, the exploratory nature of this part of the study makes it difficult to predict the results beforehand. Subsequently, only the first research question was framed through the CAP model.

A key goal of the CAP model (Streveler, Smith & Pilotte 2012) is clearly explicating the alignment between the pedagogical approach, assessment and the content the class or activity is intended to help students learn, which I will now do for my study.

This study espouses a situative cognition approach, as described in section 1.4 (Johri & Olds 2011; Greeno 1997; Choi & Hannafin 1995). Following this, students in the class were asked to engage in a number of activities that were often group-based and intended to simulate aspects of professional practice. As mentioned above, the survey instrument for assessing students' learning is also geared toward measuring students' procedural understanding (Anderson & Krathwohl 2001) of the design process. In other words, the instrument is meant to measure students' understanding of the practices and thinking involved with the design process and thus is aligned with the kind of activities they will be doing. In relation to the content, the students' most important learning involves different design process practices and thinking, which is what they did throughout the activities. Therefore, these two components are also aligned. Indeed, the intended outcome of professional skills was taught through simulated professional practice, which was measured by the changes in professional thinking; thus the three are aligned.

For this project, the Enduring Understandings students should take away from the class are design process knowledge, skills and thinking that help move them from being a novice designer, toward more informed designers. Specifically, I designed activities with *Minecraft* to have an influence in students' thinking on ideation, iteration, reflection and collaboration skills/practices or ways of thinking. Advancing in these skill domains would also indicate that students have become better-informed designers. However, collaboration itself is perhaps an "Important to be Familiar with" concept rather an Enduring Understanding, as it is an ability that spans many domains and is a little less central to my study than the other design skills and ways of thinking. Additionally, in the class it was important for students to be familiar with the platform itself and more broadly the use of digital platforms for learning. The "Good to Know" content relates to notions of engineering and how design relates to engineering, a professional identity issue. Svarovsky (2011), Shaffer (2007) and Gee (2002) have all researched how games for learning can impact professional identity. However, given the limited research on using games for design learning for engineers, the identity-development component of the study is more exploratory than hypothesis-driven.

On the pedagogical side of the model, it is often useful to scaffold students' introduction to a new or complex areas through different instructional strategies or technologies. Scaffolding refers to a process whereby a teacher or more knowledgeable other assists a student such that they achieve more on a task than they could have individually (Wood, Bruner & Ross 1976). In later educational research the concept of scaffolding was extended to include technology platforms that assisted students in a similar manner to the earlier definition (Quintana et al. 2004; Reiser 2004). Scaffolding for some educational design may employ several scaffolds including those that involve teachers, peers and technology (Kim & Hannafin 2011); these types of scaffolds should be viewed as an interconnected system (Kim & Hannafin 2011; Reiser 2004). In other words, scaffolds from teachers or peers impact technology scaffolds and vice-versa.

The scaffolds for this study included instruction strategies (implemented by myself and the instructional staff) as well as a set of *Minecraft* technological scaffolds. In terms of the instructional strategies, the activities (detailed in section 3.3.5) were accompanied by worksheets that decomposed their design work into individual ideation, group ideation and/or combining concepts for activity 1 and stakeholder feedback seeking, concept evaluation and concept selection for activity 2. As Quintana et al. (2004) explain, decomposing an activity/process into steps can make the activity space clearer for students and thus allow them to better navigate it.

On the technological side, *Minecraft* gently constrains students' search of the solution space. This is accomplished through the pre-shaped building blocks in *Minecraft,* which lend themselves toward creating structural concepts (such as buildings) or larger concepts. While other designs are possible, the ease of creating larger concepts or structural concepts will likely gently push students in that direction and subsequently reduce their search of the solution space for their design. In this way, *Minecraft* scaffolds students' designs by reducing the complexity (Quintana et al. 2004) of a seemingly boundless solution space. Additionally, *Minecraft* scaffolds students' concept generation abilities by providing a means to quickly generate concepts through relatively straight-forward game interface without need for sketching, drafting or drawing abilities. Collectively these scaffolds illuminate the (often ambiguous) process of the concept generation stage of design, gently reduce students' search of the solution space to make the task less overwhelming and facilitate the generation of concepts through interface scaffolds.

### 3.3.4 Pilot Game-based Learning Activity

The semester prior to conducting this study, I conducted a small pilot in the same class the present study happened in: engineering 1. The purpose of the pilot was to test *Minecraft* as an ideation platform for first year engineering students. This also gave me the opportunity to test out a ideation activity through *Minecraft* and modify it as needed depending on how students engaged. The piloted activity eventually became activity 1, discussed in section 3.3.5 below.

For the pilot activity I came into a single class session in engineering 1 after working with the instructor to ensure that each design team had downloaded one copy of the game to one of their computers. Due to the difficulties of establishing a server that could support a class of over 100 students, I instead had each team select a person who would download the game and allow their team members to also use their computer for the activity. Similar to activity 1 described below, students were asked to generate ideas for their design project on a local (not a server run) game session of *Minecraft*. The activity was largely open with no expectations on what students would build. Students had approximately a half an hour to work and were instructed to swap their computer with their team members after a fixed time, so all students got an opportunity to build in *Minecraft.*

During the class period I walked around the class and spoke with students to see what designs they were creating and what difficulties might arise from using a game in the classroom. Two difficulties became apparent as I observed students use of the game. One, many students were not engaged with the task; and, two other students were confused about the purpose of the task or my expectations of what they would do. This feedback was fruitful for revising the activity to include more required components (that students produce a set of ideas on the platform) and provide clearer instruction on the platform and activity itself. While it is challenging to address engagement directly, by requiring some concrete output, giving students an introduction to *Minecraft* (the results of this pilot lead to the creation of activity 0 to introduce students to *Minecraft*, see section 3.3.5) and more explicit instructions (in the form of an activity worksheet) students were better equipped to use the platform, understand what was expected of them and how to accomplish it. As demonstrated later in the paper, I believe this led to greater engagement and performance on the activities in this study.

### 3.3.5 Game-based Learning Activities

As mentioned in the literature review, games work better as pedagogical tools when scaffolded than when students are only encouraged to “play” them with no structure from an instructor (Salmani-Nodoushan 2009). While there are scenarios where free-play may be beneficial, and indeed “activity 0” in the activities below is primarily a free-play activity, such free-play does not easily lend itself toward a project-based learning experience such as the design project in engineering 1. I therefore developed semi-structured (rather than unstructured) activities, with the exception of activity 0, as the main pedagogical means of the content. I chose semi-structured over highly structured activities, as I had an interest in informal uses of the platform and therefore I wanted to minimize the structure inherent to the activities. I worked with the instructor of the class to ensure the broad design topic for the class involved designs that could feasibly be created in *Minecraft*.

There were 3 major activities. The first activity (activity 0) happened in the second week of March 2014. The second activity (activity 1) happened half a week later. The final activity (activity 2) concluded a little over a week after activity 1.Furthermore, the server was maintained for approximately 4 weeks after the final activity to give students continued access to the server through much of their design project. Figure 3.3

depicts when the duration and timing of activities or server availability. Activity 1 took approximately an hour to complete, activity 2 took approximately an hour and a half to complete and both had worksheets or deliverables to submit (although activity 2 was more open than activity 1, as I detail below).

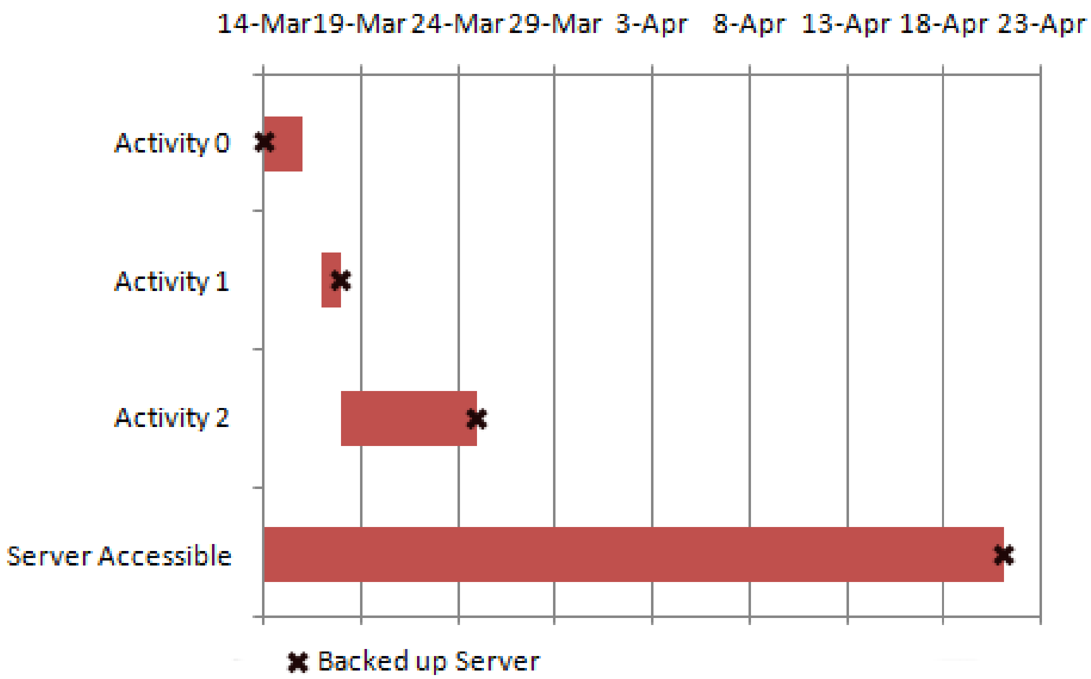



*Figure 3.3 - Length of Activities or Server Availability*

There were 3 major activities. The first activity (activity 0) happened in the second week of March 2014. The second activity (activity 1) happened half a week later. The final activity (activity 2) concluded a little over a week after activity 1.Furthermore, the server was maintained for approximately 4 weeks after the final activity to give students continued access to the server through much of their design project. Figure 3.3 depicts when the duration and timing of activities or server availability. Activity 1 took approximately an hour to complete, activity 2 took approximately an hour and a half to complete and both had worksheets or deliverables to submit (although activity 2 was more open than activity 1, as I detail below).

Activity 0 is the least structured activity of the set: students were asked to log onto individual *Minecraft* accounts and explore the world of *Minecraft* in class. They were also encouraged to build something (not necessarily something related to their design project) on the platform. This free-play was intended to give students some time to adjust and familiarize themselves with the platform, without many constraints. I also created small tutorial stations that describe some basic game-play functions, like moving in the game, managing your inventory, and "flying" within the game. This was an opportunity for students who are less familiar with using digital platforms like this (Huang, Hood & Yoo 2013; Schradie 2011; Monroe 2004) to adjust and catch up to their peers; in other words the tutorial acted as a scaffold for those unfamiliar with *Minecraft* in particular. During this time, I was available in person for any student who had questions. This initial free-play also has similarities with “messing about” in design, where students are given some materials and a design idea to play around with (Crismond &Adams 2012; Kolodner et al., 2003). This less-structured class was intended to be an opportunity where students might find interesting uses of *Minecraft* or plant the seed for future goal-making and informal use -- features for which researchers have argued games are so useful (Gee 2002; 2010).

Activity 1, on the other hand, was a bit more structured than activity 0. This activity involves ideation, reflection in-and-on action, possible iteration, and collaboration throughout its tasks. The activity starts with students logging onto *Minecraft* individually with their group. Each group started in their own designated area on the virtual world of *Minecraft* with a sizeable portion of virtual "land" to build upon. Having started their design projects already, each student is first asked to build concepts of their design project individually. Activity 1 was therefore intended to be a more preliminary exploration of ideas, although later in the course curriculum students were asked to build physical prototype of their design. Activity 1 did not specify how many ideas the student should build, and encouraged them to build several different ideas. At the beginning of the task they were asked to work individually but in the company of their team members; this was intended to avoid group dynamics at the beginning of ideation, as some researchers have documented how individual students may overly influence the group (Tonso 2007, 2006; Valkenburg & Dorst 1998). However, I still wanted students working near each other (within the virtual space of the game) so they could potentially learn from or build on others' creations from individual work when they joined as a team. Generating (or transforming) many ideas like this, with suspended judgment, is the essence of ideation (Crismond & Adams 2012; Goldschmidt 2003; Shah & Vargas-Hernandex 2003).For any designs, students were also be asked to place one or more "signs" (this is a literal, informational sign, a placard "posted" in the virtual ground of *Minecraft*) with a brief description/explanation of the design. Signs are a simple implementation that function to capture ideas and arguments that can be reviewed later. Such design rationale tools (although often more sophisticated) have received concerted attention in and of themselves (Bracewell et al. 2009).

Once all the team members completed however many ideas they want to build, they were asked to briefly describe their design(s) to their teammates either through *Minecraft's* chat function, or in person, since this activity happened during a class period.

Both the sign posting activity and the report out were intended to be an opportunity for reflection-on-action (Schön 1984). While the collaboration here –turn taking and sharing –was somewhat “forced” by the activity, it was structured this way with hopes that students would recognize aspects of their teammates’ design that would be useful for the overall project. Thus students may see each other’s contributions as ideas that can be built upon, borrowed from and combined for their design project —taking more of an interdisciplinary view rather than a multidisciplinary view (Borrego & Newswander 2008; Klein 1990). Indeed, after the students shared their designs, they were asked to work with their current ideas (or new ideas that emerge from the discussion) to come up with a set of ideas to carry forward for their design project. This could happen through multiple paths such as selecting ideas they have already built, modifying existing ones, or building new ones. It is here that local iteration, within the design step of idea generation, may happen (Jin & Chuslip 2006). Thus the outcome of activity 1 was be a set of ideas, vetted to some degree, to build upon for their design project. The outcome could have been considered a manifestation of the each team's mental model (Dong, Kleinsmann & Deken 2013).

Activity 2 occurred after activity 1 and was open for a little over a week. Students were free to complete activity 2 at any point in this time frame. Skills brought to the fore in this activity include ideation, collaboration (particularly with non-team members), and some degree of reflection and iteration. For this activity, students were asked to identify some user or person who may be affected by their design. Given that the broad design project topic was centered in the university, many students spoke with other (non-class) students for this activity. Then they gave an early stage presentation/demonstration of their project to potentially affected persons or stakeholders. This presentation could be of two or more designs. Students could use *Minecraft* or other means to visualize/present their design project ideas. This activity, at least as it pertains to *Minecraft*, was more voluntary than the previous activity. A core idea here is that collaboration was to extend beyond the bounds of their team and to the people, clients and users the design may affect (Brown & Katz 2009). Preparing a brief presentation to someone outside the team may also engender some reflection-on-action (Gerlick, Davis, Brown & Trevesian 2010; Schön 1984). Students were asked to elicit feedback from the affected person or stakeholder, including the positive evaluations and concerns they had over the designs the team presented. At this point, the students should have answered any questions the user/affected person may have. After students were finished presenting and discussing with the stakeholder or affected person they were asked to answer a final question about whether they think they should modify their design and which design projects they think they should carry forward in the design process. Students were asked to use feedback from the stakeholder or affected person to shape these decisions and to make an argument for the actions they intended to take. This question was intended to spark some iteration for the team, as well as reflection. As many have argued, discussion and argumentation are critical components of the design process (Oak 2011; Bucciarelli 2003, 1996; Rittel & Webber 1973).Thus the outcome of activity 2 is an expanded view of their problem and a set of more focused design ideas.

In this final section of the methods chapter, I introduced the CAP model, applied it my research question about whether students advanced to more informed designs and gave a detailed description of the activities I developed for the class. Now that I have laid out the context and data collection procedures, research design and analytical methods and pedagogical methods for this manuscript, I turn to the results.

# CHAPTER 4. RESULTS AND DISCUSSION

This chapter has two major components: results and discussion. I then present results from each method I used, and then directly discuss them. I present the results of the visual content analysis first due to the generality of the questions the visual content analysis addresses (which were, is there evidence students can use the platform for design and how are those objects distributed across (in-game) space and class time?). The remainder of the chapter follows the same order as the methods chapter. After all the results and discussions have been presented individually, I turn to an integrated discussion of the visual content analysis with discourse analysis and thematic analysis results, as well as a discussion of ANOVA integrated with discourse analysis results.

Before presenting the results I give a brief narrative on how one team, referred to here as team 9 (not their actual team number), interacted with the platform. This narrative is intended to give the reader a window into how students and teams interacted with the platform before delving into the research results.

Team 9 had four members, one of which was one of my interviewees (Devlin) who shared much of the information on which this narrative is based. On the day of activity 1, the in-class divergent concept generation task, members of team 9 logged onto the *Minecraft* server along with the rest of the class.

As Devlin later described to me, he and his team members mostly explored the functionality of the platform that day. They built a large underground structure with a series of rooms for each team member, some shared communal spaces and a long tunnel that allowed them to enter from another part of the game-world. Devlin, an occasional gamer, explained during this time in the project he was not sure that *Minecraft* could work well as a tool for an engineering class. However, two of his other team members pushed him and the rest of the team to try to use *Minecraft* for concept generation. Devlin was hesitant and first, but joined his team on the server, outside of any of the official class activities. As his team started to build an automated wheeled chair, Devlin's hesitancy diminished and he started to think the platform could be a good way to make rough initial models of an idea. His team coordinated on the server to build two designs, the wheeled chair mentioned above, and pair of robotic arms (both were considered class artifacts; see section 3.2.6).

After completing the class designs they built some other artifacts that were later labeled as non-class artifacts, including an American and a Chinese flag. Team 9 represents an interesting case as they started with non-class related use of the game, opted to use it for class outside of the bounds of the official activities and continued to display a mix of class and non-class artifact construction. Other teams used the platform in different patterns including mostly just for class or mostly not for class.

4.1 Visual Content Analysis

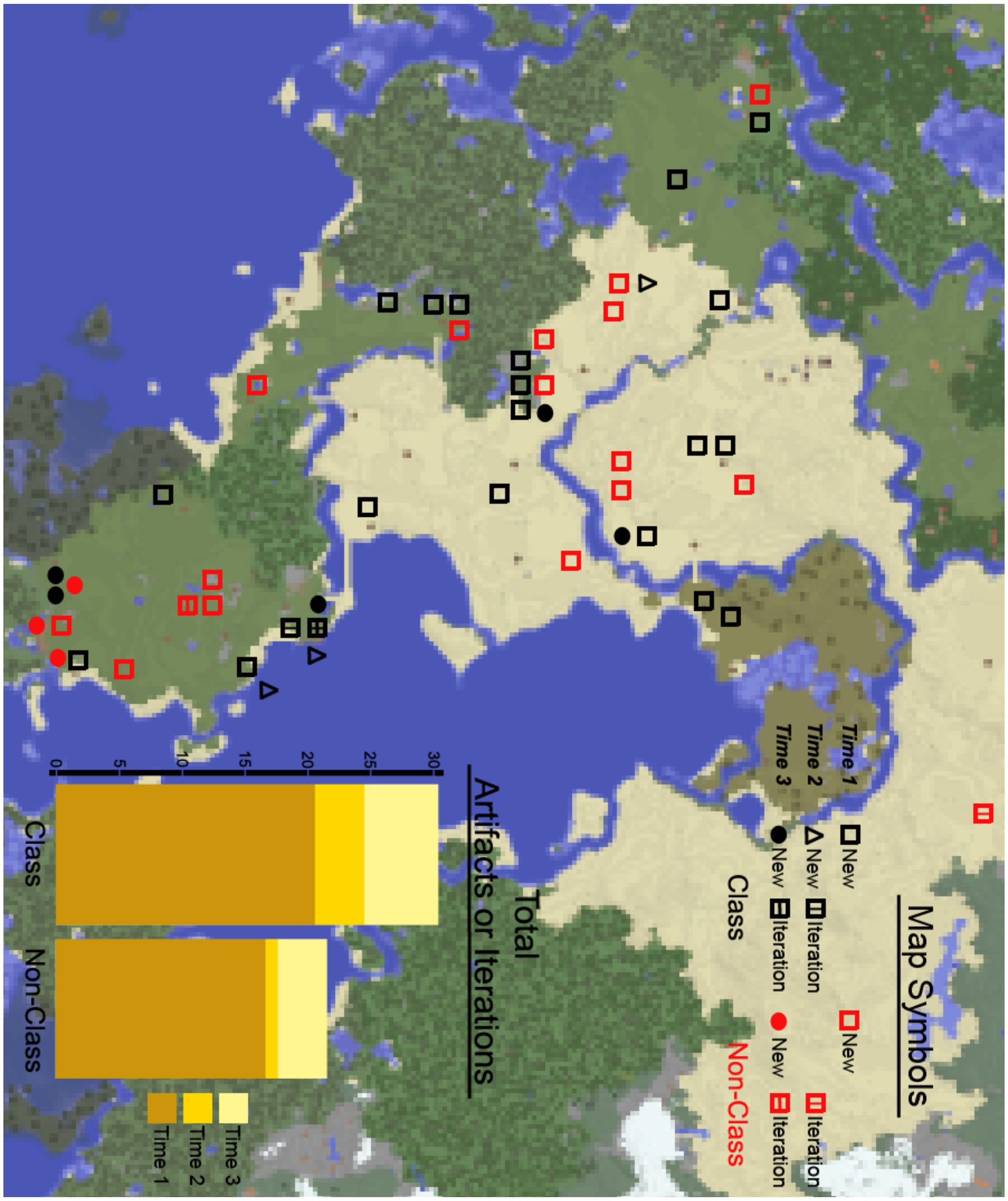



*Figure 4.1 – Class and Non-Class Artifacts*

Figure 4.1 displays the locations of students' "for class" and "not for class" artifacts on a 2-dimensional map of the server's virtual "world." The legend illuminates the meanings of the artifact symbols scattered across the map. All artifacts are displayed on a single map, due to the small number of creations at time point 2 and 3, and for ease of comparison. The bars in the bottom right of the graph display the number of class and non-class artifacts at each time point.

While it may have been more expedient to assume that, since students built some artifacts on the platform, they were capable and willing to use it for class ends, the logic tree and mapping provides a more detailed analysis. Logic tree classifications help sort artifacts into sets that are most likely and least likely "for class" as well as provide counts for these sets (see section 3.2.6 for a description of the logic tree). I use these sets and their counts (displayed on the map in figure 4.1) to answer whether students were able to use the platform for design. I also use the map in figure 4.1 to answer how artifacts were distributed across (in-game) space and over time.

First, I discuss what students built on the server. As can be seen from the bars and other map symbols, students built many "for class" and "not for class" artifacts, and built or modified additional class artifacts. Cumulatively, students built 29 designs (including redesigns) in the "for class" set and 22 for the "not for class" set. This is a fairly conservative measure: I discarded many artifacts from analysis because I wanted to assess only those that were clearly "for class" or "not for class". Thus the actual number of artifacts on the server is closer to double the total of class and non-class artifacts.

Figure 4.2a – Class Artifact Example: Dormitory (Inside)

*Figure 4.2b – Class Artifact Example: Double-Decker Bus*


*Figure 4.2c – Class Artifact Example: Convertible Knapsack/Sleeping Bag*

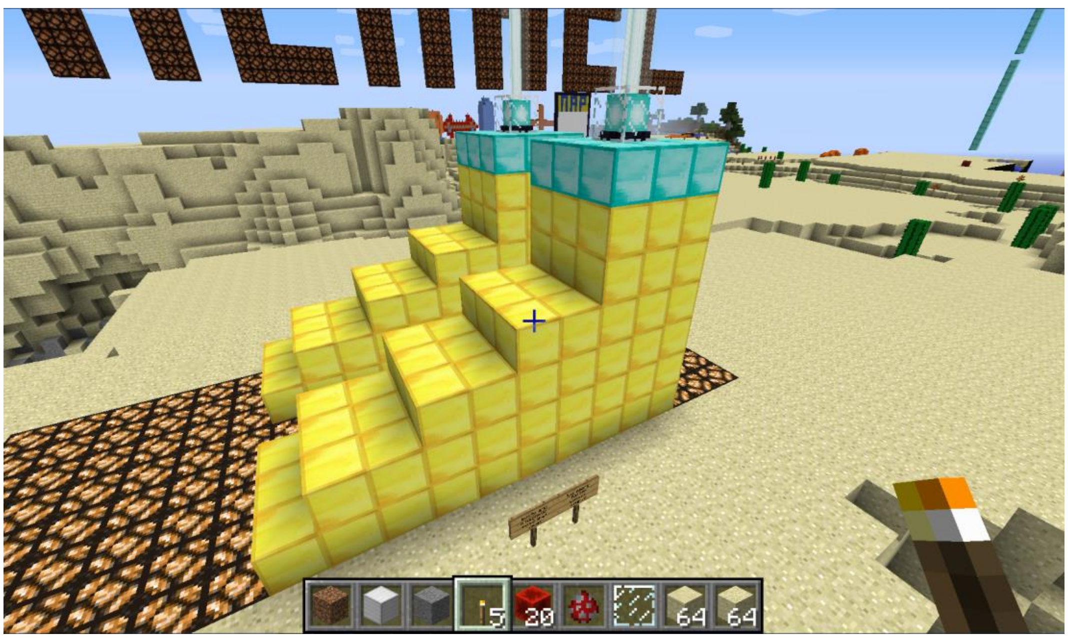



*Figure 4.2d – Class Artifact Example: Magnetic Boots and Rails*

Figure 4.2 displays 4 examples of student artifacts that were classified as “for class.” I selected these as they represent some of the major domains in which students designed artifacts. Starting at a), the first image appears to be a dormitory, with study and sleeping quarters. In b) students built a double-decker bus. The artifact in c) is a convertible knapsack and sleeping bag. The dual functions of this artifact was explained in signage, as well as the large double-headed arrow indicating the artifact could be transformed into either form. In d) students built a pair of magnetic boots and magnetic rails for accelerated travel around the campus. Signage explains the designs and their functions; without that signage it would have been difficult to identify the artifact. Many of these designs in figure 4.2 are fairly detailed, such as the dormitory, or have multiple components, such as the convertible knapsack. Most of the other artifacts in the class set were also detailed or had multiple components, although there were also some simpler designs such as a chair and table. In the discussion section following this section I discuss what the counts and artifacts mean for students' ability to use the platform to design.

Generally, both "for class" and "not for class" artifacts are interspersed across the in-game space together (see figure 4.1); they are not strongly segregated (or surrounded predominantly by artifacts of the same type) across the virtual landscape (although there is one lone non-class artifacts in the upper right part of the map). Figure 4.3 displays several additional images from the (in-game) world that demonstrate the proximity of class and non-class artifacts.

*Figure 4.3a – Class and Non-Class Artifact Proximity*

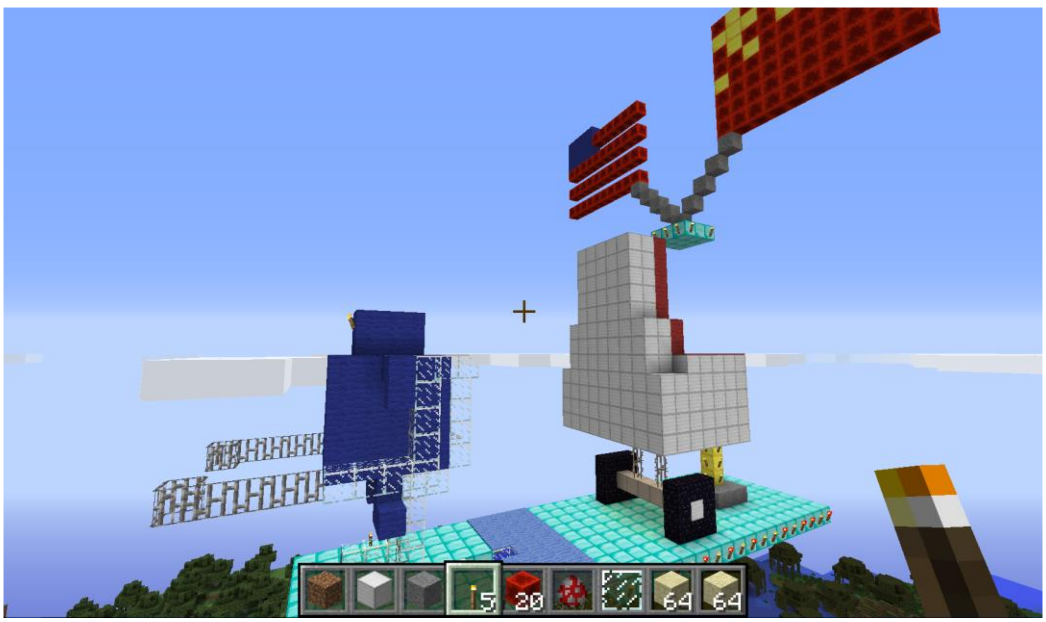


*Figure 4.3b – Class and Non-Class Artifact Proximity*


*Figure 4.3c – Class and Non-Class Artifacts*

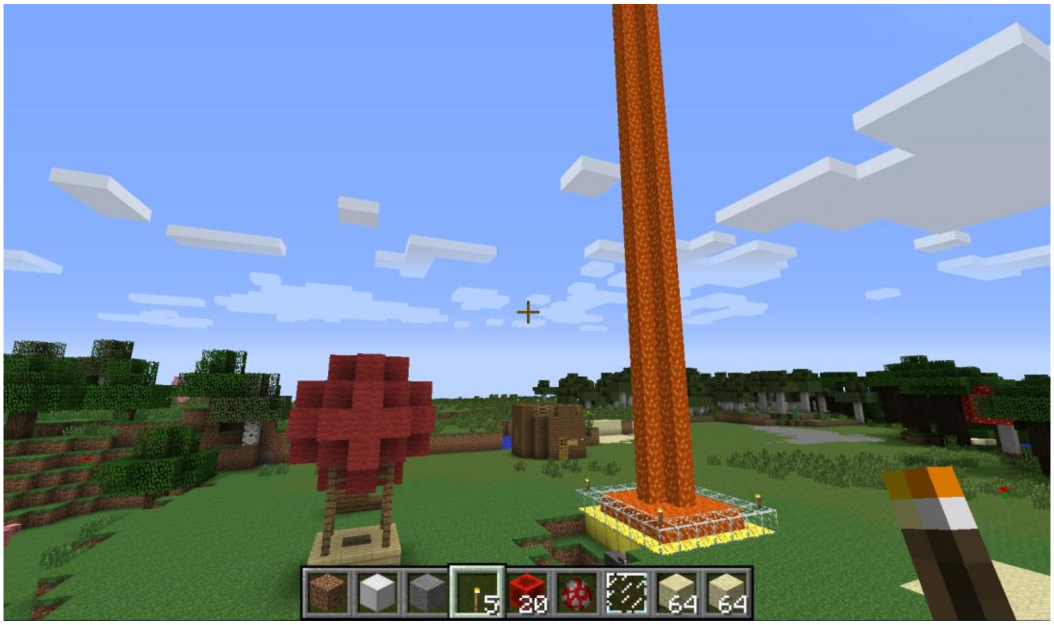



*Figure 4.3d – Class and Non-Class Artifacts*

In a) in figure 4.3 a water pillar can be seen next to brick building (which contains a class-related design). In the distance, a cross (a "not for class" symbol) can be seen near the convertible knapsack and other "for class" related artifacts. In the second image, b) two flags ("not for class" symbols) float near an exoskeleton and wheelchair (both "for class" artifacts). Turning to c), the gray and brown blocks on the ground spell out names ("not for class" symbols) and another cross is situated in the middle of the screen. In the distance several "for class" artifacts including buses, the dormitory displayed earlier and some other exoskeletons can be seen. Finally, in d) a pillar of lava ("not for class") can been seen near a hot air balloon (a "for class" artifact). These are just some of the examples of how "for class" and "not for class" artifacts are interspersed together across the in-game world.

Turning to the distribution of artifacts across time, I return to figure 4.1's histogram bars. Across the 3 time points, the number of class objects increased continuously from 19 to 23 to 29, whereas the non-class artifacts saw minimal additions at time 2 (from 17 to 18) but had more gains at time 3 (from 18 to 22).Lastly, the area furthest south on the map, separated from the land on the west by a thick forest and connected to the northern desert area by a bridge, hosted a large concentration of the time 2 and 3 new artifacts on the server: 11/15 artifacts, or 73%.

### 4.1.1 Visual Content Analysis Discussion

I used the visual content analysis to answer two questions: is there evidence that students can use the platform for design? And how are the artifacts students made distributed across (in-game) space and time? Examining how students use the platform over time and (in-game) space reveals key dimensions in how students interact with the platform. Turning to the first part of this question, the results in the last section 4.1 showed that, even when discarding a large amount of ambiguous designs, students/teams made 29 artifacts related to class. Assuming that at least some of the ambiguous designs (i.e. artifacts that could not be clearly labeled by my logic tree) were also for class would suggest students/teams made an even larger set of designs for class. The number of artifacts provides evidence that students were able to use the platform for designing artifacts. While this may appear to be a low bar to achieve, in a pilot study using *Minecraft* 6 months earlier, students primarily built "not for class" artifacts rather than "for class" artifacts, suggesting that students' ability or willingness to use the platform for class purposes should not be taken for granted. Furthermore, I presented several artifacts in the visual content analysis results that had multiple components or many details to their design. If students were unable to or were unwilling to use the platform to design artifacts, these designs would not be present on the server. This finding, while relatively simple, is important, considering game-based learning lacks much empirical support and given how minimally I structured the class activities.

The second part of my question had two components: distribution across in-game space and time. I discuss the distribution of the artifacts across space first. One of the striking findings from the visual content analysis was that class and non-class artifacts were intermixed often at close proximity, across the virtual landscape. Other researchers using informal media have found similar results. For instance, Ebner, et al. (2010) designed a course where students used a micro-blogging platform (similar in constraints to Twitter) to coordinate and share knowledge for a class on new media and management.

They found that students used the platform for class as well as more general social ends. Furthermore, the researchers found that these uses coexisted; that is, one use did not overwhelm or suppress the other type of use. Although the "objects" created by students in Ebner et al. (2010) and this study differ, they both can be viewed as instances of collaboratively-built knowledge. Similarly, in figures6 and 8, class and non-class artifacts seem to coexist. This raises a new question: could play, or at least non-class use, and class use coexist without one distracting from the other? I discuss this point further in the cross methods section 4.5.2, where I draw on some preliminary evidence from the interviews that suggest students switch between modes of production. However, more research is needed to explore on students who build "for class" and "not for class" artifacts and what other effects may come from these two modes of production.

Now I turn to discussing the temporal dimension of artifacts' distribution. First, students continued to make both "for class" and "not for class" artifacts after the first activity. That is, students are still creating new artifacts or iterations. The presence of more "for class" artifacts at time 2 and fewer "not for class" artifacts may be related to activity 2, which coincided with when I backed up the server; however, students were not required to build new designs for this activity. Students who did build new designs or iterations at the third time point, on the other hand, did so outside of any class activities. This finding suggests some students continued to engage with the platform even after formal activities had come to a close. Importantly, the logic tree I used also led me to discard artifacts at time point 2 and time point 3; therefore, students built additional designs that may have been related to "for class" or "not for class" throughout the time I left the server available.

In the visual content analysis results, I also reported on how the most southern area of the *Minecraft* map saw the highest amount of subsequent additions or modifications to existing designs. Another intriguing aspect of this area is that all 3 participants from the high-use group built their designs here. Note that other teams/students built or modified designs here as well, not just 3 high-use interview participants and their teams. Students (including those in the high-use group) were assigned starting areas in *Minecraft* randomly, which should result in a less lopsided distribution of highly active users, all other things behind held equal. Thus, it is curious to find such an active hub for ongoing use of the platform. Similarly to other areas on the server, the southernmost section also had a mix of "for class" and "not for class" designs. Some of these designs were added at later time points as well. Therefore, it does not appear to simply be an area where only "serious" and class-dedicated students built and modified their designs. I discuss this finding in more detail in the cross-method section 4.5.2, near the end of the chapter.

## 4.2 Factor Analysis for Design Scale Identification and Testing

To address the first research question of whether there was a detectable change in students' design abilities when comparing their pre and post survey responses, I assessed if the design survey questions formed scales. In other words, were there sets of questions within the total number of survey questions that measured similar constructs, such as “design process” and “collaboration” (discussed in section 3.2.2)? This assessment was a two-stage process. In the first stage, I collected responses to a broad set of questions in the more advanced first year engineering 1 class to identify a subset of questions that could be used as an instrument in the class that would use the game. Full details on this early instrument development stage can be found in section 3.2.2.In the second stage, I used the instrument developed in the first stage in the intervention class. I conducted factor analysis and calculated Cronbach's alpha for both the first and second stages to determine the best set of measures of design process thinking and collaboration. Results are reported in table 4.1 and table 4.2.

Table 4.1 displays the factor loadings for the trial of the survey instrument. One metric for determining the number of factors (or sets of questions) from the large group of questions is to only include factors with eigenvalues greater than or equal to 1 (Kim & Mueller 1978).

Table 4.1
Trial Factor Loadings

| | **Trial Survey Factors** | |
|---|---|---|
| Questions | Collaboration | Design Process |
| In the design process I am comfortable exploring an idea without knowing how it will be used later. (idea 1) | 0.041 | 0.203 |
| In the design process trying out design solutions can lead to new understanding of the problem. (idea 2) | -0.201 | 0.711 |
| In the design process the more ideas you generate the more opportunities you can explore. (idea 4) | 0.067 | 0.730 |
| In the design process sometimes it's useful to follow a semi-promising idea instead of waiting for the ideal solution to appear. (iteration 1) | -0.319 | 0.164 |
| In the design process design stages may be repeated. (iteration 2) | 0.024 | 0.578 |
| In the design process tasks are best handled by assigning sub-tasks to team members to be done individually. (collab 1) | 0.369 | -0.150 |
| In the design process work is done best individually rather than in teams. (collab 2) | 0.524 | 0.174 |
| In the design process group decisions should only be made by those with relevant technical knowledge. (collab 3) | 0.595 | 0.314 |
| In the design process team members who mostly modify existing ideas contribute less than those proposing new ideas. (collab 4) | 0.293 | 0.269 |

Only the first two factors (as displayed in table 4.1) had eigenvalues of 1 or greater. Furthermore, the third factor only had one question that loaded at 0.4 or higher, suggesting that factor 3 was mostly capturing the variation of a single question. The first factor is labeled "collaboration" as three collaboration questions loaded moderately to highly (.35-.6) on this factor. The second factor has two ideation and one iteration questions that load highly on it, so I labeled it "design process."

Cronbach's alpha, a test of reliability for sets of questions, was assessed as acceptable at 0.72 for the high loading design process questions and poor at 0.51 for the high-loading collaboration questions. Due to the small number of questions for each factor and the weak reliability for the collaboration factor, I included one iteration question, one ideation question, and one collaboration question that loaded weakly on the trial factor analysis in the subsequent instrument. I also hypothesized that these weak loading questions may load differently when they are used in an instrument without duplicates (variants) of the given questions. Although questions were developed separately for ideation, iteration and reflection, this factor analysis suggests that the design process skills do not load onto separate factors, but instead merged into a single factor (or cross-loaded with collaboration).

Table 4.2
Intervention Pre and Post Factor Loadings

| Questions | Pre Survey Collab. | Pre Survey Design Process | Post Survey Collab. | Post Survey Design Process |
|---|---|---|---|---|
| In the design process I am comfortable exploring an idea without knowing how it will be used later. (idea 1) | -0.034 | 0.003 | -0.226 | 0.334 |
| In the design process trying out design solutions can lead to new understanding of the problem. (idea 2) | 0.307 | 0.507 | 0.063 | 0.616* |
| In the design process the more ideas you generate the more opportunities you can explore. (idea 4) | 0.106 | 0.878 | 0.117 | 0.792* |
| In the design process sometimes it's useful to follow a semi-promising idea instead of waiting for the ideal solution to appear. (iteration 1) | -0.063 | 0.239 | -0.163 | 0.430* |
| In the design process design stages may be repeated. (iteration 2) | 0.262 | 0.521 | 0.109 | 0.557* |
| In the design process tasks are best handled by assigning sub-tasks to team members to be done individually. (collab 1) | 0.026 | 0.033 | 0.471* | -0.291 |
| In the design process work is done best individually rather than in teams. (collab 2) | 0.209 | 0.337 | 0.783* | 0.099 |
| In the design process group decisions should only be made by those with relevant technical knowledge. (collab 3) | 0.999 | 0.165 | 0.687* | 0.102 |
| In the design process team members who mostly modify existing ideas contribute less than those proposing new ideas. (collab 4) | 0.483 | 0.313 | 0.826* | -0.024 |

To explore if the factor structure identified in the previous step remained as above or changed in some ways as I hypothesized, I conducted a factor analysis on the pre and post survey data. If a set of factors can be identified from engineering 1 students' responses, this set can then be used to test differences in their pre and post survey scores. Table 4.2 displays the factors for the pre and post survey. Like for the trial survey, two factors emerged for both the pre and post survey. While there were 3 factors for both the pre and post survey that had eigenvalues of 1 or greater, both of the third factors had only a single question with a loading greater than 0.4. Therefore only two factors were selected for both pre and post responses.

Comparing the pre and post factor analysis reveals that the factor structure is less stable for the pre factors than the post factors. For instance, collaboration 1 and collaboration 2 have much weaker loadings on the pre factor collaboration than the post factor collaboration. For the design process factor, iteration1 displays a similar pattern. Collaboration 4 also cross-loads on both the design process and collaboration factors. Ideation 2 displays a similar pattern. When a question has medium to high loadings on multiple factors, it suggests the question may not fit well with a single factor. In other words, it captures variance from multiple factors. We can shed light as to why the factor structure changes from pre to post by considering the context in which these questions were given to students. Students entering engineering 1 on average have limited experience with design work and collaboration on design teams. A weaker factor structure reflects students responding differently on related questions (e.g. high agreement on one ideation question and low agreement on another). I administered the post survey near the end of the semester, after students had participated in the game activities and had been exposed to much of engineering 1 content. If students have a deeper understanding of design and collaboration, we would expect that the post survey factors would be more stable. Indeed, Cronbach's alpha also reflects this: an unacceptable 0.49 for the collaboration factor and questionable 0.60 for the design factor in the pre, and an acceptable 0.77 and slightly low 0.68 for the collaboration and design factors in the post, respectively.

Given that the lower stability of the design process and collaboration factors can be understood in light of students' educational trajectory, I used the post factor analysis to select questions for the final scales. Using 0.4 (Specter 1992) as a threshold for inclusion leaves both factors with 4 questions each (marked with an asterisk). From this, I generated a "design process" and "collaboration" scale for the pre, post and comparison class data. I discuss the scales in more depth in the following section on the ANOVA results.

### 4.2.1 ANOVA Comparisons

Table 4.3 displays descriptive statistics for the pre, post and comparison scales. The mean column in the table indicates that the means on the two scales are slightly lower on the post-survey when compared with the first. Furthermore, the means are the highest in the comparison group. Before testing whether the pre-post or post-comparison means, it is important to check if the scales are highly correlated. Highly correlated scales may have interaction effects that are not controlled for when each scale is tested separately in an ANOVA.

Table 4.3
Pre, Post and Comparison Group Descriptive Statistics

| | **Minimum** | **Mean** | **Standard Dev.** | **Max** | **N** |
|---|---|---|---|---|---|
| **Pre-Survey** | | | | | |
| Design Scale | 2.5 | 4.14 | .53 | 5 | 101 |
| Collab Scale | 1.5 | 3.16 | .62 | 4.5 | 101 |
| **Post-Survey** | | | | | |
| Design Scale | 1.75 | 4.04 | .59 | 5 | 108 |
| Collab Scale | 1 | 2.98 | .86 | 5 | 108 |
| **Comparison** | | | | | |
| Design Scale | 1.5 | 4.21 | .52 | 5 | 94 |
| Collab Scale | 1.5 | 3.36 | .68 | 5 | 95 |

Table 4.4
Correlations between Scales by Group

| | Pre-Survey | | | Post-Survey | |
|---|---|---|---|---|---|
| | Design | Collab. | | Design | Collab. |
| Design | 1 | | Design | 1 | |
| Collab. | .20 (.051) | 1 | Collab. | .02 (.8) | 1 |
| | | | | **Comparison** | |
| | | | | Design | Collab. |
| | | | Design | 1 | |
| | | | Collab. | .19 (.07) | 1 |

Multiple analysis of variance, or MANOVA (Bray & Maxwell 1985), can test multiple scales simultaneously, making it a good alternative to individual ANOVA tests if scales are highly correlated. Table 4.4 displays the correlations between scales for the pre, post and comparison groups. The design process scale and collaboration scale border on statistical significance for the pre and comparison group. However, neither relationship is strong (0.2 or below), suggesting it is reasonable to treat them as uncorrelated.

Table 4.5 and Table 4.6 display the results for the pre-post and post-comparison separate ANOVA tests on the design process and collaboration scales. For both scales in table 4.5, there were no significant differences in pre and post means: design process $F(1,207) = 1.33$, $p = .25$, not significant; and collaboration $F(1,207) = 2.8$, $p = .10$, not significant. In contrast, in table 4.6 scales in the post and comparison class were significantly different, with design process $F(1, 200) = 4.06$, $p = 0.45$* and collaboration $F(1,201) = 12.19$, $p <.001$**. Comparing the means on the design process scale for post-survey (M = 4.04, S.D. = .59) and comparison class (M = 4.21 S.D. = .52) and collaboration scale, post-survey (M = 2.98, S.D. = .86) and comparison class (M = 3.36, S.D. = .68) reveal that, for both scales, the comparison class was higher than the class with the *Minecraft* intervention. This suggests that, while the *Minecraft* intervention may not have negatively influenced students' design process and collaboration skills measured by the instrument within the class relative to the other class, their skills may not have advanced as far as the comparison class.

I examined the statistical differences further by calculating the effect size, Cohen's d, for each significant difference. These are displayed in table 4.7. For Cohen's d, a 0.2 is considered a small effect and 0.5 is considered a medium effect. Table 4.7 reveals there was a small to medium effect for the difference in design process scores, and a medium effect for the collaboration scores.

Table 4.5
ANOVA Pre-Survey Post-Survey

| **Measures** | **Pre-Survey Mean (SD)** | **Post-Survey Mean (SD)** | **F (DF)** | **p<.05** |
|---|---|---|---|---|
| Design Process Scale | 4.14 (.53) | 4.04 (.59) | 1.33 (1,207) | .25, ns. |
| Collaboration Scale | 3.16 (.62) | 2.98 (.86) | 2.8 (1,207) | .10, ns. |

Table 4.6
ANOVA Post-Survey Comparison Class

| **Measures** | **Post-Survey Mean (SD)** | **Comparison Mean (SD)** | **F (DF)** | **p<.05** |
|---|---|---|---|---|
| Design Process Scale | 4.04 (.59) | 4.21 (.52) | 4.06 (1,200) | .045* |
| Collaboration Scale | 2.98 (.86) | 3.36 (.68) | 12.19 (1,201) | <.001** |

Table 4.7
Effect Size for Statistical Differences

| **Measures** | **Effect Size** |
|---|---|
| Design Process Scale | .31 |
| Collaboration Scale | .49 |

Table 4.8
ANOVA Pre-Survey Post-Survey for Individual Items

| **Measures** | **Pre-Survey Mean (SD)** | **Post-Survey Mean (SD)** | **F (DF)** | **p<.05** |
|---|---|---|---|---|
| Idea 1 | 3.46 (.97) | 3.49 (1.04) | .03 (1,205) | .85, n.s. |
| Idea 2 | 4.27 (.76) | 4.16 (.83) | 1.02 (1,208) | .31, n.s. |
| Idea 4 | 4.38 (.72) | 4.16 (.94) | 3.54 (1, 208) | .06, n.s. |
| Iteration 1 | 3.74 (.83) | 3.75 (.88) | 0 (1, 205) | .95, n.s. |
| Iteration 2 | 4.17 (.78) | 4.07 (.75) | .8 (1, 207) | .37, n.s. |
| Collaboration 1 | 2.47 (.87) | 2.28 (.97) | 2.36 (1, 205) | .13, n.s. |
| Collaboration 2 | 3.64 (1.04) | 3.38 (1.15) | 2.90 (1, 206) | .09, n.s. |
| Collaboration 3 | 3.15 (.97) | 3.07 (1.18) | .32 (1, 204) | .57, n.s |
| Collaboration 4 | 3.34 (.95) | 3.21 (1.10) | .84(1, 206) | .36, n.s. |

Finally, in table 4.8 and 4.9 I display ANOVA comparisons for pre/post and post intervention/comparison respectively for differences in individual question means. Although the factor analysis revealed the questions formed two factors, in testing the factors, contrasts between specific questions are lost. However, it is important to note that, in testing differences between each of the nine questions for pre/post and intervention/comparison, eighteen tests were run, which means that the standard alpha level of .05 would likely lead to at least one false positive (that is, finding a difference where there is none). Alpha levels are the error threshold researchers are willing to accept for statistical tests. At .05 with eighteen tests there is a 90% (.9) chance that one of the tests is a false positive. Thus, tables 4.8 and 4.9 need to be interpreted with caution.

Table 4.9
ANOVA Post-Survey Comparison Class for Individual Items

| **Measures** | **Post-Survey Mean (SD)** | **Comparison Mean (SD)** | **F (DF)** | **p<.05** |
|---|---|---|---|---|
| Idea 1 | 3.49 (1.04) | 3.26 (1.17) | 2.29 (1, 200) | .13, n.s. |
| Idea 2 | 4.16 (.83) | 4.35 (.74) | 3.07 (1, 201) | .08, n.s. |
| Idea 4 | 4.16 (.94) | 4.39 (.81) | 3.63 (1, 200) | .06, n.s. |
| Iteration 1 | 3.75 (.88) | 3.79 (.79) | .09 (1, 201) | .77, n.s. |
| Iteration 2 | 4.07 (.75) | 4.30 (.76) | 4.45 (1, 200) | .04* |
| Collaboration 1 | 2.28 (.97) | 2.46 (.90) | 1.96 (1, 199) | .16, n.s. |
| Collaboration 2 | 3.38 (1.15) | 3.99 (.94) | 16.3 (1, 199) | < .001** |
| Collaboration 3 | 3.07 (1.18) | 3.46 (1.04) | 6.17 (1, 199) | .01* |
| Collaboration 4 | 3.21 (1.10) | 3.59 (1.07) | 6.12 (1, 199) | .01* |

Table 4.8 shows that, at the individual item level, there were no questions that were statistically significant from pre/post in the intervention class. It seems the individual questions follow the same pattern as the factors. In table 4.9, however, there were some questions that showed statistically significant differences. For questions within the design scale, only iteration 2, which dealt with whether students felt stages within design could or could not be repeated, showed a significant difference: $F(1,200) = 4.45$, $p = .04$*. Comparing the means on the design intervention ($M = 4.07$, $S.D. = .75$) and comparison ($M = 4.30$, $S.D. = .76$) course reveals that the comparison course may be larger (taking into consideration the higher chance for error given the number of tests). None of the other design scale questions appear to be significantly different, suggesting this particular question may have contributed substantially to the differences between pre/post scales.

Turning to the collaboration questions, collaboration 2, 3 and 4 may be significantly different. For collaboration 2: $F(1, 199) = 16.3$, $p = < .001$** with intervention ($M = 3.38$, $S.D. = 1.15$) and comparison ($M = 3.99$, $S.D. = .94$);

collaboration 3 $F(1, 199) = 6.17$, $p = .01^*$ with intervention (M = 3.07, S.D. = 1.18) and comparison (M = 3.46, S.D. = 1.04); and collaboration 4 $F(1, 199) = 6.12$, $p = .01^*$ with intervention (M = 3.12, S.D. = 1.10) and comparison (M = 3.59, S.D. = 1.07). Again taking into consideration at least one of these differences may be a false positive, it nonetheless appears that many of the items that make the collaboration scale are greater for the comparison class. Thus the individual questions, similar to the collaboration scale, suggest there is a stark difference between the intervention and comparison class on collaboration.

### 4.2.2 ANOVA Discussion

In this section I discuss the results for the ANOVA analysis from only the ANOVA results. In section 4.5.1 I discuss ANOVA results as informed by discourse analysis results. In this section, I compare the contexts of the intervention and comparison classes for interpreting their ANOVA results. I employ a design-based research approach (Barab & Squire 2004) in this study and therefore incorporate (instead of excluding or controlling) contextual features into the analysis of differences in students' scores in the intervention and comparison class.

Results from the pre/post ANOVA test showed no statistical difference in students' responses to the design process and the collaboration factors. To a lesser degree, there is some evidence of learning in the pre/post. Comparing the factor loadings in table 4.2, the loadings for the design and collaboration scale were much stronger (i.e. higher) for the post survey. Additionally, in the post survey, collaboration questions loaded more consistently with the collaboration scale (i.e. they were not split between the design and collaboration scales, as was the case in the pre-survey). Although there was no detectable change in students' scores, the stronger and more consistent factor loadings suggest students' responses at the post-survey were more indicative of the underlying factors (i.e. design process and collaboration as latent constructs).In other words, students' post responses suggest students had a better understanding of the underlying factors/constructs being measured. There is thus some evidence of learning, although not what I hypothesized and not enough to identify any gain or loss in scores.

One reason for not detecting any pre/post change in the design factor may be a ceiling effect. In both the pre/post-tests, the design factor was above 4.0 (out of 5.0). This left limited room for detecting (positive) change at post, since the average score at pre-survey is already high. It may be that the students' responses' would have been better measured (for the design scale) on a 7-point Likert scale that allowed for more agreement options (e.g. somewhat agree, agree, strongly agree). Basically this would allow for greater detail on students' agreement with the design scale questions, which would then potentially leave more space for detecting change. It is important to note, however, that when the post and comparison scores were tested in an ANOVA, there *was* a statistically significant difference. Both scores (post and comparison) were over 4 as well. The ceiling effect does not preclude detecting any difference, but it may diminish the likelihood of detecting a difference.

Turning to the collaborative scale, both pre and post scores were around 3.0 (out of 5.0). It is unlikely a ceiling effect influenced the ability to detect a change, since there was more room for change.

This was one of the first attempts at implementing game-based learning for engineering design. From a design-based research approach, the lack of change in the design scales suggests the need to refine the class activities. Design-based research employs an iterative scheme, pushing researchers to improve activities and learning tools from prior research results (Collins, Joseph, & Bielaczyc 2004). I discuss possible improvements for the class activities when I compare the ANOVA and discourse analysis results (section 4.5.1).

I now turn to the post/comparison differences. Note that I was only able to capture the comparison post, not pre. Thus is it not possible to definitively state whether differences between the post and comparison post started from similar pre-survey values, or whether their pre-survey values differed substantially to start with. Following this, statistical differences should be interpreted with caution, as the classes may have started (pre) at different levels.

Results for the intervention and comparison post-survey showed that there were statistical differences between the groups on both the design process and collaboration scales (in both instances, the means were higher for the comparison class).

The structure of the comparison class's design teams and sub-teams suggest one reason the comparison class may have scored higher on the collaboration scale. In the comparison class, students were able to join other sub-teams (which were effectively the equivalent of teams in the intervention class), work with new people and experience new team dynamics. In contrast, in the intervention class, students were given permanent teams. Furthermore, in the comparison class there were incentives to work with other sub-teams, as ultimately each large team was working on a single project in competition.

Although it is difficult to say definitively, it seems plausible the incentives for collaboration and the ability to work with a larger set of people and experience a wider array of team dynamics led students in the comparative class to have higher collaboration scores. The instructor of the comparison class also shared an important qualification on the team dynamics: they observed that some teams were relatively permanent (i.e. no one switched to another team) and some students appeared to take advantage of the team structure (i.e. exert minimal effort in their large team). Despite this, the comparison class's scores were statistically higher on the collaboration scale than the intervention class's scores.

The structure of the design project in the comparison class may also explain why students in the comparison class scored statistically higher on the design process scale. Students in the comparison class were part of a much larger design project and had opportunities to get involved in multiple parts of the project. Viewing and participating in the design process from multiple sub-components and the integrated design (the re-imagined campus building) may have led to a greater understanding of the design process. It seems plausible that these opportunities in the comparison class may have led to higher scores on the design scale.

In addition to the processes in the comparison class that may have led to higher design process and collaboration scores, as I discussed above, students who minimally used the gaming platform for class, or did not collaborate with their team on the platform, may have effectively opted out of the game-based learning project, thereby suppressing the scores in the intervention class. Promisingly, the structure of the comparison class design project and teams could be incorporated into the game-based learning project, which could lead to greater collaboration and understanding of the design process, although this would require future trials of the game-based learning and pedagogical structure to verify.

On a final note for the design process and collaboration scales: given the low alpha scores at the pre-test and slightly low alpha score for the collaboration scale at the post-test, future work seeking to use this scale in this study would first need to revise the scales.

## 4.3 Discourse Analysis Results

To explore the ways students interacted with the game platform, for research question 2A and research question 2B (see section 1.1), I asked how students with different engineering and gaming discourses or identities, respectively, used the game. Discourses are ways of shaping the salient features and making sense of some part of the social world through speech and/or text (Fairclough 2003, 1991). A discourse carries many assumptions about the world, and when someone uses a discourse, their speech or text emphasize some aspects of the social world while obscuring others. When people use discourses they create selves or identities for themselves through the discourse and they may create identities for others they speak of through the discourse (Fairclough 2003, pp 160-161). When a person uses a discourse in relation to themselves this can also be called "self-positioning" (Harré & Lagenhove 1991). Using Fairclough's discourse analysis, I identified students' broad engineering discourses, narrower within the engineering 1 class discourses, and gaming discourses/identities to answer research questions 2a and 2b. I identified these discourses, specifically the broad engineering and gaming sets, using questions about engineering and gaming as well as context-specific (i.e. the class) questions. Discourses and identities are not stable, and may change over time or across context (indeed, the development of new identities, in part through acquiring discursive practices, is a core tenet of theories of community of practice--see Lave and Wenger 1991). By capturing the broader and more context-specific discourse I can develop a fuller understanding of how students with different engineering and gaming discourses or identities interacted with the platform.

To address the second part of these sub-questions (where I asked about the relationship between identities/discourses and platform use), I divided students into limited, moderate, and high use groups (see section 3.2.4) and I identified shared within-group discourses. Note that these groupings are based on students' informal use, not the nature of their discourses—discourses were analyzed after the groups were established. While I cannot untangle whether context affected discourse or vice-versa, capturing students' broader discourse of engineering and gaming does provide some grounding for their discourses. These groupings reflect prominent patterns in how students interacted with the game. Also, I report on individual discourses that either support or counter the group discourses to qualify the findings within groups.

Below, I begin with the engineering discourses for each group broadly, and as they relate to class and then turn to the gaming discourses and identities across groups. Table 4.10 displays the groups. The number at the end of the text in the first column indicates the size of the group. Each row is one group. Numbers after a discourse indicate how many students in that group used it.

Table 4.10
Group Outcomes Matrix

| **Class related use of game** | **Engineering Discourses** | **Gaming Discourses** | **Class Discourses** |
|---|---|---|---|
| Low - only use when required , did not go back on or only went back on to play (5) | 1)Earlystart/exposure (2)<br>2)Family w/ engr's (2)<br>3) Makers (3)<br>4) Professional skills (2)<br>• Teamwork, Comm. | 1) Gaming is for Boys (3)<br>2) Affordances & Constraints (3)<br>Gamers (3), Ocs. Gamer(2) | 1) Uninteresting (3)<br>• Boring, Forgettable, prefer student-led activities |
| Mid - used beyond class requirements for class - worked on design outside of class, watched videos on how to use MC (3) | 1) Earlystart/exposure 2 | 1) Representational Fidelity (3)<br>Ocs. Gamer (2), Non-Gamer (1) | 1) MC formalization (3)<br>• Make Required, ICA, Modules |
| High - used substantially for developing design and/or in final presentation (3) | 1) Management/ budgeting (2) | 1) Classroom tool 3<br>Gamer (1), Ocs. Gamer (1) Non-Gamer (1) | *No Shared Discourses* |

## 4.3.1 Engineering Discourses

In this section, I report on the results for shared engineering discourses by each group, following the same order as table 4.10. Starting with the limited use group, table 4.10 shows they had 3 shared broad engineering discourses and one engineering class-related discourse. Two members spoke of early exposure to engineering. For example, Qian told the following story:

> [Qian, F] ...actually I don't have so much experience about [engineering] it's just like my father is an engineer and he inspired me from when I was young... when I was in the primary school we are asked to write some essays and I wrote, always have some my ideas about my future career.

Qian discusses two aspects of early exposure to engineering; having a family member who was in engineering and expressing interest in engineering at an early age. Similarly, Jing discusses her exposure to engineering:

> [Jing, F]...my father like... collect a bunch of the stuff in my house and in the basement and we have a, place for him. Instead of... find someone to repair it...the fan in our house in is repaired by him. So sometime... he will let me to help him to do that.

Here Jing is describing her father's work area for repairing and making things for their household. As she mentions at the end of her quote and discusses in more depth elsewhere, she became increasingly involved in projects with her father. For Qian and Jing, these early exposure experiences influenced their current (as of the interview) concept of engineering and pursuit of engineering degrees. While this "early exposure" discourse is centered on these individuals and their trajectory through engineering, not engineering as an external "thing", it may matter for how they interact with *Minecraft*; for example, how they view *Minecraft* as a learning tool for engineering in relation to their concept of engineering.

The second common discourse from this group concerned what engineers do. Two students spoke of engineering as:

> [Zhi, M] If someone really like to cooperate or create something new they will like engineering...
> [Gang, M] They can design something... design a structure and build some high buildings.

In addition Jing spoke of formative engineering experiences with building things in her family:

> [Jing, F] ...we made a model, we made a board. we made all kind of things, we made a... radio, we made... all the furniture in-in my room is made by some, is made by our hands.

Across these quotes, engineering is framed as work that involved creating or building things. This is a common function in engineering, and emphasizes an object orientation (Woodcock, Graziano, Branch, Ngambeki &Evangelou 2012).However, the final broad discourse about engineering from this group incorporates some social aspects. Two respondents in this group emphasized the importance of professional skills for engineering:

> [Zhi, M] I think I'd say that engineering is about... everyone... works as groups, you can cooperate with others...

> [Liang, M] ...you want to be... focused on the stakeholders and... direct users, their needs and you will think in their way to develop your design and you want to make your criteria and the goal more measurable so that when people look at it, [they] will say, 'okay this is feasible.'

Both respondents mention teamwork: either broadly, as in the first quote, or more specifically as in the second quote. Liang also mentions focusing on stakeholders and users. Therefore some social dimensions of engineering are included under "professional skills." This social dimension is qualified somewhat when Liang states "you will need to think like them" instead of emphasizing communicating with stakeholders or users. Liang further qualified this shared discourse with an individual discourse about engineering and society:

> [Liang, M] ... engineers [are] going to do their best to put beneficial design into reality. So that people can live in a better life through the design that [the] engineer did. So basically what we did as engineer is offer people like different options to live better life.

While Liang discusses how engineering impacts society, this is construed as a one-way transmission. People can live a better life or have different options due to what engineers have created. In this and the second quote above, stakeholders and users are not agents but passive entities who the engineer can easily read ("think in their way") and to whom they offer their ingenuity. Another individual discourse from Jing also qualifies interacting with stakeholders or users:

> [I] Do you think that person would normally be on a team and not an engineer, who would go talk with the stakeholder more..?
>
> [Jing, F] Yeah. I think that person should take a management class. Or... like a community or something. It's more than engineer. But a community is important, doesn't mean it's not important. It's just...I just feel it's weird...

Here, Jing distances interacting with stakeholders or users as something that engineers wouldn't do. She states that this doesn't mean that speaking with stakeholders or users is unimportant, but that it is "more" than engineering work. Thus, although the discourse on professional skills incorporates some social aspects, the social aspect refers primarily to other engineering team members and not to people outside of engineering. Otherwise, an object orientation appears to prevail for the limited-use group.

Finally for engineering discourses from the engineering class context, three members of the limited use group framed the class as uninteresting:

> [Qian, F] That's all I think about my class, sometimes I just forgot it.
> [Jing, F] ... maybe because every student think [engineering 1] is annoying.

[This student states that they do not find the class annoying. Later the same student shares]:

> I cannot imagine if [we] don't have *Minecraft* we're going to do in those like 2 classes. Maybe we do the boring project.

In context of comparing *Minecraft* and the class Gang also states:

> [Gang, M] We're very free. We just have ideas and then create it, just create it. And compared to the normal class we just do the individual part in class. So we just learn ourselves and I just write down some notes.

In different ways, these respondents frame the class as uninteresting, something they just forget about, found annoying or boring. Two of the respondents also spoke of

*Minecraft* activities in more favorable terms than the class itself. It is important to note, however, that this is the limited-use group and much of these students' *Minecraft* use was for play, not for their design projects. It seems this group is generally not greatly engaged with the engineering class.

Turning to the moderate use group, there was one shared broad engineering discourse and one classroom engineering discourse. The first shared discourse, similar to the limited use group, focused on early exposure to engineering:

> [Collin, M] Yeah, Ferrari was the best, it's always been the best in my opinion. And I'm just always been fascinated by cars and doing research when I was young and just Ferrari was always the best and won everything. So, they have always been like the dream job of mine.

> [Cheng, M]...there was a time that me, my brother [made] a boat that uses an engine from a toy car... we learned to like dispart [disassemble] the toy car and remove the engine and put it into our boat.

In the first quote, Collin describes his early interest with Ferrari. From an early age cars and especially Ferrari fascinated him and he cites this interest and future dream job as a motivation for pursuing engineering. Before sharing the story in the second quote, Cheng stated that he had limited experience with engineering before entering first year engineering. Nonetheless, as he explains in the quote above, he and his brother taught themselves how to dissemble one toy and integrate its engine into another. While this experience may not be as large of an influence on Cheng to pursue engineering--at least in contrast to Collin's fascination with cars--it still affected Cheng's current (as of the interview) view of engineering. In contrast to how respondents in the limited use group discussed early exposure, respondents in the moderate use group make no mention of parents or relatives who were/are engineers. Instead, their early exposure is framed as driven primarily by them.

For the classroom discourse, all 3 respondents in this group emphasized increased formality for the gaming platform:

> [Cheng, M] ...it would be better for us to have a in class, ICA [in-class activity] where we can really try to use *Minecraft*...
>
> [I] ...are you thinking something that is connected to your design project?
>
> [Collin, M] It does not necessarily have to connect with our design project, but I mean the professor can give us a specific topic like build a house using these following given materials in whatever creative ways you can. But yeah it would have just been to cool to have like different problems or different designs we have to make in *Minecraft* before we actually started making our own stuff.
>
> [Ying, F] Well, I think, for me, personally, I think, like if... the professor push more, if this is required thing that you have to do, I think I could, we could spend more time on it and do better on it.

In the first two quotes, these students suggest other related activities that could be done in *Minecraft* to practice and scale up to their design projects. As both of these students indicate, these activities do not need to be explicitly related to their design projects and might instead be mini design activities under certain conditions or constraints. The third student suggests directly increasing the formality of *Minecraft*. This is likely in part a response to the second activity, which involved presenting their design to stakeholders and could have been completed through multiple means, *Minecraft* included, as well as the open structure of the game activities. On this second point, later in the semester, students had to turn in a list of ideas for their design project. While they could use their *Minecraft* designs for this, they weren't required to; some did, however.

This could be one area where the game activities could have been more formalized within the class curriculum.

Ying felt if they (as students) were required to use *Minecraft* in more ways, she would have devoted more time to the platform. Elsewhere in his interview, Cheng also expressed a desire that more aspects of using *Minecraft* were required. Thus all respondents in the moderate use group framed the informality of the platform as detrimental either to their ability to use the platform or persistence in using the platform. This raises questions about how much this group would have used the platform if it had been formalized in some of the ways they suggest, as well as how this would have affected other groups' usage.

Lastly, for the engineering discourses in the high use group, there was one broad discourse. For both the moderate use and high use groups, there were fewer shared discourses than for the limited use group. This may be in part because the moderate and high use group had only 3 people each, whereas the lower use group had 5.

In the high use group, two of the respondents framed engineering in somewhat broader terms than the other groups:

> [Nicole, F]...like mechanical engineers they deal with their... like constructions they can work in [air]duct productions, they can be top managers of the plant... they can work everywhere... because people assume that engineers just like work in one place, so they are very diverse.
> [Delvin, M] I would say an engineer is a person who is looking to complete a task using a budget... like different tools and looking to build together a solid model to achieve something.

In the first quote, Nicole frames engineers as versatile workers. They may serve in technical roles but they may also serve in more people/project focused roles like a manager. While managers are often in positions of power (Vecchio 2008) in the people-oriented aspects of their jobs (unless they are interacting with peers or their supervisor), this framing incorporates substantial social interaction/responsibility within an engineer. In the second quote, Devlin places budgeting as a central component of engineering work. Budgets or financial constraints are external to the strictly technical process of designing something; however, in most if not all scenarios of design, the budget will be present as a constraint. Only the high use group mentioned it as a constraint. Unlike stakeholder/user constraints mentioned by the limited use group, Devlin's framing of budgeting constraints go beyond the control of the engineering team. Together, these two quotes push engineering to also incorporate business aspects in their work, either through the roles engineers can take on or as constraints to the engineers work. In this way, it seems respondents in the high use group frame engineering as including other, non-technical aspects. This may also affect how they use *Minecraft* as an engineering tool as their conception of engineering appears to differ from those of their classmates interviewed in this study.

### 4.3.2 Gaming Discourses

Next I turn to gaming discourses across the three groups. These can be seen in column 3 of table 4.10.Like the engineering section, I report on shared discourses of each group in the same order as table 4.10. As I explained in section 3.2.4, I assigned each student a gaming identity based on their responses to questions about playing games and gaming's importance in their lives. These identity labels and the number of students within each category are also displayed in each groups' cell. I will discuss the distribution of gaming identities in each group before turning to that group’s gaming discourses.

In the limited-use group, as can be seen in table 4.10, 3 of the 5 respondents were identified as gamers and the other 2 as occasional game-players. This use group has the largest number of students who identify gaming as an important part their life and who indicated they play games frequently. One of the occasional game-player's self-positioning provides an important counterpoint to this. During the interview while discussing the game she explained:

> [Qian, F] When I told my [male] friends that I played that... he show me the how you say that? ...a world under the water, it's really amazing. But I can't do that, I don't, so maybe my game ability is weak.

Here Qian is sharing a story where she told her male friend about using *Minecraft* in the engineering class. Her friend showed her some underwater structures they had built. She found these structures impressive but positioned building them as above her abilities. This was not a single instance, as she also positioned herself as less capable than her teammates who had built electronically operated railways and downplayed her ability to play games, until I suggested mobile games are also videogames. Therefore, although this group had the most "gamers" and other members were occasional game-players, Qian's self-positioning shows this was not only a group of people who highly value and self-identify as gamers. Also there appears to be a gender dimension to her self-positioning as her framing places her as less able than male players or as not playing "real" games (which are often stereotypically masculine games, e.g. see Misa 2010; Lazarro 2008).

The limited-use group evoked 2 discourses about the game. First, following the way Qian framed herself in relation to games, students, including both women in the group, shared a discourse about gaming being "for boys":

> [Jing, F] I know some of them, actually most of them like to play games, especially the boys and because it's an engineering class and boys is more than [girls].
>
> [Gang, M] So for the girls I think they do not love games... they do not want to learn how to play it. And then they can't, so of course they cannot enjoy the game... I have some game experience so I know, when I first attach *Minecraft* at first I have to learn how to, how to control it or how to play it. And then I can play it well.

In the two quotes above, Jing, a female student (gamer) and Gang, a male student (gamer) present games as something that most boys like to play or something girls do not "love" and therefore are not interested in learning how to play. Gang spoke of "girls" (women) in general, as well as the women on his team in this way. Across these cases games in general and *Minecraft* in specific are cast in exclusionary terms for women. In contrast to Qian's self-positioning toward games (shown earlier) and male game-players, Gang self-positioned himself as able to learn to play the game well, unlike girls. Although Jing does not self-position herself as a poor gamer, she still makes reference to being a major interest for most boys, thus characterizing games/gaming as masculine. Recent research shows that gaming, like computing, remains a masculine domain (Lazarro 2008), with women often concentrated in more traditionally female roles in the gaming industry (Prescott & Bogg 2010), which then often results in games with stereotypical portrayals of males and females (Martins et al. 2009; Burgess, Stermer & Burgess 2007; Jansz & Martis 2007; Sheldon 2004). Although I took steps to distance *Minecraft* in the engineering class from some masculine themes (e.g., violence and aggression; see section 2.4), the broader masculine culture around games was still very apparent to students in this group.

The presence of masculine gaming culture and differential positioning of ability by gender may have impacted the ways these students used the platform, individually and with their teams. This discourse was only present in the limited-use group. No other group or individual evoked it. This does not mean the cultural trappings of gaming had no effect on other groups, but if it did it was not made explicit or foregrounded by other students. The stark presence of this discourse was particularly worrisome, as the limited-use group also had the most women (although still a small number). It is possible this exclusionary discourse was more poignant in its effects on the two women in this group.

The second shared discourse of the limited-use group focused on the affordances and constraints of using *Minecraft* to design:

> [Jing, F] Yeah we tried to make a chamber because we have a body suit and a chamber, we need to decide which one we want to use. So I made a chamber using the sketch up but... more we use is brainstorm and prior art... because it's not easy to make it [bodysuit] in, its clothes..
>
> [Qian, F] If I want to build a house it is really easy, but if I want to build a rail there is not so many materials to build it...
>
> [Zhi, M] I think *Sketch Up* is like 3D, it can build 3D models, but I think in the *Sketch Up* we can [make] more detailed.

In the first quote, Jing shares that neither *Minecraft*or Sketch Up (another tool used in class) were good platforms for building a bodysuit. Instead of either digital platform, her team used other ideation strategies. In the second quote, Qian emphasizes that there aren't many materials for building railways. Finally, Zhi states there are limits on how detailed designs can be in *Minecraft*. All of these are constraints on form or type that limit what students can build in the platform.

On the affordances of the platform:

> [Zhi, M] I think at first I would pick the *Minecraft* because I think it's interesting and we don't need to like draw everything specific at first, just in general idea.

> [Jing, F] ...maybe we can build like transportation things

When I asked Zhi if and when he would use platforms like *Minecraft*, Sketch Up or hand sketching, he stated that *Minecraft* would be useful for a general (not detailed) design. Jing, in the second quote suggests using *Minecraft* for transportation designs. Above in the previous set of quotes, Qian suggests *Minecraft* has lots of resources for making houses/buildings. In these ways, the students emphasize the constraints and affordances of using *Minecraft* for their design project. It is noteworthy that the limited use group identifies the strengths and weaknesses of the platform, which are based on more than perception (e.g., the games code and what assets are available to create with). The starkness of the limitations/specific affordances to this group may be related in part to their limited use of the platform.

In the moderate use group, there were two occasional game-players as well as one non-gamer. This non-gamer, however, had played games in the past, and may have identified as a gamer or at least an occasional game-player at a younger age. He explains that, in the context of being an engineering student, he doesn't have much time, and prefers playing sports in his free-time. The moderate use group, overall, compared to the limited use group, appears to be less interested in gaming.

The sole gaming discourse evoked by the moderate use group concerned how well designs or built things in *Minecraft* could represent their "real world" counterparts. In the first quote below, Ying discusses an aberration between the in game physics (i.e. gravity) and what would happen in the world outside of the game. The second quote, from Collin, describes the dimension consistency between *Autodesk Inventor* and the real world--something *Minecraft* lacks.

Finally in the third quote Cheng, in comparing *Sketch Up* and *Minecraft*, emphasizes the more accurate shape and appearance of objects built in *Sketch Up*.

> [Ying, F] I found some problem... because I was building a tunnel and it's like there was a hole... like there is a little square on it. In the real world I think it's going to fall.

> [Collin, M] It's just more complicated... I like *Autodesk Inventor* specifically because I can draw a box with dimensions [and] it's just there. I can extrude it to a certain you know depth and it is the exact size I want it... it's like real world.

> [Cheng, M] With *Sketch Up* I think it can be used to design things that has a more accurate shape or appearance. But *Minecraft*, all things in *Minecraft* are block-based.

The thread running through all these quotes is that there is a disconnect between representations in *Minecraft* versus the real world "thing." While this may appear to be a natural objection, depending on the degree of innovations to which a design project is aimed, there may be limited comparable objects or processes in the real world to attempt to mirror/represent in the in-game design. Furthermore, an early emphasis on exactness may detract from exploring more possibilities within the problem space students are situated in. While detail and exactness may be a significant concern for later design stages, I intentionally planned *Minecraft* activities for the earlier, more exploratory ideation stage (Prats et al. 2009; Dym et al. 2005). Nonetheless, all of the members of the moderate use group evoked this discourse negatively. Considering this group came on the platform beyond class requirements and then quickly stopped using the platform, their shared discourse of the platform's representational fidelity may have had a role in minimizing their continued use.

Lastly, the high use group contained one student with each of the 3 gamer labels: non-gamer, occasional game-player and gamer. In contrast to the non-gamer in the moderate use group, the non-gamer in the high use group never was a heavy game-player, although she mentions sometimes playing games with friends or family. The high use group thus appears to be the most heterogeneous in terms of gaming identity. The high use group also seems to have less of a gaming emphasis than the low use group, similarly to the moderate use group.

The sole shared gaming discourse of the high use group framed the game as a classroom tool:

> [Devlin, M]... the more and more I looked at it, it was like okay this could work for an engineering project more than I thought it would and it would be an amazing way to just create an initial model for our various designs and prototypes.
>
> [Nicole, F] So for the transportation one we used Minecraft, so to show our road and how aliens can walk around the campus.
>
> [Steven, M] I think just ... building something on *Minecraft* will greatly help them. Of course they have to think about the physics and the center of gravity on real life. I think that will give them a motivation to be creative on their designs. So... I think it's really good method to generate general concept.

In the first quote, as discussed in the opening narrative, Devlin hints at some of his initial hesitancy in using *Minecraft* for design. After working with the platform this gave way to a view that *Minecraft* could be useful for numerous initial models. In the second quote, Nicole discusses how her team used *Minecraft* to visualize the campus and new the transportation system they developed. Finally, in the third quote, Steven acknowledges that students will have to consider real world physics, but nonetheless frames *Minecraft* as a good method for creating a general (not final) design. Furthermore, Steven suggests *Minecraft's* lack of representational fidelity may spark creativity when designing, instead of solely being a hindrance. Whether as a means for visualization, creating broad designs or sparking creativity, these students frame *Minecraft* as a tool toward classroom ends. It is important to note that this discourse is not based on the fact that these students continued to use the platform to a substantial degree (and hence are in the high use group).While all students in this group did continue to use the platform, they also framed the specific ways in which the platform could be a classroom tool. I identified this high use group discourse from these shared discursive practices.

Devlin's individual discourse about gaming habits sheds some further light on this shared discourse:

> [Devlin, M] Or there's it's not even like a game but different software's to build. I just test those out for fun, just like make little models and stuff like that...
>
> I: Do you think you have an interest in more of these building type of things?
>
> R: Yeah! I mean, they're fun but ... I look at them more like can I get this objective done.

In the first part of Devlin's statement, he refers to software that are "not even a game[s]" that he likes to build models in. Later, he extends this group to include games like *Roller Coaster Tycoon* where building and experimenting with different models is a core game-play mechanic. When I asked him if he has more an interest in building software/games, he made an important point: his use is objective-driven, instead of being driven by having fun or spending time with friends, for example. Devlin was the only student in the interviews to mention this kind of game-play. While this discourse only became apparent in later analysis (and therefore I wasn't able to ask him directly about it), it seems plausible that if he took an objective-driven approach to past building games/software (*Minecraft* is also a building game) that this could have influenced his use of *Minecraft*. More broadly, the high use group's framing of *Minecraft* as a class tool seems plausibly related to their more substantial use of the platform in class.

### 4.3.3 Discourse Analysis Discussion

This was an exploratory study into the use of a gaming platform for engineering design that contributes to our understanding of the relationship between engineering and gaming discourses/identities and game-based learning outcomes. In other words, in this analysis I sought out relationships and not whether game use outcomes or discourse practices caused the other. In light of the limited research on game-based learning for engineering and how students' discourses or identities affect their use of the game, I used a qualitative, emergent approach for identifying the forms of these discourses or use outcomes. However, I also asked interviewed students about their pre-college understanding of and experience with gaming and engineering, which allowed me to look for similarities and differences in discursive practices over time. Questions that explored students' earlier conceptions of gaming and engineering lend some credit to the effect of discursive practices/identities on use outcomes. Nevertheless, not all discursive practices or identities were static across students' responses and both may shift across contexts. Therefore I reported most results as relationships and tendencies, not casual relationships. The results from this part of the analysis suggest further lines of research for understanding the interaction between students' and games used for learning.

I identified one finding concerning how students' discursive framing of engineering related to their use of the platform, and two findings concerning how students' discursive framing of gaming and gaming identities relate to their use of the platform. These are, respectively: 1) that students who explicitly framed engineering more broadly tended to use the platform more; 2) students who less intensely identified as gamers tended to use the platform more; and 3) students who embraced the platform as a classroom tool and also expressed awareness about its limitations tended to use the platform more. In what follows, I discuss each finding in detail.

The finding concerning engineering discursive practices is perhaps the most complex of all the findings. First, both the limited use group and the high use group explicitly framed engineering in ways beyond being a purely technical, object-oriented discipline (Biglan 1973). For the limited-use group, this included an emphasis on teamwork within an engineering team, and to some extent, acting on users/stakeholders' needs. For the high-use group, this included framing engineers as capable of some people-oriented roles like managers and heedful of external constraints on engineering work. There were several qualifications on the limited-use framing, however. Stakeholder/user interaction was presented primarily as a one-way interaction, with engineers supplying the needs of users/stakeholders without feedback from those same users/stakeholders. Furthermore, one student's individual discourse distanced interacting with stakeholders/users from engineering work and suggested others with a management or community background should interact with them instead. In a related vein, the limited-use group also framed the engineering class, which emphasizes stakeholder and user interaction as critical for design projects, as an uninteresting or irrelevant class. Thus it appears that the high-use group, which frames engineers as capable in person-oriented job functions and acknowledges external influences (i.e. two-way transmissions between engineering projects and outside), has a broader definition of engineering than the limited-use group. This finding suggests students with broader definitions of engineering may tend to be more open to unusual (for engineering) class interventions like game-based learning. This is an important finding, as it may indicate one barrier game-based learning faces with engineering populations. The limited-use group did use the game, but this use was primarily for non-class purposes, which may also reflect how the students in the limited-use group viewed the game in relation to class. I am not able to relate this theme to the moderate-use group as members did not express any shared discourses about engineering (broadly).

The second finding concerns gaming identities and suggests that students who less intensely identified as gamers tended to use the platform more. All but 1 of the 4 respondents who were gamers were in the limited-use group. Their identities as gamers were both self-labeled and generated from criteria I developed, including the time and importance they dedicated to games. The two non-gamers were in the moderate-use and high-use groups, respectively. Compared to the limited-use group, students in the moderate and high-use groups expressed less interest or time dedicated to playing games, although all participants had played some games at some point. This was a surprising finding, as many researchers (Hayes & Duncan 2012; Ritterfield, Cody & Vorderer 2009;Squire 2006; Gee 2002) have argued that the ubiquity of games for current students and younger generations lends generous credit to using games in learning environments. It appears the relationship may be more complex.

One additional shared discourse from the limited-use group may shed some further light on their limited class use of the game. Both female students and one male student (referring to female teammates) highlighted an exclusionary discourse, where gaming is portrayed as a domain primarily for boys/men. I discussed these trends in gaming culture in more detail in section 2.4. This exclusionary discourse was particularly prominent for the limited-use group and may have had some effect on the 2 women in that group (indeed, one continually downplayed her ability to perform in games).While this study did not seek out casual relationships, the most logical influence of masculine gaming culture and its related discourses is that it externally, or through internalization, may have restrained how these two women (and potentially others in the course) used *Minecraft*.

This finding suggests two cautions for the use of game-based learning in engineering and other domains. First, how students position themselves toward gaming may influence the degree or ways they use the game(s). Simply identifying as a gamer may not translate into quickly adapting to game-based learning. Second, there are significant gendered dimensions to gaming that may influence game-based learning even when steps are taken to minimize noxious behaviors (as discussed before, I removed aggressive enemies from the games and removed the ability to hurt or kill other players). Game-based learning that replicates or encourages exclusionary discourses or behavior from the broader gaming culture deeply damages the affordances games can bring to learning.

The third finding was that students who embraced the platform as a classroom tool and also were cautionary about its limitations tended to use the platform more. All three of the use groups highlighted some positive and some negative aspects of using the platform in class. However, there was a difference in the relative influence or scope of these points. The limited-use emphasizes specific designs (buildings, transportation, and clothing) that *Minecraft* lends or does not lend itself toward designing. This group gives similar emphasis to negative and positive aspects and the scope is smaller since they are largely dealing with a specific set of things that could be designed and not the platform more broadly. The moderate-use group gives more weight to the lack of representational fidelity on the platform, which is broader in scope as it deals with anything that might be designed on the platform. To a lesser degree, the moderate-use group also framed *Minecraft* as appropriate for class to some degree when they discussed making *Minecraft* more formalized within class. In contrast to these, the high-use group gives more emphasis to *Minecraft* as a classroom tool with an awareness of the limitations of the platform. Their scope is also broad since they are discussing the platform as a whole. Thus it seems students who used *Minecraft* the most were those who had a greater emphasis on the ways *Minecraft* can facilitate or assist their design projects, with an active awareness of its limitations. This again has important implications for the assumed link (Hayes & Duncan 2012; Ritterfield, Cody & Vorderer 2009, Squire 2006; Gee 2002) or straightforward connection between students' everyday experience with games and using game-based learning in the classroom. It is not possible to say whether views of the game came first and affected use, whether these developed over time, or whether these views were an outcome of a particular mode of usage. Nevertheless, the relationship between how the game is framed and how it is used is a vital consideration when using game-based learning.

I am not claiming that students' discourses about the games are only framing devices. *Minecraft* is composed of many lines of code, game-play affordance, artwork, and a user interface that places constraints on how a person uses the game. Framing cannot obviate these conditions, but it may affect how the platform is used.

## 4.4 Informal Use Taxonomy

As I discussed in section 2.2.1 of the literature review, one of the potential strengths of using a gaming platform is that games (unless overly constrained) leave open the possibility for students to set their own goals and work toward them (Gee 2010, 2002). Documenting the goals and actions students take can shed light on the ways students interact with the platform and may also be generative for developing recommendations for future engineering design platforms. In order to leave open the possibility that students might come on the class server beyond the activities that were part of class (i.e. what I am calling informal use, see section 2.1) I operated and maintained the server from the first introductory activity to the post-survey. After the post-survey, which was near the end of the semester, I took the server down. The only exceptions to the servers' availability were for setting up new activities or to perform some maintenance or updates. Furthermore, I maintained a presence on the server by both logging into it with my 'instructor' account or by monitoring the presence of students on the server through a web-based monitoring tool. Through either tool I could send messages to students who were currently logged onto the server. I also visually inspected the artifacts on the server and used logging data to track some changes. Ultimately however, unless students attempted to damage other students' artifacts, I only observed the server, sent out occasional messages, and responded to students' questions. Outside of this, students were free to use the server as they wished. It is within this context that I reanalyzed my participants' interviews through thematic analysis to identify the ways students used the platform informally.

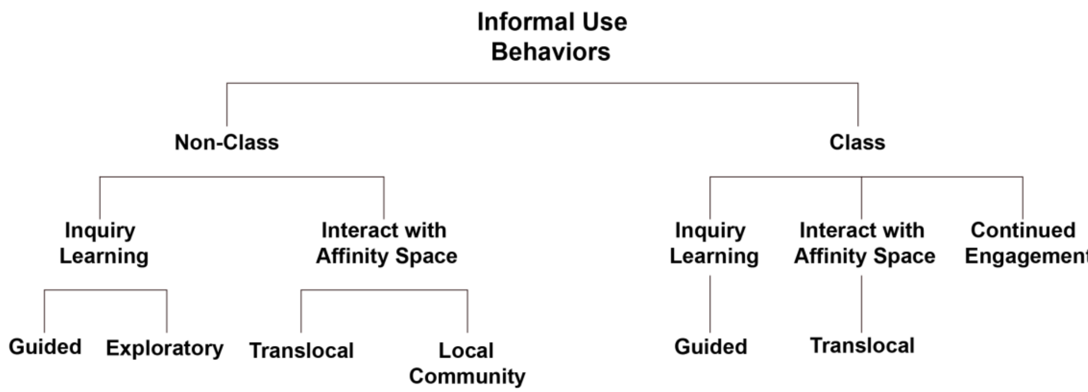



*Figure 4.4 – Taxonomy of Informal Use Behaviors*

I used thematic analysis to make an abstracted set of categories to describe the ways students used the platform informally. The taxonomy in figure 4.4 was constructed from these categories; see section 3.2.5 for a detailed discussion of how I formed this tree. Each box represents an abstraction from a participant's action or across many of the concrete actions of my participants. At the highest level of abstraction at the top of figure 4.4, students' intent (or goal) for using the platform informally was either "class" or "non-class" purposes. The "class" category is narrower, including only those instances where students joined the server in some capacity and degree to work on class-related material. The "non-class" category includes all other intents/goals, often playing the game with teammates or exploring the game individually. In what follows, I compare and contrast the ways students (informally) used *Minecraft* for "class" or for "non-class" goals, providing specific examples to illustrate the categories. I only include select quotations as much of the text reflects simple actions that are more succinctly expressed in paraphrasing.

Both branches for the taxonomy (for class, for non-class) contain inquiry learning. Inquiry learning is a student-centered approach where students learn by asking and seeking results for a question of interest within a learning context (Spronken-Smith& Walker 2010; Justice 2007).The questions students ask may involve long research projects or briefer questions within the context of other teaching designs (Sabine 2011). This approach to teaching resonates with Gee's (2010, 2002) discussion of learning in games (see section 2.2.1) where players ask questions, develop hypotheses, test out ideas, evaluate results and modify actions accordingly. Gee's cycle for learning in games is essentially the same as the inquiry learning process for students (e.g., see Justice 2007, pp 203). The only difference is that these inquiries in my class were entirely student-driven, whereas inquiry learning in the classroom typically has some instructor guidance or structure.

Within the "non-class" branch of the taxonomy, students conducted two types of inquiry learning: guided and exploratory. In guided inquiry students sought answers for specific questions, whereas in exploratory inquiry they sought broader understanding. For example, one student was curious about how "deep" the game-world was and burrowed as deeply as he could to assess this. On the more exploratory side, another student on the same team flew (airborne) across the land masses and bodies of water in the game-world to survey what it looked like.

The “class" branch students also conducted small guided inquiries. For instance, one student from the moderate-use group explained:

> [Collin, M] In my dorm room, I went on... I was really just messing around to see what all different tools I could do. And see if there was anything I could use to help like my [virtual] room...

Here the room Collin referred to was a sound-proof room, which was one of the designs his team was considering. As Collin explained, he experimented with different tools in *Minecraft* in part to identify ones that may be useful for his team's design. However, unlike the "non-class" branch, there were no instances of more exploratory inquiries in the "class" branch. This may be because the actions for class already had a well-defined goal.

Turning to the adjacent category in the non-class and class branch, students interacted with the *Minecraft* affinity space. An affinity space is a real or virtual location where people can interact and share content around some interest (see section 2.2.1). All students in the class interacted with the *Minecraft* affinity space to some degree, as the game is a portal to its content. However, there can be many forms of interaction with an affinity space (Gee 2004) and those students who used it only in class were compelled to use it as part of class activities. The students who used the platform informally were drawn to this affinity space for some reason outside of compulsory use.

Looking at the non-class branch first, some students accessed other portals/generators (e.g. websites) connected to the *Minecraft* affinity space. This category is called "trans-local" since outside portal/generators (beyond the game) were used to shape their interaction with the game. For example, one team watched user-generated instructional videos from a website on how to build structures underwater. It is possible to make underwater structures where the interior is free from water. However, this involves "tricking" the game by building a solid structure and removing only interior blocks. For the local-community category under "interact with affinity space" for non-class, it is important to recall that, although the concept of affinity space does not require participants to view the other people in the affinity space as part a community, it also does not preclude this possibility. One vivid example present in multiple teams' work was that students built shared spaces or buildings on the server, with rooms for different team members, or other communal spaces. Figure 4.5 displays several images from one of these shared spaces, including rooms for different students and an underground tunnel that leads to the structure. Hallways and ladders lead to other connected rooms. Another common example students provided was how they shared things they built in *Minecraft* with their friends, and when their friends from outside of the class shared things they had built in *Minecraft* with the student in my class. While some of these connections may be fleeting, they represented steps toward community building around and within *Minecraft*.

On the “class” branch, one student searched for videos on how to perform some building functions in the game. This was also a trans-local interaction with the *Minecraft* affinity space as they draw on distributed knowledge on a different portal (here, a website) for the space. No interview respondents spoke of developing local community, although one building on the server had a sign indicating it was a "design tower;" this may represent local community. Attempts at local community-building may, however, be difficult within the goal context of using the platform for class work.


*Figure 4.5a – A Team's Shared Space*


*Figure 4.5b – A Team's Shared Space*


*Figure 4.5c – A Team's Shared Space*


*Figure 4.5d – A Team's Shared Space*

The final category, “continued engagement,” only exists on the “class” branch. These were instances where students returned to the server and used it in a way that substantially affected their design project. For example, one team took screen captures of their design to use in their final presentation. Another team built additional artifacts outside of the class activities, as an interviewee detailed:

> [Devlin, M]...we built a platform in order to hold one human model to show, it was a very rough design of an exoskeleton, I think we used like the wiring... kind of like went away from the arm and curved. And we added some stuff like fake feet... we were looking into boots like an exoskeleton for our first prototype idea... And our second one was like a chair.

It is important to note that these actions fully overlap with the high use group of students I reported on in the previous section on student discourses. While students who came on for non-class purposes also built many things, the students I spoke with did not return (the continued engagement category) to their past creations. It is possible that more diffuse goals were less conducive for continuing engagement, but participants did not talk about this in the interviews.

### 4.4.1 Taxonomy Discussion

While some researchers have discussed the ways informal and formal learning can complement one another (Dabbagh 2012; Hall 2009; NRC 2009) and others have explored the use of informal media in formal settings (Hung, Lee & Lim 2012; Ebner, et al. 2010) few have taken a detailed look at the types of informal practices students undertake. Part of the reason for this may be the difficulty of demarcating where informal stops and formal starts (NRC 2009; Marsick & Watkins 1990).By making the *Minecraft* server continuously available to students and dedicating part of my interviews to their explicit usage/practices on the server, I was able to capture some detailed information on students' informal use. Reiterating section 2.1, informal use here means voluntary, student-structured and low-risk assessment (e.g., feedback from the game itself or individual perceptions of those of peers/friends).Carefully examining the affordances and hindrances of more informal media in the classroom is critical to delineating where they may be most fruitfully leveraged, if anywhere (Selwyn 2007).

The results from analyzing students' informal use of the platform suggest several interesting points, including the relative presence of non-class and class use, student-driven learning/activities and social dimensions of game use. I discuss each of these below.

On the broadest level, the analysis of students' informal use of the platform revealed practices that were either more distal or more proximal to explicit class content. This is an important finding as it suggests there is at least sometimes a strong linkage between more informal and formal elements of students' practices. Many of the practices I identified appeared on both class and non-class branches. Further, while by definition some students did not use the platform for informal class-related ends (i.e. the limited-use group), some students in the other use-groups used the platform informally for both class and non-class ends. For example, Devlin's(high-use) team, who had returned to the server and built designs after the class activities were done, also built a shared space on the server (non-class use).Other moderate/high use students "messed around" with the platform building non-class artifacts in addition to informal class artifacts.

There appears to be a relationship between both more proximal and distal informal uses of the platform toward class ends. This warrants further research to better understand linkages between different forms of informal practices and formal class/instructor structured practices. For example, are there some conditions or circumstances where the relative frequency of more distal or proximal informal uses vary?

Looking at specific uses the taxonomy identified several ways students engaged in informal learning. Students undertook self-defined, smaller inquiries (Sabine 2011) about using the game (i.e. not related *per se* to the class), and also about using the game toward class ends. For instance, on the "class" side of figure 4.4, several students came back onto *Minecraft* to test out other features for their design project (the Class -> Inquiry Learning -> Guided).

On a related note, although it is listed as its own entry in the taxonomy, continued engagement (such as building a different version of a design project) can also be viewed as a larger, student-enacted inquiry learning project (Justice 2007). These components of the taxonomy provide evidence that one of the affordances of using games for learning is allowing for and encouraging students to set and strive for their own learning goals. This affordance was one of the reasons Gee (2010, 2002) and others advocated using games to transform how students are taught. While the non-class inquiry learning might not directly contribute to class related learning, learning to use the game better or in new ways may nonetheless influence how the game is used for class.

Interacting with affinity spaces represents the more explicitly social aspects of informal use discovered here. An affinity space is a location (physical or virtual) where people can go and interact with others around some shared interest (Duncan & Hayes 2012; Gee 2004). Here the affinity is *Minecraft* itself and the spaces are both the local server (for the non-class branch only) and other portals/generators (both for class and non-class branches). Although building a shared space on the server, the primary example of local affinity space interaction (more accurately building/promoting) may not directly impact informal class use, local affinity space building may heighten students' engagement. For the trans-local category, many affinities (e.g. different games) have several portal/generators related to them including the game itself, discussion forums, dedicated fan sites and video storage sites (Marone 2015; Milner 2011; Duncan & Hayes 2012; Consalvo 2009; Gee 2004). Collectively, these embody the distributed knowledge (Hewlitt & Scardamalia 1998) of an affinity group. Students who accessed some of these portals/generators, such as video guides on video sharing siteseither for class or not for class, were tapping into this distributed knowledge. When feasible, tapping into distributed knowledge like this could be a great asset for class-related uses, such as when students could tap into the knowledge generated by others to suggest new directions, or to learn new skills for their current task.

Distributed knowledge like discussed above for *Minecraft* might be more abundant for commercial games (Marone 2015; Consalvo 2009; Steinkuehler & Duncan 2008; Gee 2004). This is a relevant consideration, as ultimately I am not advocating for the use of *Minecraft* for early engineers. Instead, in Chapter 5, I will develop recommendations for a serious game based off the findings of this study that would not share *Minecraft's* affinity space. Nonetheless, a serious game may also have several affinity spaces beyond the game itself (Fields & Kafai 2010); therefore the potential of this larger network of distributed knowledge could also benefit serious games.

Taken together, this analysis identified several informal uses of the platform that complemented the more formal structure I built around the game. These may also be relevant for other game-based learning projects. These practices include larger and smaller inquiry learning goals oriented toward the class and tapping into the distributed knowledge of a game’s affinity spaces for class purposes. Less directly, inquiry learning oriented toward using the game, and local affinity space building may influence the use of a gaming platform toward an educational end. One clear shortcoming of the openness of games like *Minecraft* is that some students may only minimally engage in class-related material. This raises a critical question for future game-based learning: where should an instructor draw the line on informality and formality (mandatory, teacher-structured, high-assessment) dimensions for class activities? I discuss this point in more depth in the final chapter of the manuscript.

## 4.5 Cross-Method Integration

Now that I have presented and discussed the results of each method individually, I discuss how the ANOVA results can be informed by the discourse analysis results and how the visual content analysis can be informed by the discourse analysis and thematic analysis (informal learning).

### 4.5.1 ANOVA and Discourse Analysis

In this section, I first discuss how findings from the discourse analysis may present a fuller picture of students' use of the platform, and the subsequent lack of statistical change in the design process and collaboration scale. I conclude with some broad suggestions for future iterations of game-based learning activities for engineering design learning.

One reason revealed by the discourse analysis that may contribute to not detecting any change in the design scale was students who used the platform for primarily non-class purposes. While the ability to set and strive to achieve personal goals can be a great affordance of games used in learning settings (Gee 2010, 2002), if students only set goals that have limited alignment with the class, we would not expect them to show much change in the learning outcomes being measured. In effect, students have self-selected themselves out of the exposure to *Minecraft* as a design tool in engineering 1. It is not clear how many students used *Minecraft* primarily for non-class purposes; five of my interviewees indicated they used *Minecraft* for largely non-class purposes. These students, and possibly more who used *Minecraft* in a more limited capacity as it relates to class activities, may have exhibited a muted change on the pre/post design scores. This pattern in student usage of *Minecraft*, like the ceiling effect discussed in section 4.2.2, may have contributed to the lack of detectable change in pre/post design scale scores.

The *Minecraft* activities I created were set up to be collaborative, team-based efforts. However, across many of the interviews, students indicated they worked in isolation from their team, similar to other research that finds students take a "divide and conquer" approach to collaborative work (Hsu 2015; Leonardi, Jackson &Diwan 2009; Downey & Lucena 2003).Again, it is not clear how many students worked in isolation, but I would expect that my interviewees and others who potentially took this approach would show muted change in the collaboration scale. These possible explanations for no detected changes suggest ways game activities could be better structured as learning tools

– such as by requiring more explicit deliverables (in the form of design artifacts) from teams for design learning and developing activities that have components that can only be accomplished collaboratively for collaborative learning.

### 4.5.2 Visual Content Analysis and Discourse/Thematic Analysis

In this cross methods section I discuss two points I raised during the initial presentation and discussion of the visual content analysis results: the coexistence of class and non-class artifacts, and the high level of activity in the southern quadrant of the game world depicted in figure 4.1. I address the coexistence of class and non-class artifacts first, drawing on findings from the thematic analysis.

In my original discussion of the visual content analysis, I asked whether class and non-class artifacts could coexist (that is, are both present without distracting or predominating over the other) in light of their close proximity in the game world? The thematic analysis provides some preliminary evidence that these two forms of artifacts may coexist. For instance, several of my interviewees in the moderate-use and high-use groups reported building both for class and non-class artifacts, such as shared spaces and design iterations. In the moderate use group, Collin discussed building some play artifacts when he returned to the server to test out *Minecraft* functions for his class work. Thus several of my interviewees switched between class modes and non-class modes of artifact production during their use of *Minecraft*. Given that I identified many instances of class and non-class artifacts in close proximity on the server (see figures5&7), it seems plausible that other students (who I did not interview) may have also switched between modes of production. Furthermore, Collin and Devlin also suggested in their interviews that "messing around" with the game was a way to improve their understanding of the platform and subsequently the ways they could use it for class. These findings are very preliminary, but warrant further exploration in future research.

The second issue I want to discuss in this cross method section is the high activity in the southern most area on the map in figure 4.1. One possibility for the heightened activity in this area of the game world is that the students working in that area were more active than other students. Another possibility that came up in some interviews was the presence of some “neighborhood effect.” That is, some students may have noticed more activity in the area near where they built designs, and for different reasons were encouraged to use the platform more. This phenomenon is similar to Moskaliuk, Kimmerle, Cress and colleagues'(2011) conceptions of interactive platforms where the creations of individuals may spark new ideas or responses in others using the platform (Kimmerle, Moskaliuk, Cress & Thiel 2011; Moskaliuk, Kimmerle, Cress & Hesse 2011).Awareness and responsiveness toward the activities of others is also situative cognition, attuned to the developments in the digital environment. Several of my interviewees mentioned the designs other students built. Furthermore, Devlin, one of the high-use students mentioned how others' designs on the high activity quadrant of the game-world influenced his team’s work. In light of Devlin and other students' comments, and Moskaliuk, Kimmerle and Cress's (2011) theory of digital platforms, it seems plausible that there may be some neighborhood effect happening in the *Minecraft* game-world, particularly in the southern region. If there were any neighborhood effect, it would be a promising sign for structuring the virtual space as one open design "lab." However, this finding was emergent and not something I originally intended to study. Therefore, further work on this topic is needed to see if the condition can be reproduced with similar or other digital platforms.

# CHAPTER 5. RECOMMENDATIONS, IMPLICATIONS AND CONCLUSIONS

This chapter synthesizes results from the other research questions to generate recommendations for future game-based learning platform for early engineering students. First in this chapter, I draw together two types of insights reported on in chapter 4: limitations and opportunities of game-based learning. “Limitations” are considerations that arose from the findings (results or discussion) that revealed problems with the game-based platform; future work that seeks to use game-based learning should attempt to address, change or otherwise mitigate the conditions around these limitations. “Opportunities” were positive attributes of the game-based learning activities that should be considered for inclusion or adaption into future game-based learning work. I do not call these opportunities affordances (Gibson 1979), as opportunities extend beyond affordances of the game platform as a technical object. Opportunities also include innovative uses by students that might be replicated, as well as potentially useful pedagogical techniques or scaffolding. The target of the recommendations I make in this chapter is future serious games, not *Minecraft* in particular. Thus I abstract from the specific affordances of *Minecraft*, as I did in part of the informal taxonomy. The limitations and opportunities are presented in table 5.

Table 5.1
Limitations and Opportunities of Game-Based Learning

| **Limitations** | **Opportunities** |
|---|---|
| (1) The design survey needs to be revised due to low alpha levels in the pre-survey and weak loadings. | (8) Students may use the platform informally for direct or indirect class purposes. |
| (2) Students demonstrated no detectable change in their design scores as measured by the instrument. | (9) Students built a variety of detailed designs on the server. |
| (3) Some students did not collaborate through the platform and primarily used it individually. | (10) Students built class and non-class artifacts distributed in close proximity on the server (i.e. class and non-class coexist). |
| (4) Students using the platform invoked exclusionary discourses. These discourses also exist in the broader gaming culture. | (11) Students may experience neighborhood effects in a collaborative 3D virtual world, i.e., action of others may encourage your action. |
| (5) Some students construed the game in relation to the engineering class or engineering, in ways that limited their use of it. | (12) Student-driven learning, such as setting personal learning goals and striving for them evinced in their informal uses. |
| (6) Students who have experience with games or identifying as a gamer may not immediately translate that experience into active use of games in game-based learning for class. | (13) Students accessed and used the distributed knowledge located in affinity spaces related to the game. |
| (7) Students on the edges of other players (neighbors) may experience weak neighborhood effects. | (14) Students who are non-gamers and those who do not heavily identify as gamers (i.e. occasional game-players) found game-based learning engaging. |

First, I briefly discuss 3 dimensions by which a game-based learning experience might vary. I identified these dimensions by synthesizing the limitations and opportunities reported in this study, and by drawing on theoretical frameworks used in the study. The dimensions are: formality/informality (with sub-dimensions: teacher/student structured, mandatory/voluntary and high/low assessment); game scope and accessibility (with sub-dimensions: narrow/wide design domains and high/low accessibility); and student and other social influence concerns. While presenting each dimension, I relate them to the limitations or opportunities from which they were derived. Some limitations/opportunities may relate to several dimensions, but for the sake of parsimony and keeping the dimensions grounded in the present analysis and findings, I only draw on the results or discussion for placing limitations/opportunities in dimensions. I do not discuss hypothetical relationships.

I use these more elaborate and concise dimensions to frame the recommendations instead of the sometimes-fragmented limitations/opportunities in table 5.1.From these dimensions I make an argument, in the form of recommendations, for a serious game for early engineering students learning design. In the remainder of this chapter, I draw out implications from this study and close with some concluding remarks.

## 5.1 Synthesized or Theoretically-Derived Dimensions

Table 5.2 displays the dimensions listed above, and the dimensions' associated limitations or opportunities. To conserve space, the limitations and opportunities are listed in table 5.2 as numbers, which correspond to the numbers used for each limitation or opportunity in table 5.1. Note some limitations/opportunities may be associated with multiple dimensions.

Table 5.2
Dimensions and Associated Limitations and Opportunities

| | Limitations | Opportunities |
|---|---|---|
| **Informality/formality** | | |
| teacher/student structure | (2), (3), (5), (7) | (8), (11), (12) , (13) |
| mandatory/voluntary | (3) | (8), (12) |
| high/low assessment | (1) | |
| **Game Scope & Accessibility** | | |
| wide/narrow design domain | | (9), (10), (13) |
| high/low accessibility | (3), (5) | |
| **Student and social influences** | (4), (6) | (14) |

The first dimension, informality/formality, has the same attributes as the informal learning framework I adopted in this manuscript(NRC 2009; Marsick & Watkins 1990).Teacher/student structure and mandatory/voluntary are separate sub-dimensions in this dimension, but I discuss them simultaneously here because the limitations and opportunities show similar patterns in both sub-dimensions and because all of the limitations/opportunities in the mandatory/voluntary set are also in teacher/student structure set.

As explained in section 2.1,teacher/student structure has to do with which actors in a learning setting are more responsible for structuring the activities, whereas mandatory/voluntary has to do with whether certain activities or tasks are required by instructors or not. Both sub-dimensions are better represented as continua rather than discrete states (NRC 2009; Marsick & Watkins 1990).

I first discuss the limitations that relate to the first two sub-dimensions of informality/formality. In the results, I reported no difference from the pre/post ANOVA test for the intervention class. One possible reason for no detectable change was revealed by the interviews. Several students reported working on their designs individually and only minimally collaborating with their team. The way I structured the activities had asked students to collaborate; however, I did not explicitly *require* collaboration. Students could design in isolation and still complete activities--so this collaboration was in some sense voluntary. These points relate to limitations (2) and (3).

In a related vein, limitation (7) may have also had an effect on their use of the platform. Limitation (7) concerns the fact that some students were placed at the margins or edges of the game world. If the activity on the southern-most area in the game (see section 4.1) does indeed reflect some neighborhood effect—where having other active users near you spurs your own activity (Moskaliuk et al. 2011; Kimmerle et al. 2010)—then students on the margins of the virtual world would be separated from these effects. While it may not be possible for an instructor to surround students with other students, as there will always be edges, students can be placed such that they have at least some visible neighbors. This was not always the case for how I placed some teams in my original design. For example, in figure 4.1, I placed some teams in the upper left and upper right quadrant of the virtual world where they had few neighbors, and subsequently found few or no artifacts. The terrain or the biome of the game-world did not impact this as I modified all areas to be similar regardless of biome (i.e. all areas terrains were flattened and obstacles were removed to allow for quick construction).

Moving to the opportunities related to mandatory and structured sub-dimensions, (8) and (12) both point to promising informal practices students undertook: students who used the platform directly or indirectly toward class ends and setting their own learning goals. These were student-structured activities and also more voluntary. For example, some students returned to the server to redesign one of their artifacts. In contrast to limitations potentially faced by students at the far edges of the server (7), students with many neighbors (11) may have experienced a neighborhood effect. This was most evident in the southernmost area in figure 4.1, where students created many new artifacts or iterations of artifacts. The majority of students' other iterations or new creations were also in denser artifact areas, not at the edges of the virtual world. Students' activity in these areas may have spurred other students to revise or make new designs. These neighborhood effects became a possibility because of where I placed student areas in relation to each other, but the activity itself was voluntary.

A final opportunity related to the mandatory and structured sub-dimensions was students tapping into the distributed knowledge of *Minecraft* affinity spaces. These activities were student-structured and voluntary.

Looking across limitations, how the intervention was structured pedagogically, and how mandatory/voluntary the activities were, influenced students' collaboration, how often they may have encountered other students, and how much effort some students were willing to expend toward the game. Across the opportunities these sub-dimensions influenced students' ability or interest to use the platform informally for class or other goals, the degree to which they may have encountered other students and their ability or interest in seeking outside knowledge about the game.

The final sub-dimension in the informality/formality dimension is the type or degree of assessment used. Assessments may be evaluative and high consequence (e.g. influencing a student's grade), or more situated and low consequence (such as formative feedback; Svinicki 2004) for students' development. Only one limitation (and no opportunities) relates to this sub-dimension.

My primary assessment of students' learning through the game was a formal survey that contained a design process and collaboration scale, as I discussed in section 4.2. This was a somewhat high consequence assessment as I used it to evaluate students' learning. However, my assessment's consequence for the class was not high, as the survey was treated as a complete/not complete assessment--in other words, students were not graded on their responses but only on whether they completed it. While the survey sufficed for this exploratory study, future researchers would need to revise the instrument to improve the pre alpha levels and item loadings. I will discuss this sub-dimension in more detail in the recommendations about future opportunities for assessment.

The second dimension involved game scope and accessibility. I address the design domain sub-dimension first. The design domain concerns how many different kinds of objects or processes users may feasibly design through the platform. Although there are constraints on what can be designed in *Minecraft*, it is considerably more open than other platforms used for student learning, such as those used by Chesler, Shaffer and other researchers (Chesler et al. 2015; Arastoopour, Chesler, Shaffer & Swiecki 2015; Arastoopour, Chesler &Shaffer 2014; Chesler 2013 et al.; Svarovsky 2011). For example, in the design platform *Nephrotex* (Arastoopour, Chesler, Shaffer & Swiecki 2015; Arastoopour, Chesler & 2014; Chesler 2013 et al), students design a dialyzer, which is an artificial kidney for people with renal failure. There is effectively only one domain in which students design, and specifically one device that students can design (the dialyzer); in contrast, students could design across several domains and objects in *Minecraft*.

The design domain sub-dimension has three related opportunities. Opportunity (9) concerns the variety of detailed designs students were able to build on the platform. This speaks directly to the larger set of design domains users can create in a platform like *Minecraft*. Similarly, opportunity (10) concerned the coexistence of class and non-class artifacts. The openness of the platform enabled this opportunity. It is possible to create a platform where it is infeasible for students to make non-class artifacts. This is what some work from Chesler, Shaffer and colleagues accomplishes (Chesler et al. 2015; Arastoopour, Chesler, Shaffer & Swiecki 2015; Arastoopour, Chesler & Shaffer 2014; Chesler 2013 et al).Many of the non-class artifacts students built on the server had little relation to the class artifacts; however, similarly to how informal non-class uses may indirectly affect class uses, non-class artifacts may indirectly affect class artifacts. For example, non-class artifacts could be evidence of students "messing about"' (Crismond & Adams 2012) or exploring the platform's functions, and these could influence students' later uses or artifact construction on platform, a point some interviews mentioned.

The last opportunity for the design domain sub-dimension involved students tapping into affinity spaces connected to *Minecraft* (11). A platform that allows for non-class use or a breadth of design domains is more likely to have one or more affinity spaces (beyond the game itself, which is also considered an affinity space; see Gee 2004). Researchers have found that platforms that allow for creation or design of some artifacts often have expansive affinity spaces (Marone 2015; Durga 2012; Hayes & Lee 2012).

Putting the opportunities for the design domain sub-dimension together, a platform that allows for design across several domains also enables the building of a variety of detailed designs, the coexistence of class and non-class artifacts, and the usage (and for future platforms, potentially the development of) of affinity spaces.

The second sub-dimension of game scope and accessibility is the high/low accessibility component. The mechanics for using (playing) a game may be more or less complex (Bogost 2007) and may rely on greater or fewer conventions from other games (Juul 2010). The more complex the mechanics and the more conventions the game relies on the player to know without explanation, the steeper the learning curve. The learning curve of a game also relates to how detailed creations on the platform may be. This was part of the reason I selected *Minecraft*: the curve for learning *Minecraft* is arguably less steep than a (non-gaming) platform like *Auto-desk Inventor* for computer-assisted design (CAD). Nonetheless, there is a steeper learning curve and more conventions incorporated into a platform like *Minecraft* than for your average mobile game.

There are two limitations in relation to the accessibility sub-dimension. Limitation (3) concerns students who did not collaborate. Some students' lack of collaboration was affected by the platform having too steep a learning curve. Several interviewees mentioned teammates, such as Gang's discussion of the women on his team, who limited their use of the platform because it was unfamiliar to them. Another limitation concerned how students construed the platform in relation to engineering or the class (5). All three use groups, but particularly the limited and moderate-use groups, spoke negatively of the lack of detail (e.g. use of pre-formed blocks, the use of which also requires shallower learning curve than constructing more precise shapes in other platforms) or constraints on building some designs in a platform like *Minecraft*. As I discussed in section 4.3.2, these students' construal reflect limitations in the code/affordances of the game, but also I noted that other students also construed the game in alternative ways that encouraged more use (such as done by the high-use group).

Thus the limitations for this sub-dimension run in opposite directions: issues with collaboration call for a less complex platform (with a shallower learning curve), whereas issues related to the fidelity of basic building blocks suggest making the platform more detailed (and thus with a steeper learning curve).

The final dimension is not as much of a continuum as the other dimensions. Instead, it represents concerns related to the students directly or to other social influences, such as discourses. There were two limitations and one opportunity related to this dimension; I discuss the limitations first. Relating to the social influence part of this dimension (and possibly students as well, if they internalize particular discourses, for example), limitation (4) concerns exclusionary discourses used in conjunction with the platform. As I argued in section 4.3.3, discourses such as gaming being a male domain may hinder how women use the platform. Given that this discourse and related discourses run strong in gaming culture (Cress & Shaw 2015, Salter & Blodgett 2012), there is a good chance future game platforms will also have to contend with their damaging effects.

A second limitation concerned the breakdown of the assumption that being a gamer or avid game-player will naturally engage said students in game-based learning (Hayes & Duncan 2012; Ritterfield, Cody & Vorderer 2009; Squire 2006; Gee 2002).Results from the discourse analysis show this assumption may not be valid, as other conditions can be involved, such as how the students construe the game in the game-based learning activities.

The one opportunity for the social dimension relates to the limitation above: non-gamers and occasional game-players showed signs of engagement with game-based learning activities (14). This was demonstrated by the moderate and high-use groups' informal use of the platform. These groups contained more non-gamers and occasional game-players than the limited-use group.

Drawing together these limitations/opportunities related to the students and other social influences dimension the exclusionary discourses affecting women's engagement with the game-based activities raise concerns for how games are used for learning. Students' past experience with or identity toward gaming presented both opportunities for game-based learning and challenges to past research.

## 5.2 Recommendations for a Serious Gaming Platform

Having synthesized the limitations and opportunities of a game-based platform for early engineering students' learning design into three major dimensions, I now use this framework to organize my recommendations for a future serious game for engineering design. I justify my recommendations by grounding them in the results of my analyses. This section will answer my final research question. After presenting my recommendations, I turn to the implications of this study and final concluding remarks to draw the manuscript to a close. Following the same order of the preceding section, I present recommendations and their justifications by the three major dimensions by which a game and its associated pedagogical structure or scaffolding might vary.

Of critical importance is that the platform I recommend is intended for all students, not a subsection of students who are or are not familiar with games or do or not consider themselves gamers. As instructors, we have little control over the past experiences and affinities our students bring to our classes. Therefore, if researchers crafted a platform that only a subgroup of students (with particular gaming interests or affinities) could use, this would potentially alienate or marginalize students who do not fit these specifications. The platform I recommend is intended to therefore be inclusionary; furthermore, I will make recommendations to try to mitigate some of the problematic aspects of gaming culture (e.g. exclusionary discourses) that may become activated in game-based learning projects.

### 5.2.1 Recommendations for Formality/Informality

Here I speak to the teacher/student structured and mandatory/voluntary sub-dimensions simultaneously as these two sub-dimensions are closely related. I first recommend that future instances of game-based learning have more teacher-imposed structure and also more components that are mandatory in some way. As I explained in the methods section, since this was an exploratory study and was situated within an existing class (and therefore I was somewhat constrained on what I could do within the platform), the game-based activities were minimally structured. On the positive side of this minimal structure, students were heavily involved in the one required activity for the project, and a smaller segment used it informally for many purposes, often related to class. On the less positive side of this minimal structure, some students only used it minimally for the required activity and only a smaller subset used the platform for the voluntary activity (2). Furthermore, some students did not collaborate with their team, and the students' ANOVA results show no learning gains and lower design scores than the comparison class, as measured by the survey. Students' lower scores may be partially attributable to students opting out of using the platform and to the modest nature of the intervention.

Students' lack of educational gains and mixed usage patterns suggest some changes should be made to how an instructor structures activities or the game-based environment. While it may not be feasible that all students will participate in any particular class activity, more could be done to increase participation in future instances of game-based learning. In future studies, it would be preferable if the activities were fully integrated into whatever class they were used in (i.e. part of the required curriculum). Other examples of creating more structure/mandatory components of the activities include requiring students to document team decisions about which designs to carry forward, which would promote more teamwork. Further scaffolding may also help make the activities more approachable for students. For example, the instructor could create a more detailed introduction to the game (such as having small design activities, as suggested by interviewees). These design activities could be presented in the form of small real world derived problems to that could be addressed through a designed object/process and thus lend themselves to problem-based learning methods (Prince & Felder 2006; Schmidt 1983), which could lead to greater engagement. Additionally, the scaffolding strategy of reducing the complexity of a task (Quintana et al. 2004), which I employed through the use of *Minecraft* to gently reduce students' search of the solution space, could be applied further. For instance instead of only relying on *Minecraft* to gently reduce their search of the solution space, instructional strategies could also focus students' designs into a small number of solution domains (such as buildings or structural designs).

My second recommendation for the mandatory and structured sub-dimensions is a constraint on the first recommendation. The additional teacher-imposed structure and assignment of more mandatory components to the game-based activities should still leave open the possibility for student-structured and voluntary tasks. As Gee (2010, 2002) and others have argued, one of affordances of games for learning is that they allow people to set their own goals, test them and learn from the results. This is a deeply student-driven inquiry learning process. In the discourse analysis and informal learning taxonomy, I found evidence of students engaged in informal activities that directly impacted their class work (such as building new iterations of their design) or that may have indirectly contributed to it (such as learning new aspects of the platform that could change the ways they use the game for class). An example of how indirect learning might contribute to class came from students in the moderate-use group who returned to the platform to explore game functions. Discovering new functions in the game is learning about the game, but once students are familiar with these, they could also use the function toward class activities. Therefore, allowing for informal goal setting or inquiries has the potential to positively affect students' class projects.

I have a related technical recommendation that follows from this: future platforms should be either server-accessible or web-accessible to leave open the possibility that students can access the game individually and collectively outside of the bounds of specific class time. Evidence for requiring constant access to future platforms comes from students' informal use of the platform. Students returned to the server, often outside of class, and used it proximally or distally toward class ends throughout the time it was available. Such extended use would not be possible if the game was only available within the class.

Activities that are highly structured or have many very specific mandatory components risk over-structuring the game-based learning and leaving little room for student-driven activities. Identifying clear boundaries between too few and too many structured/required components may be difficult. Still, in preparing game-based learning activities, a teacher should reflect on whether the activities they have developed allow for students to make iterations or modifications to their designs, whether students can integrate new work with their class work, whether class activities leave room for questions students may seek to answer outside of the activities, and other related questions. Future researchers should embrace a design-based approach to game-based learning for engineering design to allow for continual refinement to platform and class structure.

On the assessment sub-dimension, I recommend researchers and instructors consider other forms of assessment in addition to instruments like the survey used here, like analyzing the artifacts students built, how students use the platform, or how students interact with the team members. Procedural knowledge can be assessed through instruments like a survey (Anderson & Krathwohl 2001); however, when a researcher uses a procedural-knowledge measuring instrument, some of the actual process (i.e. the interaction of students and developmental path of different designs) is not analyzed directly. Since I found no change pre/post using the instrument, a closer analysis of students' working processes may be a useful addition to assessing students' learning. Recent research on serious games and games-based learning has begun to explore assessing students' practices within games (GlassLab 2014; DiCerbo 2014; Mislevy et al. 2012; Cassano, Martinez & Togelius 2011). For example, researchers have advocated capturing data within the game, such as comprehensively logging all of students' actions, interactions with others and other uses on the platform. GlassLab (2014), a serious game producer, and researchers like DiCerbo (2014) at Pearson Education, are exploring assessments built up from comprehensive logging of students' game use. Such assessments could unobtrusively collect data (i.e. without distracting the student from the activity), modify the game-play based on how students or teams are using it and provide summative or formative feedback to students as well as to faculty using the platform. However, in order to incorporate assessment into serious games, education specialists, programmers, learning theory specialists, game designers and other relevant contributors need to collaborate in the production of serious games (GlassLab 2014; Mislevy 2012). GlassLab (www.glasslab.com) has begun to develop games like this; however, much research remains to be done on how to appropriately analyze and synthesize logging data with educational theories to develop robust assessment schemes. There are also questions on what kind of data can be collected ethically or where the limits on data collection may encroach on privacy concerns. Nevertheless, this represents an exciting new avenue for serious games, and one a future game for engineering design learning should look to incorporate.

### 5.2.2 Recommendations for Game-Scope and Accessibility

Starting again with the design domain sub-dimension, I recommend future platforms aim to enable design in several domains. It may not be possible to create a platform where design in all or any domains is feasible, but enabling design across several domains or a broader set of domains has several advantages over focusing on only one domain. First, informal behavior, from students' general uses to artifact building, will be highly restricted if the design domains are limited. Informal media enables students the possibility of finding new uses for the media (Ebner, et al. 2010), such as students who used *Minecraft* to visualize their design projects for their final report. Broadly speaking, serious games may be created for a more formal purpose like education (Ritterfield, Cody & Vorderer 2009) but they can also incorporate informal dimensions or allow for the possibility by scoping the functionality of the platform broader than single object domains. Allowing students to explore several design domains better emulates many real-world design projects that may cross several domain boundaries (Lawson & Dorst 2009) and involve coordination among team-members with different perspectives on the things to be designed (Toh & Miller 2015). I found created artifacts in several broad domains, including buildings, transportation systems, body support systems (e.g. exoskeletons) and personal objects (such as the knapsack I presented earlier). Several teams created artifacts in different domains as well. Furthermore, if a serious game allows for creation of objects or processes across several domains, this may open the door to affinity spaces developing beyond the game itself. In this study, I found students using affinity spaces to support learning for the class. These affinity spaces could serve as distributed knowledge repositories for those who have used the game (Hayes & Duncan 2010; Gee 2004).However, unless the game is widely and regularly available(i.e., not only in class),affinity spaces may not emerge.

Therefore, a platform where it is feasible to create several types of objects and/or processes enables the possibility of informal use and perhaps affinity spaces under some conditions. Additionally, such a platform may prompt students to wrestle with higher levels of ambiguity in their projects.

The second sub-dimension of game scope and accessibility is the high/low accessibility sub-dimension. Students in the class called for both higher levels of accessibility and higher levels of detail in design, which would require more complex controls and therefore would have lower accessibility. To address these both simultaneously, I recommend creating more detailed mechanics for design that go beyond pre-existing shapes, and an explicit tutorial to introduce students to conventions (Juul 2010) used in the game for design. The tutorial could involve a small design task or tasks with explicit targets for students to design (e.g., some specific object). The design tasks could progressively introduce students to new mechanics from the serious game. Gee (2010, 2002) identifies introducing new, progressively more complex mechanics as a component of good (commercial) game design. For students who either prefer more open-ended learning or who are already familiar with many game conventions (such as some of my interviewees), instructional parts of the tutorial could be made so students can skip them. This would give students who are less familiar with games or gaming conventions a stronger foundation for later designs that may be less structured, and also allow students with more experienced with games to progress speedily through familiar content.

These design tasks could also be coupled with other learning goals such as learning about collaboration. Some possible techniques that could be coupled with the design tasks are scripted collaboration elements (Rummel & Spada 2009) such as explicit knowledge-sharing subtasks and think-pair-share's (Pluta, Richard & Mutnik 2013) that could operate as post design task reflections or debriefs.

The inability to make many modifications to existing building materials in *Minecraft*, mentioned by several students I interviewed, is perhaps less problematic for early design, but limits the usefulness of the platform for later design where precision is critical (Van Eck 2015; Brown & Katz 2009). If a platform had both premade "building blocks" as well as an editor to design new basic objects within its design domains, this would extend the platform’s viability as a digital design studio into more of the design cycle. A challenge for such a platform is that the more detailed design processes may encourage fixation on designs that appear more "finished"(Cassidy & Stone 2010; Robertson & Robertson 2009). From this study I cannot say whether it would be clearly better to restrict the more open design mechanics of the game in early stages of a class design project, or to leave this option open throughout. I leave this to future researchers.

### 5.2.3 Recommendations for Students and Social Influences

As I stated at the beginning of the recommendations section, serious games should be designed for all students regardless of past experience with games. However, exclusionary discourses, like the gender discourse I identified in the discourse analysis section, are an extreme concern for game-based learning. Outside of game-based learning, many researchers and instructors have challenged discourses and practices that engender inequality by explicitly critiquing them within the classroom. Furthermore, they have encouraged students to develop new empowering ways of thinking and doing that challenge discourses and practices that engender inequality through the tools of social analysis and critique (Rogers 2014; Rogers, Mosley & Folkes 2009; hooks 1994). Exclusionary discourses are rampant in gaming culture (Cress & Shaw 2015; Salter & Blodgett 2012), and women are underrepresented in the game industry (Prescott & Bogg 2010; Consalvo 2008) and these conditions will likely persist for the foreseeable future. An instructor or researcher cannot eliminate the problematic influence from gaming culture (or industry), which students may bring with them to class, but instructors can explicitly discuss it in class. Instructors can also encourage students to redefine or create different labels and identities for those who play games, especially in light of reports that half of all game players in the United States are women or girls (ESA 2013). I recommend instructors explicitly discuss damaging elements of gaming culture in classes that use game-based learning and help students find ways to redefine or create new labels/identities for gaming in the classroom.

Before I summarize the recommendations of this section, I discuss the risks and benefits of using a game (and its associated cultural aspects) in the classroom. An instructor faces two risks when using game-based learning: students' responses to the game, and students' actions toward other students. For individual students, the risk is that they may disengage from game-based learning due to noxious elements of gaming culture, whereas for student interactions, the risk is that some students may marginalize or ostracize other students. These risks are much higher for women (or girls) than men (or boys) in game-based learning settings. In this study, I found instances of women disengaging with the platform – primarily Qian. Furthermore, I found one student, Gang, who suggested some of his team-members who were women did not participate because women do not like games. While this is not the strong exclusionary discourse exhibited in

GamerGate or other similar events, Gang's belief may have contributed to his team-members' disengagement (recall his teammates used the platform minimally). The benefits of game-based learning in engineering design, as I have discussed throughout this manuscript, include collaborative knowledge building, instantaneous feedback, student-driven goal setting, scaffolding learning and simulating professional practice. Importantly, the vast majority of these benefits are not dependent on gaming culture. I therefore argue that game-based learning's benefits can outweigh its risks if instructors are intentional in how they structure the game and its associated pedagogy. Instructors will also need to remain alert during the activities themselves and should explicitly address gaming culture in class, as I recommended earlier.

In summary, I recommend that a future platform or instance of using game-based learning for engineering design incorporate more required activities or components while still maintaining opportunities for students to use it informally. Second, I recommend adding assessments that measure students' practices and interactions through the gaming platform, as advocated by Glass Labs (2014) and others (DiCerbo 2014; Mislevy et al. 2012). Third, I recommend that the platform allow for design across multiple subject domains. Fourth, I recommend the platform allow for greater user control/creation of objects and incorporate explicit tutorials, perhaps in the form of mini design tasks. Fifth, I recommend instructors who use game-based learning activities explicitly discuss damaging elements of gaming culture in their class and seek to encourage students to re-conceptualize what it means to play games. I argue that a serious game built (or modified) with these recommendations would engender more student involvement while still leaving avenues open for self-directed learning. Additionally, unobtrusive assessments like logged actions and interactions between teams could supplement traditional measures and provide a fuller picture of the ways students use and learn through the platform. I further argue that a platform that allows for design across multiple domains also supports a broader exploration of a design space and more team interaction over design decisions, and opens the possibility of an affinity space or spaces emerging around the game. Finally, I argue that instructors need to be explicit in addressing problematic gaming culture or it may well undermine their game-based learning projects.

## 5.3 Implications

This study has implications for several groups including instructors, game developers and researchers. I discuss the implications for each in turn below.

### 5.3.1 Teachers/Instructors

This study found evidence of students making detailed designs, and using the platform informally in relation to the class or in other uses that may be indirectly related to class ends (e.g. understanding functions of the game better and therefore open new possibilities of using it for class). However, the study was unable to identify any explicit learning gains, as measured by the design process and collaboration scale. Furthermore, students in the intervention class had statistically lower scores than students in the comparison class for both scales. It is not clear if differences in the way the students scored resulted from differences in the design project and team structure in classes or because the classes pre-scores were different. Therefore, this study offers cautionary encouragement for future game-based learning projects in engineering design and other engineering topics. Game-based learning appears to be promising for engineering design but more research is needed to identify the best ways to structure the game as a technical object, structure the class pedagogically, and encourage a culture in the classroom that promotes equal use for all students. The recommendations from the previous section are a step in this direction.

Other considerations for how to structure or scaffold game-based learning include how familiar students are with digital games, the task domain and self-structuring open-ended problems. Depending on students' experience and comfort with these tasks there may be more or less flexibility in how much scaffolding is required to assist students with the game-based learning tasks. For example, if students are generally unfamiliar with games there may need to be more introductory scaffolding (similar to tutorials for games) and if students are unfamiliar or uncomfortable with self-structuring open problems, the game activities may need to start out more structured and gradually reduce in structure.

Another implication of this study is that informal practices, goals and related actions from students may bolster their class work. However, instructors who attempt to draw informal learning into the classroom need to proceed with caution. Informal practices cannot be too directly tied to class lest they become solely teacher-structured and thereby diminish students' agency in developing and pursuing them. This embodies a teaching philosophy whereby instructors relinquish some control over the class to enable and encourage students' agency toward, personal connection to, and goal setting with, the topic. A challenge associated with this is the risk that informal practices overrun or distract from formal use. This is a concern for researchers as well. Instructors need to find a better balance between formal and informal learning.

Instructors using game-based learning face some constraints. Most games are unlikely to allow for creation and design across all design domains. Instructors are constrained to varying degrees depending on the platform they choose. Developing a new platform is likely to exceed the time and resources of most individual instructors. This means game-based learning (and other digital platforms) instructional design may be less malleable than other pedagogical tools (e.g. a design project without a digital platform).

*Minecraft* and platforms like it are better suited for students with less experience with engineering, such as high school populations, or early undergraduate engineering students. In contrast, platforms like *Minecraft* are *less* appropriate for more advanced undergraduate engineering students, who are likely to have developed a deeper technical ability in their given area. Platforms like *Minecraft*, as collaboration software, may overly constrain these students, depending on the topic area it is being used for. Indeed, engineering students from different fields will likely draw on different software packages in their work, as there is no centralized professional software across engineering disciplines.

*Minecraft* can be adapted to design projects like in this study, in lieu of game creators and/or educators developing future serious games for engineering design. However, instructors undertaking this approach will need some technical ability to modify the game (and many modifications of *Minecraft* are freely available, and may also be self-crafted), as well as establishing and maintaining a dedicated server for the class. The game is not free; however, Minecraftedu (http://minecraftedu.com/) offers discounted versions of the game for educational purposes.

Additionally, *Minecraft* could be employed for different but related design tasks and may be particularly well suited for larger scale designs. For example, a class could be divided into sub-teams (similar to the comparison class in this study) and work on components of an urban development project, a large agricultural system (it is possible to grow crops and raise livestock in *Minecraft*) or a large transportation system (e.g., a rails system or highways). By placing students on sub-teams within larger teams, students would have a manageable design task while being able to coordinate and possible work on the design from several different angles. *Minecraft* has many environmental elements, including trees, plants, animals, water and rock supplies and thus a project based around sustainability may also be promising way to deploy the game.

Instructors should be aware of the risk of exclusionary or other disruptive discourses and practices entering the classroom when employing game-based learning. These originate from the broader gaming culture and may be internalized by some students. Game-based learning holds good potential for the classroom, but if exclusionary discourses and related practices are left unaddressed, they risk alienating students. This raises several considerations for instructors. First, instructors should consider whether or not game-based learning has the potential to substantially affect the area or phenomena being studied. Due to the risk of gaming culture's exclusionary elements seeping into the classroom, game-based learning should not be used in instances where it holds little promise of engagement and learning gains. Second, if game-based learning does hold promise, the instructor should still address the potentially damaging effects of exclusionary discourses and practices in the broader gaming culture. From this work and that of others dealing with disempowering discourses (Rogers 2014; Rogers, Mosley &

Folkes 2009; hooks 1994), I recommend addressing these discourses directly in class and encouraging students to create new identities and practices or to repurpose old identities and practices around gaming. While this will not prevent all instances of these exclusionary discourses and practices from emerging, it makes their presence explicitly known to the class and equips students with ways to counter them. As I argued at the end of the previous section, if game-based learning is a good fit pedagogically, its benefits should outweigh its risks, as long as the instructor addresses and monitors the risks.

Finally it is important to note that technological scaffolding, such as Minecraft, does not happen in a vacuum. As Tabak (2004) argues, technology scaffolds happen within a larger context that includes the instructor. Instructors play a key role in structuring, guiding and assisting students' use of technology as part of the curriculum; as such, instructional interventions cannot be reduced to solely the technology.

### 5.3.2 Game Developers

This study also has a few implications for game developers, particularly those who develop serious games. First, as I mentioned in the recommendations for game accessibility, one promising way to structure the mechanics of a serious game for design would be to include both fixed or pre-formed materials for design, as well as a mechanism to design more customized materials for design objects. One example of what this mechanic might look like follows: students could build the skeleton of a building in a pre-formed shape mode, and detail the interior with furniture and more detailed physical structure in a mode where they could fully craft objects, similar to CAD. A game designed in this way would be similar to Quintana et al.'s (2004) scaffold strategy of restricting the functional modes of the technology or what functions are provided to students at different times. This would allow students to become more familiar with the design process before proceeding to potentially more complex stages (i.e. detailed design). What form this might take and how to apply it to a set of design domains would be a fruitful area for game developers to explore.

Second, in the development of serious games, it is important to create cross-disciplinary teams that include game programmers, game designers, and artists as well as educators with experience in the topic, those versed in educational theories and educational measurement or assessment. Researchers who integrate serious games with assessment have also advocated for cross-disciplinary teams like this (GlassLab 2014; Mislevy et. al 2012). Cross-disciplinary teams are not only important for work that seeks to integrate games and assessment, but also in general for the development of serious games.

### 5.3.3 Researchers

I mentioned many avenues for future research throughout the paper. I consolidate and reiterate them here. Results from future work could help refine the recommendations I made in section 5.2 for a future serious game platform for engineering design as well as advance our understanding of game-based learning. Several questions arose around informal uses of a platform like *Minecraft*. I start with more focused questions related to informality/formality and move to broader questions.

The visual content analysis raised the possibility that there may be some neighborhood effect in students' use of the platform. Future work should try to reproduce this effect and study what (if any) antecedents or co-existing conditions lead to the emergence of a neighborhood effect. In a related vein, the informal use taxonomy I developed identified informal uses that were more proximal or distal to class-related ends. Future work should attempt to identify antecedents or co-existing conditions that affect the relative frequency of proximal and distal (toward class) informal uses, as well as any relationships between proximal and distal practices.

Similarly, the visual content analysis also identified the co-existence of class and non-class artifacts. Future work should explore the relationship between non-class and class artifacts and under what conditions or topics their relative production frequency changes. An underlying question, for both practices and artifacts, worth further exploration is when and under what conditions are students' informal and formal uses, and the class and non-class artifacts students build, relatively harmonious or complimentary rather than conflicting or overwhelming for students' use of the game (i.e. whether the presence of one facilitates or suppresses the presence of the other). On an even broader level, the co-existence of informal and formal practices and artifacts raises questions about where an instructor (or researcher) should situate the intervention along the sub-dimensions of the formality/informality dimension (teacher/student structured, mandatory/voluntary, and high/low assessment). Results, particularly from the final two points, could have applicability to the entire area of informal learning, not just informal media learning.

A second area of research suggested by this study involves students' interactions with game-based learning platforms. In the discourse analysis, I presented some preliminary evidence that students who identify as gamers may not immediately translate that interest in games to engagement with a game-based learning activity. Additionally, there was some preliminary evidence that those who did not identify as gamers, or those who played games only occasionally, may be more engaged with a game-based learning platform rather than those who identified as gamers. This raises questions about how students' past experience with and perceptions or construal of games may affect how students interact with games. Likewise, I found some preliminary evidence that students with broader conceptions of engineering used the game to a greater degree for class. Future work should also explore this connection. The discourse analysis also revealed at least one exclusionary discourse that male and female students activated during the game-based learning activities: that gaming is a male domain. Future work should explore the ways in which discourses and practices from gaming culture may be activated in game-based learning activities. Researchers will need to disentangle gaming culture’s influences from broader discourses and practices that affect women and minorities in science, technology, engineering and mathematics (STEM) fields (or find connections between them).Results from studies addressing questions like these may also be applicable to the broader area of digital platform-enhanced learning.

## 5.4 Limitations

This study has several limitations. The student population in engineering 1 was heavily international (69%). It is not clear from the data I collected if this affected the results in significant ways, but it does affect the ability to generalize from the ANOVA results to other student populations. Second, I detected no difference pre/post intervention in students' design process or collaboration scale scores, and the students' scores in the intervention class were statistically lower than students' scores in the comparison class. The power of this effect-size was low to medium (for design process and collaboration, respectively), indicating the differences between the classes were weak to moderate. The instructional design I used in this study therefore requires substantial revision before it can be implemented in future game-based learning projects. In a related vein, the collaboration scale's internal reliability (i.e. Cronbach's alpha) was somewhat low, and this may have affected results by adding noise to the measures and making them less accurate.

Overall, the intervention in this study was modest in scope and scale: activity 0 and 2 were optional and not completed by all students, leaving activity 1 as the thrust of the intervention. So these results are unsurprising. At minimum, I believe a future study would need to have a series of required activities (likely three or more activities) to increase the chances of the intervention having a measurable impact on students' understanding of design. Three required activities would substantially increase students' exposure to the game-based learning intervention and thus should grant greater insight into the effect of game-based learning on design understand. Ideally, an entire design project could use *Minecraft* as its central platform, perhaps using one of the design scenarios suggested under the implications for teachers, such as designing a city or large scale agricultural system.

Finally, I found evidence after the fact of exclusionary discourses (related to gaming culture) being activated in the game-based learning activities. Although I intentionally modified the game to prevent some overt forms of disruptive behavior, I did not proactively address potentially problematic discourses in class before starting the activities. This may have negatively affected the participation of students, particularly women in the class. Future researchers or instructors aiming to use game-based learning should take these limitations into consideration when designing game-based learning activities.

## 5.5 Conclusions

This manuscript sought to contribute to the emerging empirical research on game-based learning and engineering design education. Game-based learning holds potential for engaging early engineering students in design activities. I conducted a mixed methods concurrent design to explore the use of a modified version of *Minecraft* to scaffold early engineering students' work during the concept generation stage of design. I collected survey responses, in-game artifacts and interviews with students. I developed two scales to measure students' design process and collaboration procedural understanding, which I tested through an ANOVA pre/post for the intervention class and post/post for the intervention and comparison class. I analyzed interviews using Fairclough's discourse analysis (Fairclough 2003) to identify relationships between how students framed engineering or gaming, and their use of the platform. I used thematic analysis to identify the different informal use practices of interview participants. Finally, I used visual content analysis to examine students' artifacts. Results show no effect pre/post and lower student scores for the intervention class when contrasted with the comparison class. This may be because of substantial differences in the structure of the classes, particularly the teamwork dynamics in the comparison class, as well as the modest structure of the instructional intervention. The discourse analysis showed a relationship between the ways students viewed the game and their gaming identities, as well as their use of the platform. Surprisingly, students who used the platform more for class than other students were those who viewed themselves less as gamers; students who used the platform the most were also those who emphasized the opportunities as well as the limitations of the platform. Additionally, students who used the platform more were also the students with a wider conception of engineering. Causality, however, cannot be determined through the data collected. The informal learning taxonomy unveiled a variety of ways students used the platform for class and non-class ends. The visual content analysis revealed the coexistence of class and non-class related artifacts. Furthermore, the visual content analysis suggested there may be a neighborhood effect where students in highly active parts of the server may use the game more due to the high activity of their "neighbors."

Thus, although the quantitative results are unclear, the discourse, thematic, and visual content analyses provide some evidence of students' engagement with the game and the mechanisms of that engagement, an array of ways in which students may use the platform informally toward class ends, and the promise of virtual worlds for design learning. From this work, I recommend creation of a platform that is situated more in instructional structure, but that allows for informal use opportunities, incorporates some assessment into the game itself, allows for design across several design domains, and supports students' familiarization with the game. Game-based learning holds promise for students’ learning in engineering; much work remains on researching the boundaries of informal learning, how students' past gaming experience affects their use, and how to empower students through reducing damaging influences from broader gaming culture.

# REFERENCES

# REFERENCES


Abbott, A. (2001). Chaos of Disciplines. Chicago, IL: University of Chicago Press.

Adams, R. & Atman, C. (2000). Characterizing Engineering Student Design Processes: An Illustration of Iteration.*107th ASEE Annual Conference & Exposition*. Presented at the American Society for Engineering Education Annual Conference, St. Louis, MI.

Adams, R. S., Turns, J., & Atman, C. J. (2003). Educating effective engineering designers: the role of reflective practice. *Design Studies*, *24*(3), 275–294.

Agogino, A.M., Sheppard, S.D., and Oladipupo, A.(1992). "Making Connections to Engineering During the First  Two Years," *Presented at, Frontiers in Education, Nashville, TN.*

Alcaide-Marzal, J., Diego-Más, J. A., Asensio-Cuesta, S., & Piqueras-Fiszman, B. (2013).An exploratory study on the use of digital sculpting in conceptual product design. *Design Studies*, *34*(2), 264–284.

Anderson, L. R. and Krathwohl, D. W. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Chapter 1. Allyn and Bacon.

Arastoopour, G., Chesler, N. C., & Shaffer, D. W. (2014). Epistemic persistence: A simulation-based approach to increasing participation of women in engineering. *Journal of Women and Minorities in Science and Engineering*, *20*(3).

Atman, C. J., Adams, R. S., Cardella, M. E., Turns, J., Mosborg, S., & Saleem, J. (2007). Engineering design processes: A comparison of students and expert practitioners. Journal of Engineering Education, 96(4), 359–379.

Atman, C. J., Cardella, M. E., Turns, J., & Adams, R. (2005). Comparing freshman and senior engineering design processes: an in-depth follow-up study. *Design Studies*, *26*(4), 325–357.

Atman, C. J., Chimka, J. R., Bursic, K., M., & Nachtmann, H., L. (1999).A comparison of freshman and senior engineering design processes. *Design Studies*, *20*, 131–152.

Azjen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behaviour*. Englewood Cliffs, NJ: Prentice Hall.

Ball, L. J., & Christensen, B. T. (2009). Analogical reasoning and mental simulation in design: two strategies linked to uncertainty resolution. Design Studies, 30(2), 169–186.

Ballance, C. (2013). Use of games in training: interactive experiences that engage us to learn. *Industrial and Commercial Training*, *45*(4), 218–221.

Barab, S. A., Gresalfi, M., & Ingram-Goble, A. (2010). Transformational Play: Using Games to Position Person, Content, and Context. *Educational Researcher*, *39*(7), 525–536.

Barab, S. A., Sadler, T. D., Heiselt, C., Hickey, D., & Zuiker, S. (2006). Relating Narrative, Inquiry, and Inscriptions: Supporting Consequential Play. *Journal of Science Education and Technology*, *16*(1), 59–82.

Barab, S., & Squire, K. (2004). Design-Based Research: Putting a Stake in the Ground. *Journal of the Learning Sciences*, *13*(1), 1–14.

Barron, B. (2006). Interest and Self-Sustained Learning as Catalysts of Development: A Learning Ecology Perspective. *Human Development*, *49*(4), 193–224.

Bartle, R. (2003). *Designing Virtual Worlds*. San Francisco, CA: New Riders.

Bateman, S., Teevan, J., & White, R. W. (2012). The search dashboard: How reflection and comparison impact search behavior. In Proceedings of the ACM Human Factors in Computing Systems annual conference.

Bell, D. (1976). *The Coming of Post-Industrial Society: A Venture in Social Forecasting*. New York, NY: Basic Books.

Berg, B., L. (2007). *Qualitative Research Methods for the Social Sciences* (6th ed.). New York, New York: Pearson Education, Inc.

Bertozzi, E. (2012). Killing for Girls: Predation Play and Female Empowerment. *Bulletin of Science, Technology & Society*, *32*(6), 447–454.

Bertozzi, E. (2014). The Feeling of Being Hunted: Pleasures and Potentialities of Predation Play. *Games and Culture*, *9*(6), 429–441.

Bertozzi, N., Herbert, C., Rought, J., & Staniunas, C. (2009). Implementation of a three-semester concurrent engineering design sequence for lower-division engineering students. *Engineering Design Graphics Journal*, *71*(1).

Bhaskar, R. (1975). *A Realist Theory of Science*. London, UK: Leeds Books Ltd.

Biesta, G. (2010). Pragmatism and the Philosophical Foundations of Mixed Methods Research. In A. Tashakkori & C. Teddlie (Eds.), *Sage Handbook of Mixed Methods in Social & Behavioral Research* (Second, pp. 95–118). Thousand Oaks, CA: Sage Publications Inc.

Biglan, A. (1973). The Characteristics of Subject Matter in Different Academic Areas. *Journal of Applied Psychology*, *57*(3), 195–203.

Black, A. (1990). Visible planning on paper and on screen: The impact of working medium on decision-making by novice graphic designers. *Behaviour & Information Technology*, *9*(4), 283–296.

Bogost, I. (2007). Persuasive Games: Casual As In Sex, Not Casual As In Friday. *Gamasutra*.

Borrego, M., Douglas, E. P., & Amelink, C. T. (2009). Quantitative, qualitative, and mixed research methods in engineering education. *Journal of Engineering Education*, *98*(1), 53–66.

Borrego, Maura, & Newswander, L. K. (2008). Characteristics of Successful Cross-disciplinary Engineering Education Collaborations. *Journal of Engineering Education*, *97*(2), 123–134.

Bracewell, R., Wallace, K., Moss, M., & Knott, D. (2009).Capturing design rationale. *Computer-Aided Design*, *41*(3), 173–186.

Brown, T. & Katz, B. (2009). *Change by Design.* New York, NY: HarperCollin Publishers.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101.

Bray, J., H., & Maxwell, S., E. (1985). *Multivariate Analysis of Variance*. Newbury Park, CA: Sage University Press.

Brock, A. (2011). When Keeping it Real Goes Wrong'': Resident Evil 5, Racial Representation, and Gamers. *Games and Culture*, *6*(5), 429–452.

Bucciarelli, L. (1996). *Designing Engineers*. Cambridge, MA: MIT Press.

Bucciarelli, L. (2003). *Engineering Philosophy*. Lansdale, PA: Delft University Press.

Buchmüller, S., Joost, G., Bessing, N., & Stein, S. (2011). Bridging the gender and generation gap by ICT applying a participatory design process. *Personal and Ubiquitous Computing*, *15*(7), 743–758.

Buckley, W. (1967). *Sociology and Modern Systems Theory*. Upper Sadle River, NJ: Prentice Hall.

Budnik, M. M., & Budnik, H. A. (2011.). Engineering Computer Games: A Parallel Learning Opportunity for Undergraduate Engineering and Primary (K-5) Students. In *Proceedings of the International Conference on Education, and Information Systems, Technologies, and Applications (EISTA), June* (pp. 284–289).

Bulu, S. T. (2012). Place presence, social presence, co-presence, and satisfaction in virtual worlds. *Computers &Education*, *58*(1), 154–161.

Burgess, M. C. R., Dill, K. E., Stermer, S. P., Burgess, S. R., & Brown, B. P. (2011). Playing With Prejudice: The Prevalence and Consequences of Racial Stereotypes in Video Games. *Media Psychology*, *14*(3), 289–311.

Burgess, M. C. R., Stermer, S. P., & Burgess, S. R. (2007). Sex, Lies, and Video Games: The Portrayal of Male and Female Characters on Video Game Covers. *Sex Roles*, *57*(5-6), 419–433.

Canossa, A., Martinez, J. B., & Togelius, J. (2013). Give me a reason to dig Minecraft and psychology of motivation. In *Computational Intelligence in Games (CIG), 2013 IEEE Conference on* (pp. 1–8).

Capra, F. (1996).*The Web of Life: A New Scientific Understanding of Living Systems.* New York, NY: Bantam Doubleday Dell Publishing Group, Inc.

Carr, D. (2005). Contexts, gaming pleasures, and gendered preferences. *Simulation & Gaming*, *36*(4), 464–482.

Castellani, B and R. Rajaram. (2012). Case-Based Modeling and the SACS Toolkit: A Mathematical Outline.*Computational and Mathematical Organizational Theory*, 18(2): 153-174

Castells, M. (2000).*The Rise of the Network Society.* Oxford: Blackwell Publishers.

Cheryan, S., Meltzoff, A. N., & Kim, S. (2011). Classrooms matter: The design of virtual classrooms influences gender disparities in computer science classes. *Computers & Education*, *57*(2), 1825–1835.

Chesler, N. C., Arastoopour, G., D'Angelo, C. M., Bagley, E. A., & Shaffer, D. W. (2013). Design of a Professional Practice Simulator for Educating and Motivating First-Year Engineering Students. *Advances in Engineering Education*, *3*(1), 1–29.

Chesler, N. C., Ruis, A. R., Collier, W., Swiecki, Z., & Arastoopour, G. (2015). A Novel Paradigm for Engineering Education: Virtual Internships with Individualized Mentoring and Assessment of Engineering Thinking. *Professional Engineering*, *14*(16), 18.

Chess, S. (2012). Going with the Flo: Diner Dash and feminism. *Feminist Media Studies*, *12*(1), 83–99.

Chess, S. (2014). Strange Bedfellows: Subjectivity, Romance, and Hidden Object Video Games. *Games and Culture*, *9*(6), 417–428.

Chess, S., & Shaw, A. (2015). A Conspiracy of Fishes, or, How We Learned to Stop Worrying About #GamerGate and Embrace Hegemonic Masculinity. *Journal of Broadcasting & Electronic Media*, *59*(1), 208–220.

Choi, J.-I., & Hannafin, M. (1995). Situated cognition and learning environments: Roles, structures, and implications for design. *Educational Technology Research and Development*, *43*(2), 53–69.

Chong, A., Foster, J.A., Sheridan, P.K. & Irish, R. (2013). Define "Engineering Design:" Understanding how freshman students develop their understanding of engineering, design and engineering design.*120th ASEE Annual Conference & Exposition*. Presented at the American Society for Engineering Education Annual Conference, Atlanta, GA.

Chouliaraki, L., & Fairclough, N. (1999). *Discourse in Late Modernity – Rethinking Critical Discourse Analysis*. Edinburgh, UK: Edinburgh University Press.

Cilliers, P. (1998). *Complexity & Postmodernism: Understanding Complex Systems.* Routledge: London.

Cobb, P., Confrey, J., Lehrer, R., Schauble, L., & others. (2003). Design experiments in educational research. *Educational Researcher*, *32*(1), 9–13.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design Research: Theoretical and Methodological Issues. *Journal of the Learning Sciences*, *13*(1), 15–42.

Comunello, F., & Mulargia, S. (2015). User-Generated Video Gaming: Little Big Planet and Participatory Cultures in Italy. *Games and Culture*, *10*(1), 57–80.

Connolly, T. M., Boyle, E., McArthur, E., Hainey, T., & Boyle, J. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*(2), 661–686.

Connolly, T. M., Stansfield, M., & Hainey, T. (2007).An application of games-based learning within software engineering. *British Journal of Educational Technology*, *38*(3), 416–428.

Corbin, J., & Strauss, A. (1998). *Basics of Qualitative Research: Second Edition: Techniques and Procedures for Developing Grounded Theory* (Second.). Thousand Oaks, CA: Sage Publications Inc.

Consalvo, M. (2009). Hardcore casual: Game culture Return (s) to Ravenhearst. In *Proceedings of the 4th International Conference on Foundations of Digital Games* (pp. 50–54). ACM.

Consalvo, M. (2008). Crunched by Passion: Women Game Developers and Workplace Challenges. In Y. Kafai B., C. Heeter, J. Denner, & J. Sun Y. (Eds.), *Beyond Barbie & Mortal Kombat: New Perspectives on Gender and Gaming* (pp. 177–192). Cambridge, MA: MIT Press.

Cress, U., & Kimmerle, J. (2008).A systemic and cognitive view on collaborative knowledge building with wikis. *International Journal of Computer-Supported Collaborative Learning*, *3*(2), 105–122.

Crilly, N. (2015). Fixation and creativity in concept development: The attitudes and practices of expert designers. *Design Studies*, *38*, 54–91.

Crismond, D. P., & Adams, R. S. (2012). The informed design teaching and learning matrix. *Journal of Engineering Education*, *101*(4), 738–797.

Dabbagh, N., & Kitsantas, A. (2012). Personal Learning Environments, social media, and self-regulated learning: A natural formula for connecting formal and informal learning. *The Internet and Higher Education*, *15*(1), 3–8.

Daily, J. W., & Zhang, G. M. (1993).A Freshman Engineering Design Course. *Journal of Engineering Education*, *82*(2), 83–91.

Dall'Alba, G. (2009). Learning Professional Ways of Being: Ambiguities of becoming. *Educational Philosophy and Theory*, *41*(1), 34–45.

Dall'Alba, G., & Barnacle, R. (2005). Embodied knowing in online environments. *Educational Philosophy and Theory*, *37*(5), 719–744.

Daly, S. R., Yilmaz, S., Christian, J. L., Seifert, C. M., & Gonzalez, R. (2012). Design heuristics in engineering concept generation. *Journal of Engineering Education*, *101*(4), 601–629.

de Jong, T. & van Joolingen W. R. (1998).Scientific Discovery Learning With Computer Simulations of Conceptual Domains. *Review of Educational Research,* 68(2) 179-201.

DiCerbo, K. (2014). Game-Based Assessment of Persistence. *Journal of Educational Technology & Society*, *14*(1), 17–28.

Dietz, T., L. (1996). An Examination of Violence and Gender Role Portrayals in Video Games: Implications for Gender Socialization and Aggressive Behavior. *Sex Roles*, *38*(5/6), 1998.

Dong, A., Kleinsmann, M. S., & Deken, F. (2013). Investigating design cognition in the construction and enactment of team mental models.*Design Studies*, *34*(1), 1–33.

Dorst, K. & Cross, N. (2001). Creativity in the design process: the co-evolution of problem-solution. *Design Studies, 22(5),* 425-437.

Dorta, T., Pérez, E., & Lesage, A. (2007). The ideation gap: hybrid tools, design flow and practice. *Design Studies*, *29*(2), 121–141.

Downey, G., & Lucena, J. (2003). When Students Resist: Ethnography of Senior Design Experience in Engineering Education. *International Journal of Engineering Education*, *19*(1), 168–176.

Duncan, S. C. (2010). Gamers as Designers: a framework for investigating design in gaming affinity spaces. *E-Learning and Digital Media*, *7*(1), 21.

Durga, S. (2012). Learning to Mod in an Affinity-Based Modding Community. In E. Hayes R. & S. C. Duncan (Eds.), *Learning in Video Game Affinity Spaces* (pp. 84–102). New York, New York: Peter Lang.

Dym, C., L., Agogino, A., M., Eris, O., Frey, D., D., & Leifer, L., J. (2005). Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education*, 103 – 120.

Ebner, M., Lienhardt, C., Rohs, M., & Meyer, I. (2010). Microblogs in Higher Education – A chance to facilitate informal and process-oriented learning? *Computers & Education*, *55*(1), 92–100.

Eckelman, M. J., Lifset, R. J., Yessios, I., & Panko, K. (2011). Teaching industrial ecology and environmental management in Second Life. *Journal of Cleaner Production*, *19*(11), 1273–1278.

Ennemoser, M. (2010). Evaluating the Potential of Serious Games: What can we Learn from Previous Research on Media Effects and Educational Intervention? In *Serious Games: Mechanisms and Effects* (pp. 344–373). Taylor and Francis.

Fairclough, N. (1989).*Language and Power*. London, UK: Longman.

Fairclough, N. (2003).*Analyzing Discourse: Textual analysis for social research*. New York, New York: Routledge.

Fergusen, D.M., Cawthorne, J.E., Schimpf, C. & Cardella, M. (2013). Learning Strategies and Learning Traits Critical to Practicing Engineers after College. 120th ASEE Annual Conference & Exposition. Presented at the American Society for Engineering Education Annual Conference, Atlanta, GA.

Fielding, N. G. (2009). Going out on a Limb: Postmodernism and Multiple Method Research. *Current Sociology*, *57*(3), 427–447

Fielding, N. G. (2012). Triangulation and Mixed Methods Designs: Data Integration with New Research Technologies. *Journal of Mixed Methods Research*, *6*(2), 124–136.

Fields, D. A., & Kafai, Y. B. (2010). Stealing From Grandma'' or Generating Cultural Knowledge?: Contestations and Effects of Cheating in a Tween Virtual World. *Games and Culture*, *5*(1), 64–87.

Figueiredo, A.D. (2008).Toward an Epistemology of Engineering. Workshop on Philosophy and Engineering, The Royal Academy of Engineering, 94-95.

Fish, J., & Scrivener, S. (1990). Amplifying the mind's eye: sketching and visual cognition. *Leonardo*, 117–126.

Foteinou, G. (2010). E-exclusion and the Gender Digital Divide. *ACM SIGCAS Computers and Society*, *40*(3), 50–61.

Gaber, J. (2007). Simulating Planning: SimCity as a Pedagogical Tool. *Journal of Planning Education and Research*, *27*(2), 113–121.

Gailey, C., W. (1993). Mediated Messages: Gender, Class and Cosmos in Home Video Games. *Journal of Popular Culture*, *27*(1).

Gainsburg, J., Rodriguez-Lluesma, C., & Bailey, D. E. (2010). A “knowledge profile” of an engineering occupation: temporal patterns in the use of engineering knowledge. *Engineering Studies*, *2*(3), 197–219.

Garrison, D. R., Anderson, T., & Archer, W. (2010). The first decade of the community of inquiry framework: A retrospective. *The Internet and Higher Education*, *13*(1-2), 5–9.

Gee, J. P. (2002). *What Video Games Have to Teach Us About Learning and Literacy*. New York, New York: Palgrave Macmillan.

Gee, J. P. (2004). *Situated Language and Learning: A critique of traditional schooling*. New York, New York: Routledge.

Gee, J. P. (2007). *Good Video Games and Good Learning: Collected Essays on Video Games, Learning and Literacy (New Literacies and Digital Epistemologies)*. New York, New York: Peter Lang.

Gee, J. P. (2010). Deep Learning Properties of Good Digital Games: How Far can they go? In *Serious Games: Mechanisms and Effects* (pp. 67–82). Taylor and Francis.

Gee, J. P. (2013). *The Anti-Education Era: Creating Smarter Students through Digital Learning*. New York, New York: Palgrave Macmillan.

Gerlick, R., Davis, D., Brown, S. & Trevisan, M. (2010).Reflective Practices of Engineering Capstone Teams.*117th ASEE Annual Conference & Exposition*. Presented at the American Society for Engineering Education Annual Conference, Louisville, KY.

Gibson, J., J. (2014). A Theory of Affordances (1979). In J. Gieseking J., W. Mangold, C. Katz, S. Low, & S. Saeger (Eds.), *The People, Place and Space Reader* (pp. 56–60). New York, New York: Routledge.

Giddens, A. (1986). *The constitution of society: Outline of the theory of structuration*. Berkeley, CA: University of California Press.

Giddens, A. (1979). *Central Problems in Social Theory: Action, Structure and Contradiction in Social Analysis*. Berkeley, CA: University of California Press.

Giesbers, B., Rienties, B., Tempelaar, D., & Gijselaers, W. (2013). Investigating the relations between motivation, tool use, participation, and performance in an e-learning course using web-videoconferencing. *Computers in Human Behavior*, *29*(1), 285–292.

Glaser, B., & Strauss, A. (1967). *The Discovery of Grounded Theory*. New Brunswick, NJ: Aldine Transaction.

GlassLab. (2014). *Psychometric Considerations In Game-Based Assessment*. Redwood City, CA.

Goel, V. (1995).*Sketches of Thought*. A Bradford Book.

Goldschmidt, G. (1991). The dialectics of sketching. *Creativity Research Journal*, *4*(2), 123–143.

Goldschmidt, G. (1992). Serial Sketching: Visual Problem Solving in Designing. *Cybernetics and Systems*, *23*(2), 191–219.

Goldschmidt, G. (2003). The backtalk of self-generated sketches. *Design Issues*, *19*(1), 72–88.

Gonçalves, M., Cardoso, C., & Badke-Schaub, P. (2014). What inspires designers? Preferences on inspirational approaches during idea generation. Design Studies, 35(1), 29–53.

Greeno, J., G. (1997). Theories and Practices of Thinking and Learning to Think. *American Journal of Education*, *106*, 1997.

Gu, N., Gul, L., F., Williams, A., & Nakapon, W. (2009). Second Life: A Context for Design Learning. In *Higher education in Virtual Worlds: Teaching and Learning in Second Life* (pp. 159–180). Emerald Group Publishing Limited.

Habgood, M. P. J., Ainsworth, S.E. & Benford, S. (2005). Endogenous fantasy and learning in digital games. *Simulation & Gaming*, *36*(4), 483–498.

Habgood, M. P. Jacob, & Ainsworth, S. E. (2011). Motivating Children to Learn Effectively: Exploring the Value of Intrinsic Integration in Educational Games. *Journal of the Learning Sciences*, *20*(2), 169–206.

Habraken, N. J., & Gross, M. D. (1988). Concept design games. *Design Studies*, *9*(3), 150–158.

Hall, R. (2009). Towards a Fusion of Formal and Informal Learning Environments: the Impact of the Read/Write Web. *Electronic J. of e-Learning*, *7*(1), 29–40.

Halliday, M. (1994). *An Introduction to Functional Grammar* (2nd ed.). London, UK: Edward Arnold.

Hamilton, E., Lesh, R., Lester, F., & Yoon, C. (2007). The use of reflection tools to build personal models of problem-solving. *In Foundations for the Future in Mathematics Education, Lesh, R., Hamilton, E., and Kaput, J.(eds.), Lawrence Erlbaum Associates, Mahwah, New Jersey*, 347–365.

Harré, R., & Langenhove, L. V. (1991). Varieties of positioning. *Journal for the Theory of Social Behaviour*, *21*(4), 393–407.

Hawisher, G. E., & Selfe, C. L. (1991). The rhetoric of technology and the electronic writing class. *College Composition and Communication*, *42*(1), 55–65.

Hayes, E., R., & Duncan, S. C. (Eds.). (2012). *Learning in Video Game Affinity Spaces*. New York, New York: Peter Lang.

Hayes, E., R., & Lee, Y., N. (2012). Specialist Language Acquisition and 3D Modding in a Sims Fan Site. In *Learning in Video Game Affinity Spaces* (pp. 186–211). New York, New York: Peter Lang.

Heidegger, M. (1962). *Being and Time*. New York, New York: Harper and Row Publishers, Inc.

Herring, S. R., Jones, B. R., & Bailey, B. P. (2009). Idea generation techniques among creative professionals. In System Sciences, 2009. HICSS'09. 42nd Hawaii International Conference on (pp. 1–10). IEEE.

Hewitt, J., & Scardamalia, M. (1998). Design principles for distributed knowledge building processes. *Educational Psychology Review*, *10*(1), 75–96.

Holden, C., L. (2012). The Not-So-Secret Life of Dance Dance Revolution. In E. Hayes R. & S. C. Duncan (Eds.), *Learning in Video Game Affinity Spaces* (pp. 129–161). New York, New York: Peter Lang.

Hsu, M.C. (2015). Undergraduate Engineering Students' Experiences of Interdisciplinary Learning: A Phenomenographic Perspective. Unpublished dissertation. Purdue University, West Lafayette, IN.

Huang, W.-H. D., Hood, D. W., & Yoo, S. J. (2013). Gender divide and acceptance of collaborative Web 2.0 applications for learning in higher education. *The Internet and Higher Education*, *16*, 57–65.

Hummel, H. G. K., van Houcke, J., Nadolski, R. J., van der Hiele, T., Kurvers, H., & Löhr, A. (2011). Scripted collaboration in serious gaming for complex learning: Effects of multiple perspectives when acquiring water management skills: Scripted collaboration and serious gaming. *British Journal of Educational Technology*, *42*(6), 1029–1041.

Hung, D., Lee, S.-S., & Lim, K., Y.T. (2012). Authenticity in learning for the twenty-first century: bridging the formal and informal. *Education Technology Research Development*, *60*, 1071–1091.

Ibrahim, R., & Rahimian, F. (2010). Comparison of CAD and manual sketching tools for teaching architectural design. *Automation in Construction*, *19*(8), 978–987.

IGDA. (2004). Quality of life in the game industry: Challenges and best practices. Mt. Royal, N.J.: International Game Development Association.

Ivankova, N. V. (2006). Using Mixed-Methods Sequential Explanatory Design: From Theory to Practice. *Field Methods*, *18*(1), 3–20.

Iversen, G., R., & Norpoth, H. (1987). *Analysis of Variance* (2nd ed.). Newbury Park, CA: Sage Publications Inc.

Jansz, J., & Martis, R. G. (2007). The Lara Phenomenon: Powerful Female Characters in Video Games. *Sex Roles*, *56*(3-4), 141–148.

Jenkins, H. (1998). Complete Freedom of Movement: Video Games as Gendered Play Spaces. In J. Cassell & H. Jenkins (Eds.), *From Barbie to Mortal Kombat: Gender and Computer Games*. Cambridge, MA: MIT Press.

Jenkins, H., & Cassell, J. (2008). From Quake Grrls to Desperate Housewives: A Decade of Gender and Computer Games. In *Beyond Barbie & Mortal Kombat: New Perspectives on Gender and Gaming* (pp. 5–20). Cambridge, MA: MIT Press.

Jin, Y. & Chuslip, P. (2006). Study of Mental Iteration in Different Design Situations. *Design Studies, 27(1),* 25-55*.*

Johri, A., & Olds, B. M. (2011). Situated engineering learning: Bridging engineering education research and the learning sciences. *Journal of Engineering Education*, *100*(1), 151–185.

Joiner, R., Iacovides, J., Owen, M., Gavin, C., Clibbery, S., Darling, J., & Drew, B. (2010). Digital Games, Gender and Learning in Engineering: Do Females Benefit as Much as Males? *Journal of Science Education and Technology*, *20*(2), 178–185.

Jonson, B. (2005). Design ideation: the conceptual sketch in the digital age. *Design Studies*, *26*(6), 613–624.

Justice, C., Rice, J., Warry, W., Inglis, S., Miller, S., & Sammon, S. (2006). Inquiry in Higher Education: Reflections and Directions on Course Design and Teaching Methods. *Innovative Higher Education*, *31*(4), 201–214.

Juul, J. (2010). *A Casual Revolution: Reinventing Video Games and Their Players*. Cambridge, MA: MIT Press.

Kafai, Y. B. (1998). Video Game Designs by Girls and Boys: Variability and Consistency of Gender Differences. In J. Cassell & H. Jenkins (Eds.), *From Barbie to Mortal Kombat: Gender and Computer Games*. Cambridge, MA: MIT Press.

Kafai, Y. B. (2009). World of Whyville: An Introduction to Tween Virtual Life. *Games and Culture*, *5*(1), 3–22.

Kafai, Y. B., Heeter, C., Denner, J., & Sun, J., Y. (Eds.). (2008). *Beyond Barbie & Mortal Kombat: New Perspectives on Gender and Gaming*. Cambridge, MA: MIT Press.

Kerawalla, L., & Crook, C. (2005). From promises to practices: The fate of educational software in the home. *Technology, Pedagogy and Education*, *14*(1), 107–125.

Kalkani, E. C., Boussiakou, I. K., & Boussiakou, L. G. (2005). The paper beam: hands-on design for team work experience of freshman in engineering. *European Journal of Engineering Education*, *30*(3), 393–402.

Kim, M. C., & Hannafin, M. J. (2011). Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice. Computers & Education, 56(2), 403–417.

Kimmerle, J., & Cress, U. (2009). Visualization of Group Members' Participation: How Information-Presentation Formats Support Information Exchange. *Social Science Computer Review*, *27*(2), 243–261.

Kimmerle, J., Cress, U., & Held, C. (2010). The interplay between individual and collective knowledge: technologies for organisational learning and knowledge building. *Knowledge Management Research & Practice*, *8*(1), 33–44.

Kimmerle, J., Moskaliuk, J., Cress, U., & Thiel, A. (2011). A systems theoretical approach to online knowledge building.*AI & SOCIETY*, *26*(1), 49–60.

Kimmerle, J., Thiel, A., Gerbing, K.-K., Bientzle, M., Halatchliyski, I., & Cress, U. (2013). Knowledge construction in an outsider community: Extending the communities of practice concept. *Computers in Human Behavior*, *29*(3), 1078–1090.

Klein, J., T. (1990). *Crossing Boundaries: Knowledge, Disciplinarities & Interdisciplinarties*. Charlottesville, VA: University of Virginia Press.

Kohn, N., & Smith, S. M. (2009). Partly versus completely out of your mind: effects of incubation and distraction on resolving fixation. *The Journal of Creative Behavior*, *43*(2), 102–118.

Kolko, B. (2000). Erasing @race: Going White in the (Inter)face. In *Race in Cyberspace*. New York, New York: Routledge.

Kolko, B., Nakamura, L., & Rodman, G. (Eds.). (2000). *Race in Cyberspace*. New York, New York: Routledge.

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., Puntembakar, S., & Ryan, M. (2003). Problem-based learning meets case-based reasoning in themiddle-school science classroom: Putting Learning by Design™ into practice. *Journal of the Learning Sciences 12*(4), 495–547.

Kosmadoudi, Z., Lim, T., Ritchie, J. M., Sung, R. C. W., Liu, Y., Stănescu, I. A., & Ştefan, A. (2012).Game Interactivity in CAD as Productive Systems. *Procedia Computer Science*, *15*, 285–288.

Kosmadoudi, Zoe, Lim, T., Ritchie, J., Louchart, S., Liu, Y., & Sung, R. (2013). Engineering design using game-enhanced CAD: The potential to augment the user experience with game elements. *Computer-Aided Design*, *45*(3), 777–795.

Krippendorff, K. (1980). *Content Analysis: An Introduction to Its Methodology*. Newbury Park, CA: Sage Publications Inc.

Kvasny, L. (2005). The role of the habitus in shaping discourses about the digital divide. Journal of Computer-Mediated Communication 10 (2), 5.

Labre, M. P., & Duke, L. (2004). Nothing like a brisk walk and a spot of demon slaughter to make a girl's night: The construction of the female hero in the Buffy video game. Journal of Communication Inquiry, 28, 138–156.

Lauwaert, M. (2007). Challenge Everything?: Construction Play in Will Wright's SIMCITY. *Games and Culture*, *2*(3), 194–212.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation (Learning in Doing: Social, Cognitive and Computational Perspectives*. Cambridge, UK: Cambridge University Press.

Lawson, B., & Dorst, K. (2009). *Design Expertise*. New York, New York: Routledge.

Lazzaro, N. (2008). Are Boys Games Even Necessary? In *Beyond Barbie & Mortal Kombat: New Perspectives on Gender and Gaming* (pp. 199–216). Cambridge, MA: MIT Press.

Lenhart, I. (2011). Kairotopos: A reflection on Greek space/time concepts as design implications in Minecraft. Presented at the Proceedings of DiGRA 2011 Conference: Think Design Play.

Leonardi, P. M., Jackson, M. H., & Diwan, A. (2009). The Enactment-Externalization Dialectic: Rationalization and the Persistence of Counterproductive Technology Design Practices in Student Engineering. *Academy of Management Journal*, *52*(2), 400–420.

Lewis, A. & Griffiths, M.D. (2011). Confronting Gender Representation: A Qualitative Study of the Experiences and Motivations of Female Casual Gamers. *Aloma*, *28.*

Li, D. D., Liau, A. K., & Khoo, A. (2013). Player–Avatar Identification in video gaming: Concept and measurement. *Computers in Human Behavior*, *29*(1), 257–263.

Li, F. W., & Watson, C. (2011). Game-based concept visualization for learning programming. In *Proceedings of the third international ACM workshop on Multimedia technologies for distance learning* (pp. 37–42).

Light, R., L., Singer, J. D., & Willett, J. B. (1998).*By Design*. Cambridge, MA: Harvard University Press.

Lindtner, S., & Dourish, P. (2011). The Promise of Play: A New Approach to Productive Play. *Games and Culture*, *6*(5), 453–478.

Lucas, K., & Sherry, J., L. (2004). Sex Differences in Video Game Play: A Communication-Based Explanation. *Communication Research*, *31*(5), 499–523.

Luke, A. (2000). Critical literacy in Australia: A matter of context and standpoint. *Journal of Adolescent & Adult Literacy*, *43*(5), 448–461.

Margolis, J., & Fisher, A. (2003). Geek Mythology. *Bulletin of Science, Technology and Society*, *23*(1), 17–20.

Markham, A. (1998). *Life Online: Researching Real Experience in Virtual Space.* Walnut Creek , CA: AltaMira Press.

Marone, V. (2015). From Discussion Forum to Discursive Studio: Learning and Creativity in Design-Oriented Affinity Spaces. *Games and Culture*, *10*(1), 81–105.

Marsick, V. J., & Watkins, K. E. (1990).*Informal and incidental learning in the workplace*. London, UK: Routledge.

Marsick, V. J., & Watkins, K. E. (1997).Lessons from informal and incidental learning. In J. Burgoyne, & M. Reynolds, *Management learning: Integrating perspectives in theory and practice* (pp. 295- 311). London, UK: Sage.

Martins, N., Williams, D. C., Harrison, K., & Ratan, R. A. (2009).A Content Analysis of Female Body Imagery in Video Games.*Sex Roles*, *61*(11-12), 824–836.

Maxwell, J., A., & Mittapalli, K. (2010). Realism as a Stance for Mixed Methods Research. In *Sage Handbook of Mixed Methods in Social & Behavioral Research* (Second, pp. 145–168). Thousand Oaks, CA: Sage Publications Inc.

Michael, D., & Chen, S. (2006). *Serious Games that Educate, Train and Inform*. Mason, OH: Cengage Learning.

Miles, M., B., & Huberman, A. M. (1994).*Qualitative Data Analysis* (Second.). Thousand Oaks, CA: Sage Publications Inc.

Milner, R. M. (2011). The Study of Cultures Online: Some Methodological and Ethical Tensions. *Graduate Journal of Social Science*, *8*(3), 14–32.

Misa, T., J. (Ed.). (2011). *Gender Codes: Why Women are Leaving Computing*. Hoboken, NJ: Wiley.

Mislevy, R.J. Behrens, J.T., DiCerbo, K.E., Frezzo, D.C., & West, P. (2012). Three things game designers need to know about assessment. In D. Ifenthaler, D. Eseryel, & X. Ge (eds.), *Assessment in game-based learning: Foundations, innovations, and perspectives* (pp. 59-81). New York: Springer.

Monroe, B. J. (2004). *Crossing the digital divide: race, writing, and technology in the classroom*. New York, New York: Teachers College Press.

Montola, M. (2012). Social Constructionism and Ludology: Implications for the Study of Games. *Simulation &Gaming*, *43*(3), 300–320.

Morgan, D. L. (2007). Paradigms Lost and Pragmatism Regained: Methodological Implications of Combining Qualitative and Quantitative Methods. *Journal of Mixed Methods Research*, *1*(1), 48–76.

Moskaliuk, J., Kimmerle, J., Cress, U., & Hesse, F. W. (2011). Knowledge Building in User-Generated Online Virtual Realities. *Journal of Emerging Technologies in Web Intelligence, 3*(1).

Moskaliuk, J., Kimmerle, J., & Cress, U. (2012). Collaborative knowledge building with wikis: The impact of redundancy and polarity. *Computers & Education, 58*(4), 1049–1057.

National Research Council (NRC). (2009). *Learning Science in Informal Environments: People, Places, and Pursuits*. Washington, D.C.: The National Academies Press.

National Science Foundation. (2008). *Fostering Learning in the Networked World: The Cyberlearning Opportunity and Challenge*.

Neely, W.L., Sheppard, S. & Leifer, L. (2006).Design is Design is Design (Or is it?) What we say vs. what we do in Engineering Design Education.*113th ASEE Annual Conference & Exposition*. Presented at the American Society for Engineering Education Annual Conference, Chicago, IL.

Niglas, K. (2010). The Multidimensional Model of Research Methodology: An Integrated Set of Continua. In *Sage Handbook of Mixed Methods in Social & Behavioral Research* (Second, pp. 215–236). Thousand Oaks, CA: Sage Publications Inc.

Nilsson, E. M., & Jakobsson, A. (2010). Simulated Sustainable Societies: Students' Reflections on Creating Future Cities in Computer Games. *Journal of Science Education and Technology*, *20*(1), 33–50.

Olds, B., M., Moskal, B., M., & Miller, R., L. (2005). Assessment in Engineering Education: Evolution, Approaches and Future Collaborations. *Journal of Engineering Education*, 13–25.

Pagnotti, J., & Russell, W. B. (2012). Using Civilization IV to Engage Students in World History Content. *The Social Studies*, *103*(1), 39–48.

Pluta, W. J., Richards, B. F., & Mutnick, A. (2013). PBL and Beyond: Trends in Collaborative Learning. Teaching and Learning in Medicine, 25(sup1), S9–S16.

Prats, M., Lim, S., Jowers, I., Garner, S. W., & Chase, S. (2009). Transforming shape in design: observations from studies of sketching. *Design Studies*, *30*(5), 503–520.

Prensky, M. (2001). *Digital Game-Based Learning*. Columbus, OH: McGraw Hill.

Prescott, J., & Bogg, J. (2011). Segregation in a male-dominated industry: Women working in the computer games industry. *International Journal of Gender, Science and Technology*, *3*(1).

Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of Engineering Education*, 95(2), 123.

Przybylski, A. K., Rigby, C. S., & Ryan, R. M. (2010). A motivational model of video game engagement. *Review of General Psychology*, *14*(2), 154–166.

Quintana, C., et al. (2004). A Scaffolding Design Framework for Software to Support Science Inquiry. *Journal of the Learning Sciences*, 13(3), 337–386.

Rahimian, F. P., & Ibrahim, R. (2011). Impacts of VR 3D sketching on novice designers' spatial cognition in collaborative conceptual architectural design. *Design Studies*, *32*(3), 255–291.

Rajan, P. Raju, P.K. & Sankar, C.S. (2013).Serious Games to Improve Students Learning in Class.*120th ASEE Annual Conference & Exposition*. Presented at the American Society for Engineering Education Annual Conference, Atlanta, GA.

Ratan, R., & Ritterfield, U. (2010). Classifying Serious Games. In *Serious Games: Mechanisms and Effects* (pp. 10–24). Taylor and Francis.

Reed, M., & Harvey, D. L. (1992). The new science and the old: complexity and realism in the social sciences. *Journal for the Theory of Social Behaviour*, *22*(4), 353–380.

Reiser, B. J. (2004). Scaffolding Complex Learning: The Mechanisms of Structuring and Problematizing Student Work. Journal of the Learning Sciences, 13(3), 273–304.

Rigby, C. S., & Przybylski, A. (2009). Virtual Worlds and the Learner Hero: How Today's Video Games Can Inform Tomorrow's Digital Learning Environments. *Theory and Research in Education*, *7*(2), 214–223.

Rittel, H., W., & Webber, M., M. (1973). Dilemmas in a General Theory of Planning. *Policy Sciences, 4*, 155–169.

Ritterfield, U., Cody, M., & Vorderer, P. (2009). *Serious Games : Mechanisms and Effects*. Taylor and Francis.

Robertson, B. F., & Radcliffe, D. F. (2009). Impact of CAD tools on creative problem solving in engineering design. *Computer-Aided Design*, *41*(3), 136–146.

Rogers, R. (2014). Coaching Literacy Teachers as They Design Critical Literacy Practices. *Reading & Writing Quarterly*, *30*(3), 241–261.

Rogers, R. (2011). *An Introduction to Discourse Analysis in Education* (Second.). New York, New York: Routledge.

Rogers, R., Mosley, M., & Folkes, A. (2009). Standing Up to Neoliberalism through Critical Literacy Education. *Language Arts, 87*(2), 127–138.

Rose, G. (2008). *Visual Methodologies: An Introduction to Researching with Visual Methods*. Thousand Oaks, CA: Sage Publications Inc.

Rowan-Kenyon, H. T., Coso, A., Swan, A. K., Bailey, R. R., & Creager, M. F. (2012). The role of gender in student perceptions of leadership on interdisciplinary engineering teams. *Journal of Women and Minorities in Science and Engineering*, *18*(2).

Rummel, N., & Spada, H. (2005). Learning to Collaborate: An Instructional Approach to Promoting Collaborative Problem Solving in Computer-Mediated Settings. Journal of the Learning Sciences, 14(2), 201–241.

Ryan, R. M., Rigby, C. S., & Przybylski, A. (2006). The Motivational Pull of Video Games: A Self-Determination Theory Approach. *Motivation and Emotion*, *30*(4), 344–360.

Salmani-Nodoushan, M. A. (2009). The Shaffer–Gee perspective: Can epistemic games serve education? *Teaching and Teacher Education*, *25*(6), 897–901.

Salter, A., & Blodgett, B. (2012). Hypermasculinity & Dickwolves: The Contentious Role of Women in the New Gaming Public. *Journal of Broadcasting & Electronic Media*, *56*(3), 401–416.

Schelling, T. (1980). The Strategy of Conflict. Harvard University Press.

Schmidt, H. G. (1983). Problem-based learning: rationale and description. Medical Education, 17(1), 11–16.

Schön, D. (1984). *The Reflective Practitioner: How Professionals Think in Action*. New York, New York: Basic Books.

Schradie, J. (2011). The digital production gap: The digital divide and Web 2.0 collide. *Poetics*, *39*(2), 145–168.

Searle, K. A., & Kafai, Y. B. (2012). Beyond Freedom of Movement: Boys Play in a Tween Virtual World. *Games and Culture*, *7*(4), 281–304.

Seely, B. (1999). The Other Re-engineering of Engineering Education, 1900–1965. *Journal of Engineering Education*, *88*(3), 284–295.

Selfe, C. L., & Selfe, R. J. (1994). The politics of the interface: Power and its exercise in electronic contact zones. *College Composition and Communication*, *45*(4), 480–504.

Selwyn, N. (2007). Web 2.0 applications as alternative environments for informal learning-a critical review. In *Paper for CERI-KERIS International Expert Meeting on ICT and Educational Performance* (pp. 16–27).

Shaffer, D. & Gee, J.P. (2005). Before every child is left behind: How epistemic games can solve the coming crisis in education.

Shaffer, D. W. (2006). Epistemic frames for epistemic games. *Computers & Education*, *46*(3), 223–234.

Shaffer, D., W. (2007). *How Computer Games Help Children Learn*. New York, New York: Palgrave Macmillan.

Shaffer, D. W., Hatfield, D, Svarovsky, G., Nash, P, Nulty, A., Bagley, E., Frank, K., Rupp, A., & Mislevy, R. (2009). Epistemic Network Analysis: A prototype for 21st Century assessment of learning. *The International Journal of Learning and Media. 1*(2), pp. 33-53.

Shah, J. J., Smith, S. M., & Vargas-Hernandez, N. (2003).Metrics for measuring ideation effectiveness. *Design Studies*, *24*(2), 111–134.

Shah, J. J., Vargas-Hernadez, N., Summers, J. D., & Kulkarni, S. (2001). Collaborative Sketching (C-Sketch) an idea generation technique for engineering design. *Journal of Creative Behavior*, *35*(3), 1–31.

Sheppard, S., Macatangay, K., Colby, A. & Sullivan, W.M. (2008). Educating Engineers: Designing for the Future of the Field. San Francisco: Jossey-Bass.

Short, D. (2012). Teaching Scientific concepts using a virtual world - Minecraft. *Teaching Science*, *58*(3), 55–58.

Siewiorek, N.,Shuman, L., Besterfield-Sacre, M., & Santelli, K. (2010). Engineering, Reflection and Life Long Learning.*117th ASEE Annual Conference & Exposition*. Presented at the American Society for Engineering Education Annual Conference, Louisville, KY.

Simon, H. (1957). *Models of Man: Social and Rational Mathematical Essays on Rational Human Behavior in Social Settings*. Hoboken, NJ: Wiley.

Simon, H. (1969). *The Sciences of the Artificial*. Cambridge, MA: MIT Press.

Sio, U. N., & Ormerod, T. C. (2009). Does incubation enhance problem solving? A meta-analytic review. *Psychological Bulletin*, *135*(1), 94–120.

Sirken, M., Herrmann, D., J., Schechter, S., Schwarz, N., Tanur, J., M., & Tourangeau, R. (Eds.). (1999). *Cognition and Survey Research*. New York, New York: John Wiley and Sons, Inc.

Smith, S. M., & Blankenship, S. E. (1991). Incubation and the persistence of fixation in problem solving. *The American journal of psychology*, 61–87.

Song, F., W. (2009).*Virtual Communities: Bowling Alone, Online Together*. Peter Lang Publishing.

Song, F., W. (2010). Theorizing Web 2.0: A cultural perspective. *Information Communication and Society*, *13*(2), 249–275.

Spector, P. E. (1992). *Summated Rating Scale Construction*. Newbury Park, CA: Sage Publications Inc.

Spronken-Smith, R., & Walker, R. (2010). Can inquiry-based learning strengthen the links between teaching and disciplinary research? *Studies in Higher Education*, *35*(6), 723–740.

Squire, K (2005) Educating the fighter. Horizon 13(2): 75–88

Squire, K (2003) Replaying history: learning world history through playing Civilization III. Unpublished dissertation. Indiana University, Bloomington IN.

Squire, K. (2006). From Content to Context: Videogames as Designed Experience. *Educational Researcher*, *35*(8).

Stalder, F. (2006). *Key Contemporary Thinkers: Manuel Castells*. Cambridge UK: Polity Press.

Steinkuehler, C (2007). Massively multiplayer online gaming as a constellation of literacy practices. ELearning 4(3): 297–318

Steinkuehler, C (2005) Cognition and learning in massively multiplayer online games: a critical approach. Unpublished dissertation. University of Wisconsin, Madison WI.

Steinkuehler, C., & Duncan, S. (2008). Scientific Habits of Mind in Virtual Worlds. *Journal of Science Education and Technology*, *17*(6), 530–543.

Stones, C., & Cassidy, T. (2010). Seeing and discovering: how do student designers reinterpret sketches and digital marks during graphic design ideation? *Design Studies*, *31*(5), 439–460.

Straubhaar, J., Spence, J., Tufekci, Z., & Lentz, R. G. (2012). *Inequity in the Technopolis: Race, Class, Gender, and the Digital Divide in Austin*. Austin, TX: University of Texas Press.

Steinmetz, G. (1998). Critical realism and historical sociology. A review article. *Comparative Studies in Society and History*, *40*(01), 170–186.

Steinmetz, G. (2007). *The Devil's Handwriting: Precoloniality and the German Colonial State in Qingdao, Samoa and Southwest Africa*. Chicago, IL: University of Chicago Press.

Streveler, R. A., Smith, K. A., & Pilotte, M. (2012). Aligning Course Content, Assessment, and Delivery: Creating a Context for Outcome-Based Education. In *Outcome-Based Science, Technology, Engineering, and Mathematics Education: Innovative Practices* (pp. 1–26). Hershey, PA: Information Science Reference.

Suden, J., & Sveningsson, M. (2012). *Gender and Sexuality in Online Game Cultures : Passionate Play*. Taylor and Francis.

Susi, T., Johannesson, M., & Backlund, P. (2007). Serious games: An overview.

Svarovsky, G. (2009). *Unpacking the Digital Zoo: An analysis of the learning processes within an engineering epistemic game*. University of Wisconsin, Madison, WI.

Svarovsky, G. N. (2011). Exploring Complex Engineering Learning Over Time with Epistemic Network Analysis. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(2), 4.

Svinicki, M., D. (2004).*Learning and Motivation in the Postsecondary Classroom*. Bolton, MA: Anker Publishing Company.

Tanes, Z., & Cemalcilar, Z. (2010). Learning from SimCity: An empirical study of Turkish adolescents. *Journal of Adolescence*, *33*(5), 731–739.

Tashakkori, A., & Teddlie, C. (Eds.). (2010). *Sage Handbook of Mixed Methods in Social & Behavioral Research* (2nd Ed.). Thousand Oaks, CA: Sage Publications Inc.

Teddlie, C., & Yu, F. (2007). Mixed Methods Sampling: A Typology With Examples. *Journal of Mixed Methods Research*, *1*(1), 77–100.

Thompson, T. L. (2011). Work-learning in informal online communities: evolving spaces. *Information Technology & People*, *24*(2), 184–196.

Thornham, H. (2008). "It's A Boy Thing": Gaming, gender, and geeks. *Feminist Media Studies*, *8*(2), 127–142.

Tobias, S., & Fletcher, J. D. (2012). Reflections on "A Review of Trends in Serious Gaming." *Review of Educational Research*, *82*(2), 233–237.

Toh, C. A., & Miller, S. R. (2015). How engineering teams select design concepts: A view through the lens of creativity. *Design Studies*, *38*, 111–138.

Tonso, K. L. (2006). Teams that work: Campus culture, engineer identity, and social interactions. *Journal of Engineering Education*, *95*(1), 25.

Tonso, K. L. (2007). *On the Outskirts of Engineering: Learning Identity, Gender, and Power via Engineering Practice*. Sense Publishers.

Turns, J., Newstetter, W., Allen, J. K., & Mistree, F. (1997). Learning Essays and the Reflective Learner: Supporting Reflection in Engineering Design Education. In Proceedings of the ASEE Annual Conference.

Valkenburg, R., & Dorst, K. (1998). The reflective practice of design teams. *Design studies*, *19*(3), 249–271.

van Dijk, J. A. G. M. (2006). Digital divide research, achievements and shortcomings. *Poetics*, *34*(4-5), 221–235.

van Joolingen, W., de Jong, T., & Dimitrakopoulou, A. (2007). Issues in computer supported inquiry learning in science. *Journal of Computer Assisted Learning*, *23*(2), 111-119.

Vargas-Hernandez, N. V., Shah, J. J., & Smith, S. M. (2010). Understanding design ideation mechanisms through multilevel aligned empirical studies. *Design Studies*, *31*(4), 382–410.

Vecchio, R., P. (Ed.). (2008). *Leadership: Understanding the Dynamics of Power and Influence in Organizations* (2nd Ed.). Notre Dame, IN: University of Notre Dame Press.

Vincenti, W., G. (1990).*What Engineers Know and How They Know it: Analytical Studies from Aeroneautical History*. Baltimore, MD: John Hopkins Press.

von Neumann, J., & Morgenstein, O. (1944). *Theory of Games and Economic Behavior*. Princeton, NJ: Princeton University Press.

Wankel, C., & Kingsley, J. (2009). *Higher Education in Virtual Worlds : Teaching and Learning in Second Life*. Emerald Group Publishing Limited.

Wertz, R. (2013). Theory to Practice: A Reflection on the Application of Engineering Education Coursework to New Course Development.*120th ASEE Annual Conference & Exposition*. Presented at the American Society for Engineering Education Annual Conference, Atlanta, GA.

Wiggins, G. & McTighe, J. 1998. *Understanding by Design*. Chapter 1. "What is backward design?" Alexandria, VA: ASCD.

Wingrave, C., Norton, J., Ross, C., Ochoa, N., Veazanchin, S., Charbonneau, E., & LaViola, J. (2012). Inspiring creative constructivist play. In *CHI'12 Extended Abstracts on Human Factors in Computing Systems* (pp. 2339–2344).

Won, P.H. (2001). The comparison between visual thinking using computer and conventional media in the concept generation stages of design. *Automation in Construction*, *10*(3), 319–325.

Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem solving. Journal of Child Psychology and Psychiatry and Allied Disciplines, 17, 89–100.

Woodcock, A., Graziano, W. G., Branch, S. E., Ngambeki, I., & Evangelou, D. (2012). Engineering students' beliefs about research: Sex differences, personality, and career plans. *Journal of Engineering Education*, *101*(3), 495–511.

Young, M. et al. (2012). Our Princess Is in Another Castle: A Review of Trends in Serious Gaming for Education. *Review of Educational Research.*

Yu, L. (2006). Understanding information inequality: Making sense of the literature of the information and digital divides. *Journal of Librarianship and Information Science*, *38*(4), 229–252.

Yurtseven, H. O. (2002). How does the image of engineering affect student recruitment and retention? A perspective from the USA. *Global Journal of Engineering Education*, *6*(1), 17–23.

Zemke, S. (2010). Students Preconceptions and Heuristic Learning Design. *117th ASEE Annual Conference & Exposition*. Presented at the American Society for Engineering Education Annual Conference, Louisville, KY.

Zyda, M. (2005). From visual simulation to virtual reality to games. *Computer*, *38*(9), 25–32.

APPENDICES

## Appendix A: Interview Protocol

*Introduction*
Thank you for agreeing to participate in this follow-up research interview. The purpose of this interview is to delve deeper into your experiences with and impressions of the game-based activities you engaged in. Additionally, some of your past experiences with engineering and games are explored to put your current experiences in fuller context. All of your responses are confidential and any reported findings will contain no personally identifying information. Completing the interview is optional and not tied to your class grade. You may stop at any time. You may also skip or pass any question you are uncomfortable answering.

*Information Sheet*
*Before we get started, please take a few minutes to read this information sheet that goes into more detail about the study and how we will protect your identity (read information sheet).*(Hand participant consent form).

*Tape-Recording*
If it is okay with you, I would like to tape record our conversation. Making a tape recording will help me ensure I capture our full conversation accurately.

Identity and Interests Questions

1) How would you explain what an engineer is and does to someone unfamiliar with the profession?

2) On a scale from 0 – 10, (where 0 = nonexistent at all and 10 = extremely strong), how strongly do you identify with that definition of engineering?

2a) Describe the experiences that led you to view yourself in this way.

3) Before doing the game-based activities in class had you played videogames?

4) Before entering this class how important was the activity of gaming—playing videogames—to you?

4a) How long have you been playing (video) games?
4b) How did you start playing (video) games

5) Looking back, has your notion of what an engineer is and does changed after going through most of the Engineering 1class? Why? If yes, what lead to this change?

6) Were you able to participate in any of the game-based activities in class? Which?

7) Next I'd like to talk about your experience with the class related game activities. Thinking back to [activity 1] could you describe to me what you built and how you went about translating the idea in your head to the game? Please start from the beginning, as best you can recall. Describe what you actually did as well as what you were thinking while doing parts of the activity.

*While the participant discusses their experience, use prompts to elicit more detail. How did you translate the idea in your head? Were there any surprises? Prompt them about what they were doing at any given time, what they were thinking or what they were feeling at that time. Also during this time use the prompt(s) below when appropriate:*

*What was (were) your team member(s) doing at this time? Did you notice any differences in what your team member(s) were doing at this time? What did your team member(s) seem to be thinking?*

*Once the participant has gone through [activity 1] repeat this for [activity 2, activity 3] time permitting.*

8) Think about a learning activity (such as a lab-based experiment) you had in another class. How does that learning activity compare with the game-based activities in this class? Did you find either engaging?

9) How do you think your past experience with (video) games influenced doing game-based activities in this class?

Informal Learning

10) Outside of the 3 game-based activities done in class, what are some ways the game might be used for design learning?

11) Do you know anyone who accessed the classes' dedicated server for a reason similar to one you listed or some other use beyond the 3 game-activities done in class? What did they use it for?

12) Did you ever use or access the classes dedicated server for something not directly related to one of the 3 game based activities? What for?

13) What got you motivated or interested in using the game platform this way? Did you continue? Why or why not?

14) [If they mention using the game for class based things that are part of my study's activities]. How did these additional activities impact your design project?

# Appendix B: Final Survey Questions

Collaboration Scale

1) In the design process tasks are best handled by assigning sub-tasks to team members to be done individually.

2) In the design process work is done best individually rather than in teams.

3) In the design process group decisions should only be made by those with relevant technical knowledge.

4) In the design process team members who mostly modify existing ideas contribute less than those proposing new ideas.

Design Process Scale

5) In the design process I am comfortable exploring an idea without knowing how it will be used later (Ideation).

6) In the design process trying out design solutions can lead to new understanding of the problem (Ideation).

7) In the design process the more ideas you generate the more opportunities you can explore (Ideation).

8) In the design process sometimes it's useful to follow a semi-promising idea instead of waiting for the ideal solution to appear (Iteration).

9) In the design process design stages may be repeated (Iteration

# Appendix C: Fairclough's Discourse Analysis Questions

Italicized questions were questions I added to the analysis.

**Intextuality**

Which (if any) texts are included (referenced), which are significantly excluded?

Are the other texts attributed and if so, specifically or non-specifically?

Are attributed voices directly reported (quoted) or indirectly reported?

**Assumptions**

What existential, propositional or value assumptions are made?

**Semantic/grammatical relations between sentences and clauses**

What are the predominant semantic relations between sentences and clauses (e.g. causal, conditional, contrastive, etc)?

Are there higher-level semantic relations over larger stretches of the text (e.g. problem-solution)?

Are grammatical relations between clauses predominantly paratactic, hypotactic or embedded?

Are particularly significant relations of equivalence and difference set up in the text?

**Exchanges, speech functions and grammatical mood**

What are the predominant types of exchange (activity exchange or knowledge exchange) and speech functions (statement, question, demand, offer)?

What types of statement are there (statements of fact, predictions, hypotheticals, evaluations

What is the predominant grammatical mood (declarative, interrogative, imperative)?

**Discourses**

What discourses are drawn upon in the text and how are they textured together?

*What discourses associated with engineering (as a predominantly technical field) are drawn upon?*

**Representation of social events**

What elements of represented social events are included or excluded and which included elements are most salient?

How abstractly or concretely are social events represented?

How are social actors represented (activated/passivated, personal/impersonal, named/classified, specific/generic)?

How are time, space and the relation between space-times represented?

**Styles**

What styles are drawn upon in the text and how are they textured together?

**Modality**

What do authors commit themselves to in terms of truth (epistemic modalities) or in terms of obligation and necessity (deontic modalities)?

To what extent are modalities categorical (assertion, denial, etc), to what extent are they modalized (with explicit markers of modality)?

What levels of commitment are there (high, medium, low) where modalities are modalized?

What are the markers of modalization (modal verbs, modal adverbs, etc)?

**Evaluation**

To what values (in terms of desirable or undesireable) do authors commit themselves?

How are values realized, as evaluative statements, statements with deontic modalities, statements with affective mental processes, or assumed values?

# Appendix D: Examples of Forms Generated from Discourse Analysis

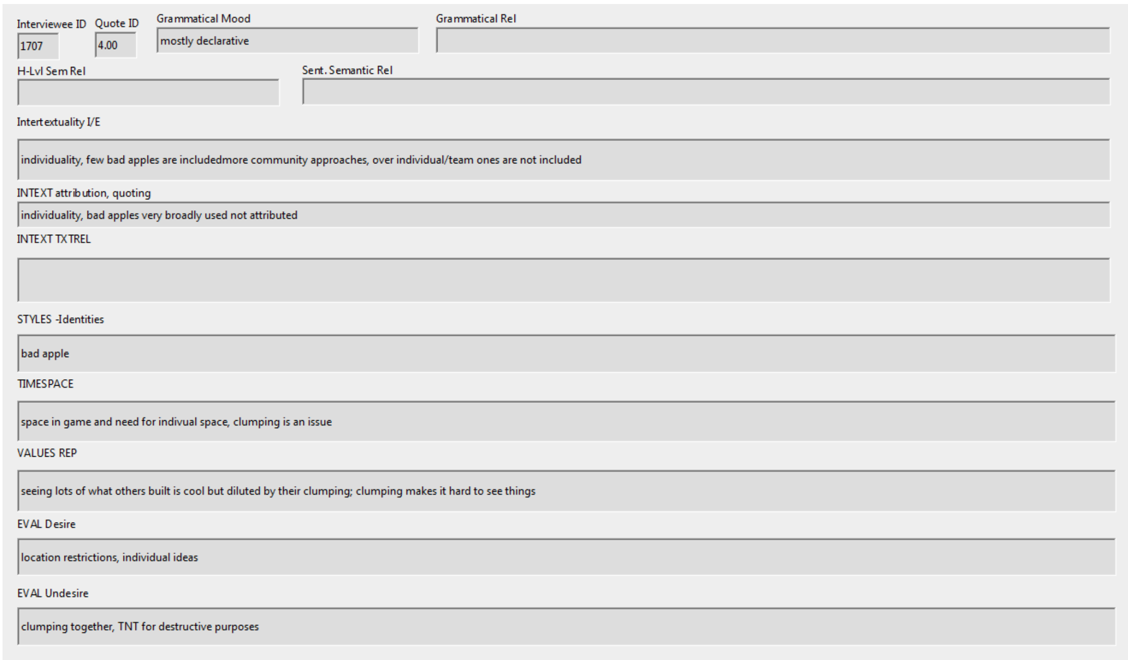
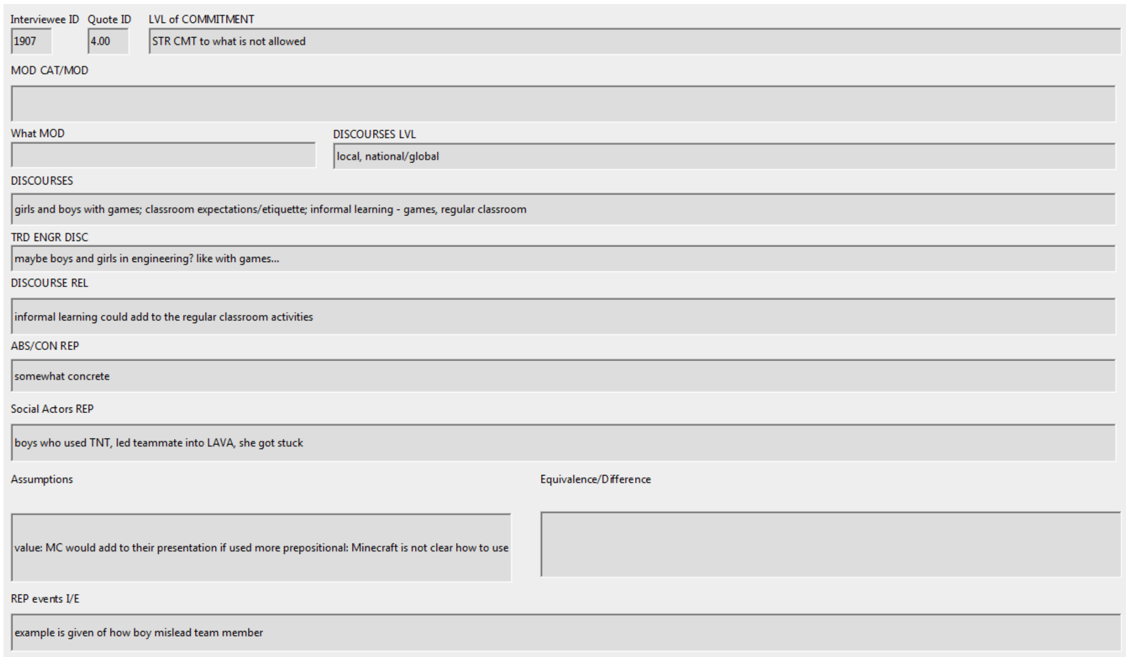

Interviewee ID: 1707
Quote ID: 4.00
Grammatical Mood: mostly declarative
Grammatical Rel:
H-Lvl Sem Rel:
Sent. Semantic Rel:
Intertextuality I/E: individuality, few bad apples are includedmore community approaches, over individual/team ones are not included
INTEXT attribution, quoting: individuality, bad apples very broadly used not attributed
INTEXT TXTREL:
STYLES -Identities: bad apple
TIMESPACE: space in game and need for indivual space, clumping is an issue
VALUES REP: seeing lots of what others built is cool but diluted by their clumping; clumping makes it hard to see things
EVAL Desire: location restrictions, individual ideas
EVAL Undesire: clumping together, TNT for destructive purposes

*Figure D 1 – Example of Form Generated from Discourse Analysis*



Interviewee ID: 1907
Quote ID: 4.00
LVL of COMMITMENT: STR CMT to what is not allowed
MOD CAT/MOD:
What MOD:
DISCOURSES LVL: local, national/global
DISCOURSES: girls and boys with games; classroom expectations/etiquette; informal learning - games, regular classroom
TRD ENGR DISC: maybe boys and girls in engineering? like with games...
DISCOURSE REL: informal learning could add to the regular classroom activities
ABS/CON REP: somewhat concrete
Social Actors REP: boys who used TNT, led teammate into LAVA, she got stuck
Assumptions: value: MC would add to their presentation if used more prepositional: Minecraft is not clear how to use
Equivalence/Difference:
REP events I/E: example is given of how boy mislead team member

*Figure D 2 – Example of Form Generated from Discourse Analysis*

# VITA

# VITA

Corey Schimpf

## Education

PhD, School of Engineering Education, Purdue University. **Aug 2015**
*First school of engineering education in the US to offer a PhD.*
*Dissertation: Scaffolding Early Engineering Design Learning with a Videogame: Exploring Minecraft's Influence on Design Ideation.*

MA, Sociology, Purdue University **May 2010**
*Thesis: Bringing Social Psychology into Agent-Based Modeling*

BA, Sociology, Kent State University (Summa Cum Laude) **May 2008**

## Research Experience

*PhD Research* *2012-2015*

- Conducted an independent study of digital game platform to scaffold engineering students design process learning to develop recommendations for future platforms.
- Analyzed student generated content through visual content analysis to identify patterns in students' platform use and possible insights into students' learning.
- Constructed an informal use taxonomy through thematic analysis that revealed the multitude of ways students informally used the platform.
- Discovered relationships between students' engineering and gaming discourses and their use of the platform through discourse analysis.
- Conducted interviews with students who had used the platform to capture their past engineering and gaming experiences and informal use of the platform.
- Employed ethnographic methods to better understand the social context of a first year engineering course and inform my dissertation focus.

*Research Assistant in Social Policy for Engineering Education Lab* *2013-2015*

- Identified and interviewed key informants to map out veteran students interactions with university offices and possible barriers to their success.
- Led a research team of 3 to analyze 44 interviews about students' co-op and internship experiences to identify supports, barriers, and pathways to industry experience.
- Developed a conceptual framework that delineated the forces that pushed and pulled students toward/away different in-school work experiences through grounded theory analysis.
- Coordinated an inter-rater reliability test to check that team of coders were applying the conceptual framework in agreement.
- Synthesized research on women and minorities underrepresentation in computing to generate new strategies to address their underrepresentation.
- Identified existing databases on women and minorities in computing from high school to industry and extracted data to triangulate research synthesis.
- Created interactive training workshops to teach junior students qualitative data collection and analysis.

*Research Assistant for ADVANCE Grant for Faculty Success* *2011-2014*

- Analyzed policy-user or eligible user interviews about faculty support policies to better understand perceptions of policies and inhibitors or facilitators of policy use.
- Created policy briefs for university leaders at the institution being studied, grounded in research findings, to push for changes in faculty support policies' implementation.
- Designed an open-ended survey to investigated changes in a faculty support policy's implementation and its impact on faculty members' work-life balance.
- Developed a theory of information and power networks through grounded theory analysis that illuminated differences in women use of a parental leave policy.
- Conducted interviews with STEM faculty members to capture their experiences with tenure or parental leave policies at a Midwestern university.
- Critically synthesized research on department head's role in faculty success and proposed recommendations for better equipping department heads to help faculty.

**Technical Proficiencies**

- *Industrial and Systems Engineering* – Understanding of the design process, production, system integration
- *Mixed Methods or Qualitative Software* – Dedoose, Python and NVivo.
- *Visualization Software* – R, SAS JMP, Photoshop.
- *Databases* – SQL, SQLITE.
- *Statistical Software* – SPSS, SAS, R and Python.

**Leadership Experience**

- Graduate Student Representative, University Committee on Renovating Graduate Housing 2014
- Purdue Graduate Student Government, Chair of Outreach Committee 2012 –2014
- Engineering Education Representative, College of Engineering Events Committee 2012- 2013
- Engineering Education Graduate Association, Senator 2011 – 2013
- Sociology Graduate Association, Treasurer 2009 – 2011

**Publications**

*Articles*

Schimpf, C., Mercado Santiago, M., Hoegh, J., Banerjee, D. & Pawley, A. (2013). STEM Faculty and Parental Leave: Understanding an Institution's Policy within a National Policy Context through Structuration Theory. *International Journal of Gender Science and Technology* 5(2), 79-101.

*Conference Proceedings*

Chen, X., Sambamurthy, N., Schimpf, C. Xian, H. & Madhavan, K. (2011).
Weighted Social Tagging
Research Methodology for Determining Systemic Trends in Engineering Education Research. *118th ASEE Annual Conference & Exposition*. Presented at the American Society for Engineering Education Annual Conference, Vancouver, Canada.

Schimpf, C., Mercado Santiago, M. & Pawley, A. (2012). Access and Definition: Exploring how STEM Faculty, Department Heads, and University Policy Administrators Navigate the Implementation of a Parental Leave Policy. 119th ASEE Annual Conference & Exposition. Presented at the American Society for Engineering Education Annual Conference, San Antonio, TX.

Beddoes, K., Schimpf, C. & Pawley, A. (2013). Engaging Foucault to Better Understand Underrepresentation of Female STEM Faculty. 120th ASEE Annual Conference & Exposition. Presented at the American Society for Engineering Education Annual Conference, Atlanta, GA.

Schimpf, C., Ricco, G. & Ohland, M. (2013). The Dynamics of Attracting Switchers: A Cross-disciplinary Comparison. *120th ASEE Annual Conference & Exposition*. Presented at the American Society for Engineering Education Annual Conference, Atlanta, GA.

Fergusen, D.M., Cawthorne, J.E., Schimpf, C. & Cardella, M. (2013). Learning Strategies and Learning Traits Critical to Practicing Engineers after College. 120th ASEE Annual Conference & Exposition. Presented at the American Society for Engineering Education Annual Conference, Atlanta, GA.

Schimpf, C. & Main, J. (2014). The Distribution of Family Friendly Benefits Policies across Higher Education Institutions: A Cluster Analysis. *121th ASEE Annual Conference & Exposition*. Presented at the American Society for Engineering Education Annual Conference, Indianapolis, IN.

Beddoes, K., Schimpf, C. & Pawley, A. (2014). New Metaphors for New Understandings: Ontological Questions about Developing Grounded Theories in Engineering Education. 121th ASEE Annual Conference & Exposition. Presented at the American Society for Engineering Education Annual Conference, Indianapolis, IN.

Beddoes, K., Schimpf, C & Pawley, A. (2015). Gender and Department Heads: An Empirically-Inspired Literature Review. 122th ASEE Annual Conference & Exposition. Presented at the American Society for Engineering Education Annual Conference, Seattle, WA.

Beddoes, K. & Schimpf, C. (2015). Undisciplined Epistemology: Conceptual Heterogeneity in a Field in the Making. 122th ASEE Annual Conference & Exposition. Presented at the American Society for Engineering Education Annual Conference, Seattle, WA.

Schimpf, C., Andronicos, A. & Main, J. (2015). Using life course theory to frame women and girls' trajectories toward (or away) from computing: Pre high-school through college years. (To be) Presented at the Frontiers in Education Conference, El Paso, TX.

*Book Chapters*

Castellani, B., Schimpf, C. & Haffery, F. (2013). “Medical Sociology and Case-Based Complexity Science: A User's Guide”, pp 734-754 in Medicine and Complexity Science, Sturmberg, J.P. Eds. Berlin: Springer.

**Professional Training**

- National Science Foundation Science and Technology Centers Professional Development Workshop. Indianapolis, IN, August 2nd - August 7th 2015.
- Presenting Data and Information. Workshop by Edward Tufte. Chicago, IL April 14th 2014.

- Focus Group Training at Purdue University: SPF SIG Intro. West Lafayette, IN January 10th 2009.

**Language Abilities**

- English (native), Mandarin (working) - written, speaking