PLAYING WITH SCIENCE: EXPLORING PERCEPTIONS OF SCIENCE IN ONLINE SPACES WITH *PORTAL 2*

by

LOGAN MICHAEL LESLIE

(Under the Direction of Deborah Tippins)

ABSTRACT

While the educational community should look to games as possibilities for learning in school spaces, it is also necessary to examine how games happen outside of these spaces as well, in order to understand issues such as how these social and cultural worlds function. In this dissertation, a variety of online fan communities dedicated to the video game *Portal 2* are examined with a focus on how the subject of science, broadly construed, arises in online discussions of the game. The project uses the concept of assemblage from Deleuze and Guattari to frame the study and consider how these discussions are navigated by the many disparate actors. The exploration of these varied interactions reveals a number of key findings. First, the science discussions that occur in these spaces are heavily shaped by the element of free choice as different actors choose to focus on different ideas without an external source telling them where they should and should not go with a discussion. Second, these discussions form a rhizomatic network in

which they connect in surprising ways to many different assemblages rather than unfolding in a tidy arborescent style of unidirectional progress from a foundational core idea. Finally, many particulars shape any discussion that occurs and are not likely to be exactly recreated. Therefore, similar starting points for interactions that develop on different sites or at different times can lead to discussions that unfold in dramatically different ways, forestalling replication of a particular conversation. These insights into how the communication of ideas about science occurs in these online spaces can help science educators better understand how to use tools such as games and online communities to enhance student learning about science.

INDEX WORDS: Deleuze, Guattari, Video Games, Informal Science Education, Postqualitative, Assemblage, Science on the Internet

PLAYING WITH SCIENCE: EXPLORING PERCEPTIONS OF SCIENCE IN ONLINE SPACES WITH *PORTAL 2*

By

LOGAN MICHAEL LESLIE

B.S., University of West Georgia, 2007

M.S., Stanford University, 2010

A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GA

2015

PLAYING WITH SCIENCE: EXPLORING PERCEPTIONS OF SCIENCE IN ONLINE SPACES WITH *PORTAL 2*

by

LOGAN MICHAEL LESLIE

Major Professor: Deborah Tippins

Committee: Michael Mueller
Elizabeth St. Pierre
Ajay Sharma

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
December 2015

DEDICATION

This dissertation is dedicated to my mother, Dr. Teresa Leslie, who has been my role model as a teacher, scholar, and human being. Without her guidance and support, I would never have ended up in the position I am in today.

ACKNOWLEDGEMENTS

I am indebted to a great many people who have made the completion of this dissertation possible. First, I wish to thank my committee members, who provided much-appreciated guidance and support every step of the way. Deborah Tippins has been a wonderful advisor, knowing when to push and when to give me space to breathe. I cannot thank her enough for her patience and her practical advice. Bettie St. Pierre has been an inspiration as well, encouraging me to explore unconventional approaches and to follow my instincts. She has always encouraged me to read more and pushed me into trying out new concepts which I might otherwise never have recognized as productive. Aja Sharma has been both a supportive individual as well someone willing to question when others might get a bit too enamored with fascinating concepts without thinking of the other side. Mike Mueller was one of the first professors to whom I felt a real connection when I came to UGA as well as being a positive influence on my brother when he got his MAT at UGA. He deserves special thanks for being willing to serve on my committee even after moving to the University of Alaska.

It has been a pleasure to have the encouragement of friends and fellow scholars along the way, as well. Graduate school just would not have been the same without my wonderful support system, including Matt, Heather, Brian, Len, and Pierre. I would also like to thank everyone involved in the science education department at UGA.

As I was finishing and defending my dissertation, I was privileged to be hired by the chemistry department at the University of West Georgia. I must thank my colleagues there for helping me maintain my sanity as I juggled the last stages of the dissertation project and my new teaching duties. In a way, I was coming full circle, because I began my academic journey with the UWG chemistry department while still in junior high school, thanks to the mentorship of Andy Leavitt, now chancellor of the University of Wisconsin, Oshkosh. Along with Dr. Leavitt, John Hansen nurtured my love of science and research. For that I thank them both.

Finally, I must attempt to convey my deepest appreciation to my most loyal and loving supporters, my family and two special friends who are as close as family to me. Andy and Lauren Kelso are a wonderful long-distance support team and have proven to me how important the internet can be in building and maintaining friendships. Andy has stuck with me through thick and thin; I would not have made it to this point without him. I am proud to call him my best friend. My grandparents, Frank and Lavonne Muncy, have showered me with love from the day I was born and always let me know that they believe in me, even when they don't understand me. I regret that my other grandparents, Harold and Shirley Leslie, did not live to see me earn my doctorate. My brother, Ethan, is a better sibling than I probably deserve and a wonderful housemate to boot. He convinced me to become a Bulldog football fan and, even if he did not realize the French horn was clearly inferior to the trumpet, he has always been an unwavering supporter of my direction no matter what it might be. My parents, Andrew and Teresa, have been unfailingly generous and enthusiastically encouraging. When my confidence in my

ability to see this project through has occasionally flagged, theirs never did. I am eternally grateful for their stubborn optimism and unqualified support.

TABLE OF CONTENTS

Chapter 1: Introduction

Play is older than culture, for culture, however inadequately defined, always presupposes human society, and animals have not waited for man to teach them their playing.

Johan Huzinga, *Homo Ludens*, 1938

As John Huzinga observed in his seminal 1938 study, games and play have been part of the life of human beings since before the dawn of civilization. Huzinga was one of the first to recognize the importance of play as an element of culture and of the study of play as a way to learn more about a culture. As video games have become an ever increasing way of participating in play, the need for academics to seriously consider such games has similarly increased. Science educators, for example, seeing the large role that gaming plays in the lives of many of their students, would be well-served to examine the question of how such play can contribute to participants' understandings of science, a question which is the focus of this dissertation. In particular, I explore how a particular game released in 2011, *Portal 2*, generates and facilitates discussions of science in online spaces.

Originally, the project was focused on the science content of this particular game, both the rules of physics that are employed in game play and the ways that the game comments on the nature of science through its presentation of science and scientists within its story. However, in the process of pursuing this particular strategy, I came to the realization that casting a wider online net was potentially much more useful. At that

point, I pivoted from a study of the meaning of the scientific ideas and concepts embedded in the game to a wider exploration of how other people made use of *Portal 2* to think about science.

One of the great strengths of the internet is its ability to bring together in virtual space people from a variety of different physical locations, allowing communication across time zones and political (and social) boundaries. This has led to the internet becoming a place where niche interest groups can form and flourish. As a result, there is a multiplicity of sites where people create and discuss works inspired by video games. Throughout the research process, I have been continually surprised by the seemingly infinite variety of types of content being made and discussed online, particularly in the gaming community. In this dissertation, I will focus on material found in my investigation of these sites, drawing on both the plethora of fan-created works related to *Portal 2* that could be of interest to science educators as well as the vast number of discussions related to science that arise in comment threads on these sites.

Overview of the Dissertation

In Chapter 2, I begin this exploration by considering the question: what is a game? This chapter will review the literature of a number of different potential definitions of game and discuss both how *Portal 2* does or does not fit into that definition and how those different definitions impact where researchers focus in their work. The chapter also examines research related to games in science education and what areas of games they choose to focus on and how this impacts my own study design.

In Chapter 3, I establish the theoretical framework from Deleuze and Guattari that I use for the dissertation. While I employ a number of their concepts, the majority of these connect back in some way to the idea of assemblage. Deleuze and Guattari suggest that the assumption that knowledge and many other organizations are arborescent in nature is problematic. Assemblages, rather than building up from a foundation, instead spread out in many directions with no clear starting or ending point. While adopting this insight made starting the study more challenging, the concept of assemblages was a powerful way to think about the organization of the internet, especially how it is navigated in actual practice. The internet's design allows for sites to be connected in huge networks in such a way that not all users will see the same material because they will each navigate the internet in their own way, following differing meandering paths guided by such things as advertisements, links to other sites, computer algorithms, and even their own momentary whims.

Chapter 4, entitled "Theory as Method," focuses on my methodology, describing how I gathered material and applied Deleuzo-Guattarian concepts to the analysis of the material. I begin the chapter by explaining how I explored different internet spaces to learn more about *Portal 2* and how different online communities use parts of the game in their own creations and discussions. This is followed by a consideration of how Deleuze and Guattari's concepts were deployed in the study, using specific examples from the analysis chapters. Since Deleuze and Guattari do not try to give a formulaic way to apply their concepts, looking at such examples ends up being the best way to figure out what research utilizing their ideas looks like.

The next three chapters focus on the analysis of different online spaces and how the assemblages of science and *Portal 2* interact. Chapter 5 starts with a particular forum, called Reddit, that was one of the first places I visited. Reddit is a heavily used content aggregator with a large community of commenters, and here I found many intriguing discussions related to science and *Portal 2.* Chapter 6 follows up this discussion by looking at fan created art from a variety of sites as well as the responses to that art from other gamers. Chapter 7 concludes the analysis section by focusing on videos that users created on YouTube and the discussions that arise in response to these videos. The conclusion ties all the preceding chapters together and surveys the implications of this research for a number of different, and interrelated, audiences.

Portal 2 **Synopsis**

For readers of this dissertation who are not familiar with *Portal 2,* a short description of the game is in order, as an aid in better understanding references to the game's characters and activities found in later chapters. This synopsis will be helpful in interpreting some of the interactions that players highlight from the game in their discussions in the analysis chapters. It should be noted at the start that *Portal 2* is a sequel to the original *Portal,* both of which were developed by the Valve Corporation. Both games contain a similar cast of characters, although additional characters were added in the sequel. In addition, the original game was designed to be played to completion in just a few hours and was part of a bundle of games that was put out by Valve as a package. The sequel was designed to be sold individually and was therefore designed as a longer game that included a much more elaborate narrative. For this reason, I chose to focus my research on the sequel rather than the original, although it is

important to note that for most players on the forums pieces from both games are used interchangeably. If a person talks about material that is unique to one on the games, however, it is usually from the sequel, both because *Portal 2* was issued more recently[1] and because it had significantly more narrative, which is the portion of the game upon which much of the fan creations in this study are based.

The game *Portal 2* is a single player video game with a first person perspective. It is what is known as a puzzle platform game, which means that players must solve puzzles to progress through the game. It begins with the player, known as Chell by other characters, waking up in a facility that is designed to be part of a scientific testing center. Chell learns that the original testing facility (featured in the original *Portal*) has been abandoned and fallen into disrepair. She embarks on a journey to escape the center's ruins, during which she is befriended by a robot named Wheatley who offers to help her find her way out. While she is trying to escape, Wheatley accidentally reactivates the robot that runs the facility, an entity known as GLaDOS, who had been deactivated by the player, Chell**,** in the previous game. The principle action of the game involves Chell and Wheatley's attempt to escape the facility while being pursued by GLaDOS, which involves navigating a number of obstacles and solving a number of puzzles in order to progress.

Throughout the game the player gets to explore the decaying facilities of Aperture Science, a fictional company run by Cave Johnson, which is depicted as an organization that has developed many different types of scientific advances at this site. During the exploration, the story of Cave Johnson is told through voice recordings that the player

[1] *Portal* debuted in 2007 and *Portal 2* in 2011.

hears, as well as through the physical remains of the facility he once ran. The player discovers that Cave had a very cavalier attitude towards science; he rejects such notions as safety standards in the name of progress and tends, in Cave's own memorable words, to "throw science at the wall and see what sticks." Eventually Chell ends up facing off against Wheatley, who takes control over the facility away from GLaDOS midway through the story and is revealed to be an adversary rather than an ally to the player. In the conclusion, Chell ultimately manages to defeat Wheatley and escapes the facility, finally free from the different artificial intelligences attempting to control the laboratory.

Throughout this journey of escape, there are two primary ways in which the player interacts with the game. The first is that periodically there will be puzzles to be solved using a portal gun, a device the player obtains at the beginning of the game that can make portals, that is, gateways through which the player can travel. The way the puzzles are solved is by placing blue and orange colored portals onto different surfaces. When two surfaces are connected in this way the player is able to pass through as if the two pieces of space were now the same. What is interesting from the perspective of a science educator is that properties such as momentum[2] are conserved when the player passes through a portal, leading to interesting possibilities by changing the rules of science in one way but leaving all the others intact. This allows players to solve problems based on their knowledge about how momentum works with appropriate adjustments for how the portals they create modify the world.

[2] Chapter 6 explores the question of momentum in Portal 2 in more depth. It turns out, as pointed out by one of the forum posters, that momentum is not exactly what is conserved although most online discussions of the game call what is happening a conservation of momentum. This discrepancy and what leads to it can be found in that chapter.

The second way players interact with the game is through exploring the facility between puzzles. Each time a puzzle is finished the player has to move further through the facility until they get to another one. During this time they are able to explore the area. Depending on how they choose to play, they may go through very quickly and only see a few parts of the facility or they may look more carefully and find many of the different details the developers put into the game. This includes things such as warning signs and newspaper articles, which all include particular ways of presenting science and the endeavors of Aperture Science.

Now that we have an idea of what the game is about and why it is an appropriate focus for this research project, the next step is to look at how players interact with the game and what they choose to create from their experiences with it. In order to place my investigation of this topic in its proper context, I will first lay out, in Chapter 2, a consideration of how we define what a game in and how *Portal* 2's position as a game (or not) impacts how users interact with it and use pieces of it elsewhere.

Chapter 2 What are Games?: Plugging into the Machine

When one writes, the only question is which other machine the literary machine can be plugged into, must be plugged into in order to work.

-Deleuze and Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*

This dissertation uses as its conceptual framework the work of French postmodern philosopher Gilles Deleuze, particularly his concept of assemblage. One of the goals of using Deleuze's concept of assemblage is to have it drive the entire research process and not be confined to a small space in a theoretical framework section only to disappear *in* the following chapters. When approaching the literature related in various ways to my research interest in Portal 2 and its relevance to science education, I found the idea of assemblage a particularly useful tool for clarifying my understanding as I considered how to navigate such a large amount of relevant literature with a project that spans multiple disciplines. As a starting point, I explored studies that shared my interest in the spaces related to games (as opposed to studies that dealt with only the games themselves) while also being concerned with science education. Within these narrow parameters, I found a handful of studies, including the work of Owens (2012) related to the computer game *Spore* and online spaces related to that game and of Steinkuehler[3] (Steinkuehler 2006, Steinkuehler and Williams 2006, Steinkuehler 2007, Steinkuehler 2008) with regard to

[3] Steinkuehler's work spans more than just science education but in her search for potential learning in *World of Warcraft* she specifically he includes the search for informal science reasoning as part of the research.

World of Warcraft and its online community spaces. From there, the search expanded organically to include other areas relevant to the assemblage that is my focus, science learning in the informal context of digital games, including research about using games in the classroom, studies attempting to generate definitions of games, and investigations of how affinity spaces[4] such as forums impact games.

There is no handbook for how to do poststructural dissertations. As I embarked on this project, therefore, I looked to other recent education dissertations that were explicitly poststructural and examined how they were constructed, in order to gain insights that I might use in the construction of my own work. The authors of many of these dissertations choose to eschew a traditional literature review section entirely, such as Jackson's study of southern girls and small-town education and Hodges's on fanfiction writers, and instead use their theoretical framework section and the literature of authors such as Foucault and Bakhtin as their literature review (Jackson 2003, Hodges 2011). I was also trained in thinking about post-structural research through classes related to the topic, such as my post-qualitative research methods course. One common piece of advice was to do research as if "I had never been trained to do research[5]" (St. Pierre, 2014). Therefore, readers expecting a traditional literature review will find instead that both the

[4] Affinity spaces are discussed in detail in the theoretical framework section. In short for games, they are spaces that are related to games such as forums and places where users can share fan art but are not directly connected to the game in any way. Gee defines a number of properties as being helpful in identifying something as a potential affinity space.

[5] While I was advised to do research if I had not been trained to do so, this does not mean that there are not helpful things to be learned from research practice. Instead, the focus was on trying to move away from the traditional constructs research brought to us such as our thoughts on what an interview or a literature review should exactly look like. The reason for this was that these definitions currently carry a fair bit of baggage related to positivism. In the case of the literature review, it tends to be heavily influenced by assumptions of the ability for researchers to survey the field and find holes and fill those holes with their knowledge, which relies on a foundational approach to knowledge not congruent with post-structuralism.

theory chapter and this chapter contain coverage of the literature. The focus of this chapter is specifically on what research says about how the concept of games, in particular digital games, molds and transforms as it comes in contact with different areas such as game design, education research, and anthropological study. This exploration provides insights into how to think about games in a productive way as well as into the potentially harmful ways in which they can be transformed.[6]

Hodges's dissertation on fanfiction was especially helpful to me in determining some of the structure I chose to use for my own work. Her work on fanfiction has many similarities to my desire to look at artwork created by fans as part of their process of engaging with *Portal 2*and she is similarly trying to use a poststructural approach, although primarily with Foucault, Bakhtin, and some Derrida, to consider the works. She summarizes the differences between her work and a more traditional approach as follows:

> Once again, a conventional study that is designed to find a Truth that can be universally recognized and applied would describe a concrete, linear method which would guarantee—at least in the clear and unbiased eyes of the researcher--validity and accuracy. While my methods and research practices involve no less rigor, it is necessary that they reflect the fluidity and texture of this study (Freeman, deMarrais, Preissle, Roulston, & St. Pierre, 2007; Lather, 2007), which examines ways in which the practices of writing fanfiction and participating in online fan communities shape and affect adolescents' subjectivities (2011, pp.29-30).

[6] This harmful transformation is most evident in areas where the concept of games becomes twisted by some to try and make quick easy fixes for educational woes without considering the larger contexts of what make games function. See the discussion below on gamification.

In addition, I also looked to the work of Deleuze and Guattari on how to do a literature review and took up their suggestion of starting in the middle. They discuss the trouble of focusing on the beginning and the end and of thinking of the middle as simply what occurs between these two points:

> The middle is by no means an average; on the contrary, it is where things pick up speed. *Between* things does not designate a localizable relation going from one thing to the other back and again, but a perpendicular direction, a transversal movement that sweeps one *and* the other away, a stream without beginning or end that undermines its banks and picks up speed in the middle (1980/1987, pp.25).

Of course, there is the question of why not just provide a systematic analysis of a couple of terms over a span of many years as well. In a way, the most focused area of this chapter, the coverage of studies in the section on games related to science education and affinity spaces, comes closest to fitting this description. It covers the limited studies[7]available that are primarily concerned with the spaces outside of the game itself that contribute to the game's meaning- making ability.

This narrow area gets exhaustive coverage in this review. Less extensive, but still thorough, coverage is given to other areas of research that provide important context for this study. Studies in this broader field are spread across multiple disciplines and use different language to discuss the same issues. It would not be practical to attempt to

[7] The reason for this limited coverage is there is much greater interest in a few related areas. The first is intervention style studies which use a game in a classroom space to try and teach a concept and then study how well they did that. The other is studies that either design games explicitly for education or primarily study the game as a standalone object without consideration for affinity spaces related to it. I still discuss some of these as informative to the larger concept of games but these have different goals then my own study.

review, for example, all scholarly studies dealing with digital games, even though the time frame for such a review would be limited to the past 45 years or so because digital games did not exist before the 1970s, since there are literally tens of thousands of such articles.[8]

The common strategy is to "laser focus" on a few key terms and use this as the way to limit the review of literature. This runs counter to the logic of Deleuze and Guattari. Their thinking focused on adding more through *and* rather than excluding the majority through *either/or* style logic which would focus on removing most of the material. As pointed out by St. Pierre, "The Deleuzian concepts assemblage and rhizome are particularly helpful in thinking connections rather than oppositions, movement rather than categorization, becoming rather than being" (2013 pp. 653). Including scholarship from a number of different disciplines/areas of study is essential, as they give a more useful picture of what is happening in the area of games research, but doing so by keying a search on a few terms would limit the literature to a particular viewpoint, since researchers in different areas tend to use different language even when describing similar phenomenon. For example when looking for work related to digital games and their surrounding communities scholars have referred to them as affinity spaces, communities of practice, third spaces, and simply as game forums and, while each term is different, they are all relevant to this study. Such a search would therefore inadvertently exclude a number of relevant voices in areas such as anthropology, sociology, or game studies.

With those caveats in place, I will outline the parameters of this literature review. The first, and probably most significant, is that I am limited to scholarship that can be

[8]A quick Galileo keyword search on the term "digital game" yields over one million articles and searching "computer games" yields three million. This does not even address online resources

found in English. That does not mean, however, that all the studies included here took place in the United States or even in English-speaking countries. In part because much of the scholarship deals directly with exchanges and activities in the geographically unbounded online world, many studies are not limited to a single country or region of origin. I am most interested in the studies that look at tools such as game forums and content aggregation sites and these are not bound by country in most instances, although they are by language.

In addition to traditional academic work, I also look to areas such as academic blogs and YouTube videos with an academic slant. These areas are limited by my ability to find them. There is a great deal of relevant content that exists in these spaces but which is not well-catalogued or captured by search engines. In addition to relying on search engines such as Google, therefore, I have also located online material by following links from one source that lead to other related sources. This area has grown the most during the research process, as videos such as those by Errant Signal, a YouTube author, would come up in discussions of *Portal 2* within the forums that I searched and serve to expand the literature base of the study. In addition, it may be noticeable that the majority of the studies are post-2000. The reason for this, as noted by Steinkuehler in her own work on massive multiplayer online games (MMOs), is that before that time, games were not considered worthy of study; when she began her research in 2001, she writes, no one had yet seriously addressed the question: "What, if anything, was the intellectual merit of playing in virtual worlds?" (2007, pp. 3)

The question of what exactly a game is will then be addressed through an extensive examination of a number of different definitions used in the literature and their

potential value and limitations. Delineating what a game is (and isn't) is much more challenging than it might seem initially and is important for an understanding of how this study looks at the game *Portal 2.* Unless otherwise noted, by "games" this chapter will be referring specifically to digital games, games which incorporate technology, as opposed to other types of games such as board games. The later portions of this chapter will focus on research from the last 15 years in order to situate my own analysis within that context as well as cover studies concerned specifically with spaces connected to games, such as forums.

The Definitions of Games

One of the earliest questions I had to consider was what makes a game a game? This was important to me as I needed to know what parts of *Portal 2* I needed to be analyzing and considering for my research. What follows is my exploration through a number of these definitions found in the literature and how they allowed me to think about *Portal 2*. For those who wonder which definition I finally decided to use for my analysis, I will have to disappoint and say "none." Instead, in the process of thinking through all the definitions used by other scholars, I arrived at the same conclusion that Christopher Franklin from the YouTube channel Errant Signal eventually reached, which is that any one of these serves to delimit the video game space in a problematic way (2013).The tricky part, as pointed out by Franklin, is that:

> Much like defining art it turns out defining games is largely contextual and it is extremely hard to come up with just one concrete universal definition. If you cast your net to wide you start including things that are pretty definitively not games. If I say 'games are interactive systems' and just leave it at that I have suddenly

> declared traffic patterns, governments and dead end jobs as games. If instead I say 'games are interactive software used for fun' where does that leave card games or board games or sports or games that aren't traditionally fun like *Dark Souls* or *Amnesia*?"

Franklin goes on to point out that fun is a very amorphous idea that ends up becoming problematic in defining something as a game, because it is contingent on an individual's particular experience with a game and not everyone will respond to the same game in the same way. In my case, *Portal 2* clearly falls into almost all of these definitions, as it contains all of the standard points expected in games, although not all games do. I still find it more helpful to avoid settling for a single definition; each of those discussed here was valuable for focusing on different aspects of *Portal 2* which other definitions would ignore or not consider essential to the "game."

As a starting point for understanding what constitutes a game, it is appropriate to begin with the seminal anthropological study of what constitutes play, Dutch cultural theorist Huizinga's *Homo Ludens.* Huizinga defines play as requiring the following: play is voluntary, play is outside of ordinary or real life, play is disinterested, play happens in a distinct space and time, play is ordered according to rules, play involves tension, play is absorbing, and play creates a community for those involved (1949). While over time the definition of what constitutes a game and play may have changed for many, Huizinga's work was critical as a starting point for exploring play and games more seriously. In particular, his notion of the magic circle is still commonly used today to help people think about games. The magic circle is the idea that play is bound by a particular space and time and the magic circle acts as a way of describing a separation between the "real"

world and the game. Entering the magic circle will vary depending on the game and might involve physical objects, such as a table and cards to play poker, or it could include a different limitation such as logging in to Facebook to play *Farmville*. For *Portal 2*, this entry point would be the process of starting the game and interacting with it. While interacting with the game the player is bound by rules of what the game will allow that apply while within the magic circle. It is important to note that gameplay may end when the player stops interacting with the game but that this does not necessarily mean all impact of the game disappears at this point. Huizinga himself argued that games have the ability to create social groups and could have impacts outside of the game itself.

For a more modern definition of games, we can look to the work of Salen and Zimmerman in *Rules of Play: Game Design Fundamentals*, one of the essential texts used in game design theory. They compare eight definitions that they obtained by looking at the seminal works of key authors and summarize their similarities and differences:

Elements of a game definition	Parlett	Abt	Huizinga	Caillois	Suits	Crawford	Costikyan	Avedon |Sutton-Smith
Proceeds according to rules that limit players	√	√	√	√	√	√		√
Conflict or contest	√					√		√
Goal-oriented/outcome-oriented	√	√			√		√	√
Activity, process, or event		√			√			√
Involves decision-making		√				√	√	
Not serious and Absorbing			√					
Never associated with material gain			√	√				
Artificial/Safe/Outside ordinary life			√	√		√		
Creates special social groups			√					
Voluntary				√	√			√
Uncertain				√				
Make-believe/Representational				√		√		
Inefficient					√			
System of parts/Resources and Tokens						√	√	
A form of art							√	

Figure 2.1: A table comparing different authors' definitions of games (Salen and Zimmerman, 2004, p. 9 of ch. 7)

As we can see here, even with eight well known authors who work on definitions of games there is minimal agreement on what elements are necessary for something to be considered a game with only the requirement of rules being close to unanimous although Costikyan does not make this a requirement. In the end Salen and Zimmerman arrive at a definition for their work by stating a game "is a system in which players engage in an artificial conflict defined by rules, that results in a quantifiable outcome" (2004, p. 11). For them this definition works best as they are working with game designers on how to create games. However, even when only considering digital games, this definition seems quite limiting. In particular, the requirement for conflict seems superfluous, as game developers have created numerous games that are devoid of what could be considered clash or conflict. As it relates to science education, work done with *Minecraft*, such as in learning about the body with models built in the game (Short, 2012), designates it as a game but there is no required conflict within the game.

Games as defined through win states.

One common way to define a game is the requirement of a win state. This is simply a condition that allows for a player or players to declare the game over and decide who has won the game. For many, this definition sounds quite reasonable and at first does not seem particularly restrictive. Even noted film critic Roger Ebert defined games this way and used this as a major component of his rationale of why games could never be art since they have "rules, points, objectives, and an outcome" (2010). I use his example simply to show the ubiquitousness of this definition (although it is also necessary to point out that this particular piece he wrote led to a fair amount of backlash

from people who played games who disagreed with his reasoning and found the common definition problematic).

Why does defining games through win states help to focus in on games? To have a win state means that a game must have goals within it and that allows us to consider what these goals are and how they can be achieved. For educators working on games this definition seems particularly helpful many times as these goals can be attached to educational outcomes. The goal then of game development or analysis is on how does the game help students reach this particular outcome which matches up with a desired learning goal.

Portal 2 clearly passes this test of whether it is a game or not. The goal of the game is to escape the lab in which the player has been trapped and players win when they manage to do this. In addition to this, the game is divided into smaller subsections which involve puzzles which can be won by the player reaching the door at the end and traversing through the puzzle to the next area. Each time this happens, the player is rewarded with a bit of storytelling that occurs.

The next follow up question is: how can a game not have a win state? For a good example of this, let us consider another game in which science educators are interested, *Minecraft*. Minecraft provides players with an open world in which they can gather resources and use these resources to build things according to recipes governed by the game rules. Short's look at science and Minecraft[9] provides the example of students

[9] In this piece, Short covers a number of examples of how he has utilized Minecraft in the college science classroom. He also points the reader towards teaching resources such as a wiki that have been created with the goal of helping teachers use Minecraft. The focus of these descriptions is on demonstrating what

constructing parts of the human body, such as nerve and vascular systems (2012). One reason why this particular game works reasonably well is that it is fairly free form and players can choose what way they wish to play the game. There is not a set ending state[10] where the player is done and, as such, it can be adapted to new situations such as a teacher having students build models in the game.

Games as defined through mechanics.

Some scholars have suggested defining games through their mechanics (Franklin, 2013).The defense of this is usually that by defining games as being about their mechanics, it becomes possible to distinguish video games from other forms of media such as movies and television. Games uniquely involve player input and as such a digital game could be thought of as something that is designed to focus on utilizing the player's inputs in meaningful ways as opposed to being something in which the player passively participates in. This definition can be helpful as it focuses on how the particular differences between digital games and other media can be made to be productive for the purpose of the game. This can also be valuable for educators who want to consider what games can do uniquely that would not be possible with other strategies in order to figure out where they might want to add games to their own classrooms.

---

is possible with the tool rather than something like a quantitative study to focus on the quantifiable effectiveness.

[10] When Minecraft was released there was no ending state. On November 11, 2011 there was a patch to the game which added the Ender Dragon which is suggested to be an end goal for a player. While this did add a potential completion point to the game, the majority of the focus of the game is still primarily on the world building and of all the education papers I have seen mention the usage of Minecraft, none have attempted to use the portion of the game that is made to have an ending and instead rely on working with the crafting system to create useful and interesting designs in the game world that can contribute to the topic of study of the classroom. In all the game changed very little with the addition of the Ender Dragon and as such it seems requiring an end state to be a game is not an ideal definition, since defining pre-Ender Dragon Minecraft as not a game and post-Ender Dragon Minecraft as one does not make much sense due to its fairly insignificant impact on the game as a whole.

While this definition can provide some benefit, on further examination it does have some significant limitations. The most challenging part is deciding how much interaction is enough to count. Franklin[11] points out that games such as *Proteus*[12] are often decried as not games by certain gaming demographics due to the feeling that they do not have sufficient levels of interaction even though there is clearly some interaction from the player with the game. The problem with this is "getting mad at a game because it doesn't have enough interaction is like getting mad at a song because it doesn't have enough notes. You might disagree with the minimalist aesthetic but that doesn't make it not a song" (Franklin 2013). The definition can be seen as useful in allowing researchers to actualize key features of games that could improve the classroom experience but beyond that, using this as a determinant of what does and does not constitute a game is not particularly helpful. Salen and Zimmerman's chart on the different definitions of games include a number that are related to this idea of mechanics, such as games requiring rules to limit players; requiring activities, processes, or events; and being goal-oriented (2004).

Portal 2 has sufficient interaction to be a game under this definition. Much of the game focuses on the player's ability to manipulate where they place portals to progress through physics based puzzles. While the game does have times where it is primarily

[11] Chris Franklin is the author of a web series that critically analyzes games. The particular video I am citing is about the question of the definition of games. He explores this question by using example games to question whether these definitions are useful by demonstrating what they might exclude as well as include. In addition he also includes analysis from other works such as Salen and Zimmerman's text *State of Play.*

[12] *Proteus* is an open world game where players explore a pixel art island. During this exploration the player is not pushed to explore in a specific way and there are no goals presented by the game itself which is the reason often cited by gamers if they wish to declare it not a game. In addition there is minimal interaction other than moving around the island although your exploration can have an impact such as some animals running away when they are approached as well as the player can choose when to proceed to the next season for the island.

delivering story while the player merely walks along or listens, these are punctuated by puzzles fairly consistently. Most of the time when people suggest certain things should not be classified as games because of insufficient interaction it tends to mean that the interaction is much more limited, in their mind, involving primarily simple clicking of choices, such as in *The Walking Dead*, or where the game is primarily about walking around a world and exploring it, such as in *Proteus*. In addition, this threshold seems overly subjective; many games allow for a variety of playing styles that differ in terms of the level of interaction, such as playing an open world game with missions but ignoring the missions and just exploring the country side and appreciating the aesthetic.

Games as requiring fun.

Requiring fun is a common definition since games are many times associated with play and therefore fun. In Huzinga's *Homo Ludens*, he includes fun as part of his definition:

> Now this last—named element, the *fun* of playing, resists all analysis, all logical interpretation. As a concept, it cannot be reduced to any other mental category. No other modern language known to me has the exact equivalent of the English 'fun'… It is precisely this fun-element that characterizes the essence of play (1949, p. 3).

This part of the definition of fun can be especially popular with educators who want to harness the motivational power of games. In addition it resonates with educators who wish to consider gamification as a way to improve activities in the classroom, since gamification focuses on the motivational ability of adding systems such as points and

achievements to otherwise non-game like activities. While this component of fun is essential to Huzinga's definition of play, Salen and Zimmerman do not find it a particularly helpful definition for a game designer. While fun may be a goal they hope some players achieve, this is an outcome of the game rather than part of its working parts which must go together to make fun happen for players and as such does not end up in their definition (2004).

The question of whether *Portal 2* is fun can be a tricky one. I found my game experience fun as this was one of the original reasons I kept playing the games---- I enjoyed what I was doing. The box art for the PC version of *Portal 2* includes a mention that the game is "massively entertaining" (*Valve Corporation*, 2011). Trying to identify whether the game fits this definition can best demonstrate its limitations. Whether a game is fun or not is ultimately contextual based on the player's experience with the game; simultaneously, though, this shows one of the greatest strengths of this definition. It focuses on how the particular experiences of players help us know more about the game rather than focusing on specific mechanics of how a game is built. In a sense, with this definition *Portal 2* is not a game when viewed in isolation but only when it is being played by someone and they are enjoying the experience. In this way the player is included as part of the assemblage when discussing games, which is an important idea to keep in mind as I explore the game in this research.

For games overall, however, this definition raises some other issues as well. There are now games that are focused on creating experiences other than fun. *Amnesia* focuses on attempting to scare the player while *Depression Quest* attempts to give players some insights into depression. *Papers Please* goes even further with trying to create a

sense of dread for the player as they play a border crossing guard who, in order to support his family, must exclude people from the country who desperately want to get in. While these experiences are not enjoyable, they still seem to be games and provide valuable experiences. In addition to this some of these games may provide critical insights for educators as they consider games. Games for school are unlikely to have fun as their primary goal, although many probably have some elements of fun, and as such, exploring games that are not aimed at being fun but can still be compelling might be beneficial for educators.

Why Definitions Matter

The question of the definition of games matters primarily due to issues of what gets explored as a possibility for a game and what becomes excluded. Franklin notes that many users who choose to define experiences as not-games do so primarily to exclude games that are not interesting to them and that they do not want to be a part of their activity (2013). This can have very real impacts as it directs companies about what to make and encourages or discourages game designers from trying out different strategies for building new games.

However, this exclusion is not always a bad thing. For example, McClarty et al. define games, following Salen and Zimmerman, as systems which involve artificial conflict, are defined by rules, and have a quantifiable outcome (2012). This definition is helpful for exclusion, however, as they do not wish to explore gamification in their article and they also do not want to explore virtual worlds such as *Second Life*. What is important is that these exclusions need to be done in ways that are designed to encourage productivity, such as helping a researcher focus on particular aspects of games, rather

than simply excluding products that people might not understand at first or personally not enjoy.

How This Can Help Science Education

In this exploration of definitions, a number of the less common ones have some strengths of which science educators can take advantage. One of the largest is the design requirements for some of the less traditional definitions. For example, retro games like *Geometry Wars* have much less focus on big budget graphics, an area where education-focused games cannot really be competitive, and instead concentrate on making innovations to gameplay styles to foster new types of experiences (Batrack 2013). By pushing the boundaries of what makes a game a game, it is possible for small studios to make quite compelling games that exist alongside multi-million dollar projects. By focusing along these same axes it may be possible for educators to better harness some of the advantages of games while not trying to compete in areas where clearly they are outclassed in terms of budget. No educator should be deluded into thinking they will be designing the next *Call of Duty* or *Battlefield* game just with chemistry learning instead of shooting people.

Additionally, as many of these examples show, trying to apply simple formulas for the creation of games tends to lead to mediocre follow-ups to a single great game which changed something for the better; the knock-offs attempting to formulaically copy the elements of that game are unable to recapture the experience that led to the original's success. This is another place thinkers like Deleuze can be instructive as well. As researchers we must aim not to recreate exact experiences that can be easily replicated in every classroom nationwide as part of a big multi-million dollar rollout. These attempts

at recreation tend to miss some of the steps or they attempt to place these trials into new assemblages without considering what else has changed between the original research project and the new location where the idea is deployed.

Educators and Their Interest in Digital Games

Digital interaction is growing. According to a survey done by the Buntin Group in May of 2013, the average American web user surveyed reported spending 23 hours per week online texting, emailing, and using social media such as Facebook, Twitter, or Pinterest. (eMarketer, 2013) The amount of time spent online continues to grow as more people utilize mobile platforms (smartphones and tablets) in addition to their home computers and laptops. A Nielsen survey from February of 2014 reported that American adults spent on average 34 hours a month accessing the internet through smartphones and 27 hours a month through PCs (Sterling 2014). This accords with other research that affirms that mobile internet usage now consistently surpasses access through computers and that time spent online on all platforms continues to climb (CNN Money 2014).

While social media use is a driving factor in the high rate of internet access both in the United States and around the world, millions of people also spend a great deal of time online playing games and spending time in game-related internet spaces. To use one popular game as an example, 28 million people worldwide play *Farmville* each day. The numbers add up quickly. According to an infographic by Daly, "As a planet, we spend 3 billion hours a week playing video and computer games" (Daly 2012). In terms of games and teenagers specifically, it has been found that 96% of 12-17 year olds in the US play digital games in some way (Lenhart et al. 2008) Lenhart also notes that these players tend to participate in many different types of games with 80% of teens

participating in 5+ different genres of games and that at least 75% of them play games socially rather than only by themselves.

It would be irresponsible of educators, particularly those in the field of science education, to ignore the impact of these digital interactions or the vast potential of online games and game-related online activities to help us understand and reach out to those we seek to educate. It is not surprising, therefore, that gaming and gamification[13] has attracted increased scholarly interest among education researchers in recent years. It should also be noted that in addition to presenting research and analysis in journal articles and books, scholars in this relatively new field also sometimes publish in nontraditional outlets such as scholarly blogs and You Tube videos.

Finally, it is important to note that many of the claims regarding games, both as positive forces of learning and as detriments, are likely to be extreme on either end of the spectrum with what actually occurs being somewhere in the middle. It is not as interesting to write that games have some good and bad points and can be used well or poorly in an educational setting as it is to state that games are the future of education or that games are destroying student's abilities to perform in the classroom. As Bogost points out in *How to do Things with Video Games*, "technology neither saves nor condemns us. It influences us, of course, changing how we perceive, conceive of, and interact with our world… From keeping a journal to paying a bill to reminiscing about an old television advertisement, the Web offers just as many mundane uses as it does remarkable ones" (2011a, p. 2-3).

[13] Gamification: The use of game design elements in non-game contexts. (Daly 2012)

One of the most iconic figures involved in education right now is Bill Gates as he is trying to push for more changes in schools to address concerns that schools have not changed enough to train the "workforce of tomorrow," as noted in his address at the *National Educational Summit on High Schools* (2005). In turn, educational reformers have called for changes to improve students' 21st century skills to deal with extensive changes in the job market (Levy and Murnane, 2004). To address these concerns, one area educators have turned to has been games; the Horizon report has noted that game-based learning is rapidly gaining traction (Johnson et. al. 2011).

Games are able to provide for three basic human needs: competence, autonomy, and relatedness, although not all games necessarily deal with all three (Rigby and Ryan, 2011). For educators, this means that when games are able to activate one of these three needs for students, they are also providing learning opportunities. When it comes to competence, games provide a key ability to allow for failure as part of their design, which can help students since in many other activities failure is not encouraged, although it is considered critical in many game designs (Gee, 2009). This process of failure works in games because immediate feedback is part of their design, in which failure serves to direct a player towards a particular goal (Dickey, 2005). When designed well, games allow for student autonomy in their decisions, such as with *River City* in which science students were able to explore their learning environment independently and make decisions relevant to how they would solve the problem (Ketelhut, Dede, Clarke, and Nelson, 2006).

However, for this feedback and autonomy to work, it is important to keep in mind that language matters. As pointed out by Pierce, games require a digital literacy and it is

sometimes assumed that students will pick up more than they do about how computers function (2014). This lack of digital literacy, which affects students' abilities to participate in activities such as using digital games to learn, tends to disproportionally affect immigrant children with parents who do not speak English (Pierce, 2014). There has also been significant research in education about the possibility of learning English from participation with digital games, such as Sundqvist and Sylvén's work with Swedish students to see how digital games impacted student learning of English (2014). The impact of language on the web can also be seen in areas outside of games, such as Google's move to create the .SOY domain to try to attract Latino attention to these sites although so far results have been mixed.[14]

This limitation is also relevant to *Portal 2* as well; for example *Portal 2*'s German translation does not do a particularly great job at translating the humor in the game and tends to lose the subtlety that made much of the game story function well in English[15] (killedintranslation.com/portal2/, 2011). This is important to keep in mind as this will ultimately affect all of the work I am doing here. During this work I am participating on the internet in the portion that is predominately English. Unlike one of Pierce's students who did not know there were Spanish websites, I do know about how to access other parts of the internet, but I do not have the language skills to be able to capitalize on this knowledge.

[14] Aura Bogado points out that the .Soy domain tries to segregate Latinos to particular parts of the internet while not doing much to actually encourage diversity such as opening up job opportunities at Google. It also produces some confusion with search engines due to the popularity in English of Soy products (2014).

[15] As I cannot read German I had to rely on the comparison between the German and English as provided by someone else who knew English that was comparing the two. In this case the author does go through a number of examples to demonstrate what is missing in the translation, which does make it clear that something was definitely lost.

In addition to trying to encourage games that can help with learning in the classroom there is also a move towards gamification, that is, the use of game design elements outside of the game context. Gonigal notes that gamification could improve education by providing additional opportunities for social engagement, encourage increased productivity for students, and provide more chances for students to create meanings that connect what they are learning to what they want to learn about (2010). Lee and Hammer further note that gamification can help improve motivation for students (2011). However, there are also studies, such as that done by Hanus and Fox, which suggest that gamification can actually lead to lower motivations and test scores for students meaning that any attempt to harness these benefits in an educational setting must be done carefully (2015). Hanus and Fox demonstrate to us the need for further study into the area of how games function and what becomes important in the play assemblage for games to have their positive effect. If we merely take a couple of concepts from games and try to apply them elsewhere without accounting for the impact of all the different parts of games the desired results do not appear.

Bogost (2011b) points out one of the trickiest parts of dealing with gamification is that most of it is, in his words, bullshit. To be clear he does not use this terminology for the purpose of provoking someone but instead to help distinguish between lying and marketing speech. The goal of bullshit is not focused on whether something is true or not but instead to accomplish the goal of the speaker (Frankfurt, 2005). In this case, the goal is to obfuscate meaning and capture power in a word or phrase. Gamification makes as an excellent way to market the benefits of games which are fairly amorphous and difficult to pin down while changing it into something that seems straightforward to do successfully

and is easily understandable by non-gamers. Bogost goes on to point out that "game developers and players have critiqued gamification on the grounds that it gets games wrong, mistaking incidental properties like points and levels for primary features like interactions with behavioral complexity."

Science Education - Specific Hopes for Games

While science education may have some concerns about gamification, much of the science education research is more heavily aimed at how we can utilize games to learn about particular topics or to allow for students to explore, such as in simulations, topics that might otherwise be too challenging, difficult to visualize, or otherwise not easily taught through other methods. Video games are a growing area of research in science education, as researchers learn more about how they can be utilized in the science classroom for topics ranging from water quality issues (Barab et. al. 2009 ; Schwartz 2012) to genomics (Muehrer, Jenson, Friedberg and Husain 2012) to forensics (Beier, Miller and Wang 2012). In addition to games designed specifically to serve an educational function, researchers are increasingly finding ways to use commercially designed games, such as *Little Big Planet* (Angelone, 2010), *Minecraft* (Duncan 2011, Short 2012; Tromba, 2013), and *Osmos* (Gillispie, 2011) to teach a variety of concepts in diverse areas such as physical science, ecology, and physics. In fact, *Portal 2* is frequently used to teach physics concepts (Pittman 2013) --- so much so that there are whole websites, such as teachwithportal.com, devoted to the subject.

While video games have been the object of a growing body of research in science education, most of that research has focused on how games can be used by educators to directly teach scientific content concepts (Young et al. 2012) rather than examining how

currently popular games may shape attitudes toward science. In other cases where games are seen as addressing scientific skills like using models and testing ideas, such as the work of Steinkuehler and Duncan (2008) dealing with *World of Warcraft* and "the habits of mind of students," games have been shown to address these concerns but not in ways that would make the connection to science explicit to the players.[16]The National Research Council (NRC) has called attention to the importance of exploring how science works in such non-classroom settings since "news and entertainment media merge with natural history museums and science centers, after-school programs, and computer games and gaming communities to reshape the world and people's exposure to science" (2009, p. 28).

While most researchers, working in the more traditional vein mentioned above, tend to largely ignore what might be perceived as periphery activities to game playing, such as forum discussions or fan art creations, I am not alone in pursuing research related to these arenas. For example, Owens examines forums related to the game *Spore* and what discussions players have on them (2012). Owens's (2012) paper about *Spore* is particularly interesting since Bohannon had reported on the same game in *Science* as being especially problematic and non-scientific (2008). What Owens found was that while at a purely content evaluation level Bohannon was correct, that when examining spaces of interaction, such as the *Spore* forum, that such content actually led to interesting discussions that could be evaluated as congruous with normative scientific views.

[16] Steinkuehler and Duncan show that players participating in *World of Warcraft* are utilizing strategies such as the deployment of evidence in making arguments related to the game. The different examples they see mirror scientific practices with which science educators are concerned but do so in settings that do not share the same symbols and vocabulary that would be associated with the scientific enterprise.

Research in Games Related to Science Education and Affinity Spaces

Steinkuehler is one of the most prolific authors in recent years in the area of learning which can occur in the social spaces surrounding games, as opposed to the majority of research which focuses on the games themselves as content delivery engines. She notes that when many researchers discuss games, "there is a tendency to focus solely on the relationship between games and classrooms to the exclusion of all others – a fixation whose symptoms include a near obsessive focus on the question of what game-related knowledge and skills 'transfer' to formal classrooms, despite the grand irony that it was always classrooms that were supposed to teach things that might transfer to life beyond them, not the other way around" (2007, pp.8). In this outline of her previous and current research, she outlines five primary ways in which games could be explored to find learning that we as an education community could value:

(1) Collaborative problem-solving

(2) Digital media literacy practices

(3) Informal scientific reasoning

(4) Computational literacy

(5) Cultural mechanisms for learning (Steinkuehler, 2007, pp.4)

While all five of these are clearly valuable, I will focus most heavily on her research into informal science reasoning as this work most closely resembles what I would like to achieve in the work presented in this dissertation.

In 2006, Steinkuehler worked on a piece with Williams to take both of their works on Massive Multiplayer Online games (MMOs) and incorporate them to into a theoretical framework for MMOs as "third places." In this work, the two combined Steinkuehler's

work, which was a qualitative study of cognition and learning in MMOs from an ethnography on the game *Lineage,* with Williams' survey research focusing on the game *Asheron's Call.* Williams studied first time MMO participants by providing some with a copy of the game and compared them to other participants who did not play MMOs. From these two mixed methods studies with fairly different ontologies at the outset, they found that both came to similar conclusions of third spaces being a helpful way to think about how MMOs function. In short, a third place[17] is where "individuals can gather to socialize informally beyond the workplace and the home" (2006, pp. 889).

Again in 2006, Steinkuehler also published a study utilizing a combination of discourse analysis and functional linguistics to look at chat that occurs in *Lineage*. In this fascinating work, she took apart a single line that would be a fairly standard statement for a player of *Lineage*: "afk g2g too efot regen no poms" (pp.42). She showed how this statement worked in the specifics of a "pledge hunt" to emphasize why the player who made the statement would need to leave the game and his plan to return. Steinkuehler went on to explore how this functioned, based on a number of important factors such as community-valued goals and identity issues that were central to forming the activity in which the speaker was participating and why he would make the statement in the particular way she or he did. She concludes by pointing out how much can be learned from these spaces by exploring fairly simple statements that might not stand out particularly within the game space itself.

Then in 2008, Steinkuehler and Duncan further explored MMOs with research into *World of Warcraft* that was specifically focused on informal science reasoning. In

[17] For a more detailed discussion of third places, see Olden burg's book *The Great Good Place: Café's, Coffee Shops, Bookstores, Bars, Hair Salons, and Other Hangouts at the Heart of a Community* 1999.

this work, they specifically focused on random sample of 1984 discussion posts, which were related to the game. From these posts, they used a coding scheme based on a combination of "the AAAS (American Association for the Advancement of Science) benchmarks for scientific literacy, Chinn and Malthora's theoretical framework for evaluating inquiry tasks, and Kuhn's framework for categorizing epistemological stances in argumentation" to analyze the data(pp. 532). From their coding, they found that a number of practices that were related to scientific reasoning were present in these posts, including the usage of data/evidence, using models, looking for alternative explanations of data, as well as social knowledge construction. She concluded by encouraging researchers to further explore these spaces surrounding games as potential spaces for "academic play" that could occur between school and home.

Well Played: A journal on video games, value, and meaning, which launched in 2011, had a special issue in 2013 devoted to theories of playing well[18]. Several contributors to this issue have provided valuable insights into how to think about games. O'Donnell, for example, introduces her audience to how she has approached game studies based on her background as a Science and Technology Studies (STS) scholar and poststructuralist. In her piece, rather than go through a specific game, she explores how it is possible to think about games academically and what might be meant by the journal's goal of playing well for its articles. She discusses how the attempt to "divorce ruminations on method from those of theory" caused significant trouble for her own project, as theory ultimately gives the researcher the ability to make sense of research activities (2013, pp. 5). She also includes a discussion of deconstruction and how the

[18]The journal describes its goal of Playing Well to mean that authors should closely examine their experiences when playing a game and work towards developing a literacy of games.

nature of games makes them uniquely placed to favor this and other post-structural techniques, as there is an expectation that every person will play a game differently.

In another piece in the special issue, Duncan explores how perspective can be explored in contested affinity spaces. This study is a document analysis[19] of debates between game designers and players on the *World of Warcraft* forums. What he found particularly interesting about this specific type of space is that the game designer and game players have competing viewpoints of how to understand what happens in the game and this space allowed for some exploration of what occurs when these views contradict each other. Below is an example of a post from one of the users in the study commenting on the usage of simulations constructed by the player base to understand how changes to the game would impact players:

> People perceive simcraft data as validation, much the same as people my field (Quantum Optics) feel molecular dynamics validate their data. I'm not sure what kind of exposure you had to modeling in your marine biology PhD, but simulation data is often used and accepted in the academic community as tool for understanding the underlying effects of individual variables. Yes we're talking about toy models. But the same can be said for a great many "real" experiments in science. Model systems are also toys. The benefit of studying toy models through simulation, as opposed to studying them in experiment is that you so much more control over every possible variable. There's so much more data output that can be generated from simulations. The World of Warcraft really isn't that much

[19] Duncan focuses specifically on forum discussions that occurred where the lead systems designer, screenname "Ghostcrawler", participated. From these discussions he was interested in looking at how the different viewpoints of players and game designers could interact in an affinity space. He choose Ghostcrawler as he was "a near omnipresent figure" on the forum.

> different from the "World of Science". WWS and raid parses are similar to experiments performed on model systems. Simcraft data is analogous to molecular dynamics (2013, pp. 49).

As can be seen here, there are definitely times where the world of science can come in contact with tools used within affinity spaces and relationships can be seen between how players perceive their own tools and scientific practices

In the next article in the special issue, Philippette explores a combination of MMO (Massive Multiplayer Online) forums (those devoted to *World of Warcraft*, *Everquest 2* and *Aion*, three MMOs with a largest number of players) to give another perspective on how forums can contribute to the experience of games. Philippette uses Boltanski and Thévenot's work, a grammar of political bounds based on a number of philosophies including Bossuet, Rousseau, Hobbes, and Smith, to analyze the interactions occurring on the forums. A total of 786 messages were analyzed; each was chosen for inclusion in the study based on using a search for keywords to suggest justification in their posts. To help with analysis, the author chose to only analyze the posts at an individual level rather than as part of a larger whole of the thread they were a part of and coded each post as part of one of the "Common Worlds" that were set up by Boltanski and Thévenot. The analysis suggested that player justification was not limited to a single Common World such as "efficiency, pleasure, or fairness" but instead that it was a complex network in which these interacted to all matter simultaneously (2013, pp.73).

This work also demonstrates some of the limitations of language in research into game affinity spaces. Philippette uses a number of French forums, which are translated into English for the audience reading the journal, which would normally be inaccessible

to researchers who cannot read French. As more research is done in this area, it is critical that researchers with other language capabilities continue to have their work seen and that researchers consider how experiences in other languages might both differ and be similar to experiences in the English language. Philippette also noted that trying to apply coding structures to forums could be quite challenging and required significant interpretation, since the discussions are both chaotic and unstructured in most instances. For example "sometimes long threads seem to dissolve into a series of jokes performing a phatic function in the discussion, without any content suitable for analysis" (2013, pp. 75). I would argue in the case of my own work that this is one reason I am looking at discussion threads in a more holistic manner rather than trying to separate out individual posts, as posts are clearly a part of the landscape of the forums even if their purpose may not be easily discerned by analyzing them at an individual level.

Finally, Owens's paper looking at *Spore* is the closest a study in science education has come to having similar goals to my own although he undertakes it somewhat differently. Owens explored a set of forums related to *Spore* to explore what players did with the game while at the same time considering the academic viewpoint of the game as an "intelligent design simulator." Academic studies such as "Flunking *Spore,"* which appeared in *Science* in 2008 have been critical of the game. From his interactions in these forums, he found that rather than being encouraged to take up viewpoints similar to intelligent design that players were instead encouraged to explore science further due to activities that originated in the game (2012). What was most influential from this work was the notice that it is critical to look to spaces such as forums to see how people interact with the game rather than simply applying a checklist of content standards versus

what is present. It turns out that players do not always respond as might be expected and as such it is important to consider what the game makes possible for them rather than thinking of players like a sponge that will simply absorb all the material they see as is.

Conclusion

While exploring the literature on games, it is noticeable that education researchers tend to view games in one of three ways. The first is to see the game as a series of steps that students must pass or succeed at in order to move to the next step, many times accompanied by some type of reward/point system[20], to eventually achieve a learning goal by the end of these steps. Other researchers have moved beyond this and realized that while games may have an eventual end learning step, the path to this is a non-linear one. The game is still made up of challenges that students must accomplish but those challenges can be designed such that they are achieved in different ways or in different orders to allow for choice from the students as well as to achieve differentiation for different learners. Finally**,** the authors of a few studies, such as Owens and his exploration of the Spore forum, have realized that in addition to the game and its decisions there are a multitude of other pieces relevant to the assemblage that is game playing, such as YouTube videos, twitter, discussions boards and such, that can interface with the game and become critical components to interactions that occur and contribute to science learning.

The first two ways of looking at gaming clearly serve a useful purpose for some research as it tends to focus on what can be done to create interventions that might help

[20] These systems can range from something quite simple as getting points for doing expected tasks to quite elaborate such as achievement systems or collections such as badges.

students and better teach certain topics, and therefore the emphasis is on what elements should go into the design of the game. For a better understanding of how science learning occurs, however, studies that follow the third direction will provide greater insights into how gaming actually happens when not in a small study research environment or classroom. This approach is more likely to provide insights into how these games transform as they interact with other assemblages, such as parts of the internet, to provide an experience that is markedly different than the experience of having a handful of people playing a game in a controlled direction as might have been intended by the designers of the game. I have followed this third direction in my own work. In the next chapter, I will explore the concept of Deleuze and Guattari's concept of assemblage theory in depth and how it, and some other post-structural concepts, guide the research I am doing.

Chapter 3 Theoretical Framework: Using Deleuze and Guattari

Great Work! Because this message is prerecorded, any observations related to your performance are speculation on our part. Please disregard any undeserved compliments.

-*Portal 2* announcer

The entry on Deleuze in the *Stanford Encyclopedia of Philosophy*, not surprisingly, includes a discussion of assemblages, stating that assemblages involve "emergent unities that nonetheless respect the heterogeneity of their components." At first this sounds like the common adage that the whole is more than the sum of its parts with the corollary that the part is also more than just a piece of a whole. While this may be a good first step in describing an assemblage, continued work with the idea has shown that this seemingly simple and straightforward statement fundamentally changes the way we need to think about the world. I will first explore what I mean by an assemblage and will follow this up by exploring how it could help me in my research about *Portal 2* and the game's relationship with science. While this chapter will do a bit of connecting Deleuze and Guattari's concepts to *Portal 2*, it will primarily be focused on establishing the concepts I will be using in the dissertation; the next chapter will go into a detailed look at how these concepts can be applied to my research including using specific examples from the later analysis chapters to highlight the concepts in action.

Why Do This at All?

Before describing in further detail what an assemblage is and how an understanding of this concept is useful to my research, the first question I feel I should address is: why do I need to work through concepts like this? When I discuss my research**,** I have definitely encountered a number of people who suggest that I just "tell them what I found" and leave out any explanation of the theoretical framework surrounding the work, which seems superfluous to them. While this is a simpler route that does sound tempting, as it is both easier and avoids the complaints about "empty, meaningless jargon," ignoring the concepts that provide the framework in which I am working means simply rehashing work already done in slightly different contexts in ways that are comfortable because they are familiar. In the end, all research uses ontological foundations; it is just that research that simply tells the reader what the researcher found relies on using an unexamined ontology. As Manuel DeLanda has noted "when social scientists pretend to be able to perform these tasks without ontological foundations, they are typically using an implicit, and thereby uncritically accepted, ontology" (2006, pp. 7).

In *What is Philosophy*, Deleuze and Guttari describe what concepts are, which demonstrates why these can be so hard to discuss. "Every concept has an irregular contour defined by the sum of its components, which is why, from Plato to Bergson, we find the idea of the concept being a matter of articulation, of cutting and cross-cutting. The concept is a whole because it totalizes its components, but it is a fragmentary whole" (1991, pp. 16). In my research I work together multiple Deleuzian concepts with assemblage being the primary one but also include other related ideas such as deterritorialization, capacities, and lines of flight. The problem is that it is tempting to

view these concepts as a perfect network that can address any possible situation and that have no conflicts with each other within the framework that they build. However, what actually happens is each of these concepts, and even different versions of the same concept, bring different pieces together in a fragmentary way that does not create a perfectly neat system. What makes this particular framework in which I am using tricky, but also more rewarding, is that it does not attempt to make these rough spots go away. Instead of attempting to smooth away the rough spots, I will attempt to use these places of discontinuity to allow for ideas to be examined since these ruptures tend to be where fascinating things are happening that other frameworks might gloss over because they do not play nice with the story being crafted by the work.

For example, anyone who has read *A Thousand Plateaus* can tell you that if you try to come away with a single definition of an assemblage from Deleuze and Guattari, you will likely fail, as they have many definitions within the work that change as new situations are addressed with the concept. Similarly, when we use the concept in the machine that is education research, it will be used alongside a number of other concepts, such as triangulation and data. Even if we disagree with how these concepts are used and attempt to change them, they do not cease to impact our work, as we do not work in isolation. "They are not pieces of a jigsaw puzzle but rather the outcome of throws of the dice" (Deleuze and Guattari, 1991, pp. 35)

If these concepts are fragmentary and do not always perfectly align, then how do I justify using them? Deleuze and Guattari suggest that viewing these concepts as an archipelago or skeletal frame is a helpful metaphor. In this way, the concepts still serve a purpose. They provide a method to be able to put together phenomena as they are

encountered in a way to create thought rather than to have absolute chaos. As the pair writes, "We require just a little order to protect us from chaos… This is why we want to hang on to fixed opinions so much. We ask only that our ideas are linked together according to a minimum of constant rules" (1991, pp. 201). In order to do research, a theoretical framework to allow for some sense of order is necessary. I consider the concept of assemblages a particularly useful tool to think with, as it acknowledges its skeletal nature rather than attempting to become something more than it is, which I would suggest is a problem with most of the other frameworks I have considered for this work.

After going over the constructs from Deleuze and Guattari I plan to use in this work, a follow up concern to address is why I chose to use these over other frameworks. While it is true that some other frameworks could be utilized for this study, I find that Deleuze and Guattari provide a framework that best addresses the combined challenges presented by this study. These challenges include:

(1) Statements with problematic meaning–Much of the evidence I have been looking at relies on the fact that statements can have multiple meanings both due to the humorous nature of much of the content as well as how discourse, such as "trolling,[21]" tends to work on the internet.

(2) The intersection of different types of evidence– While all research involves looking at multiple pieces of evidence, this work relies heavily on looking at a

[21] Trolling is term used for certain types of speech commonly found on the internet, although it can occur in other places as well. While if something is trolling or not is somewhat context dependent, in general it can be seen as statements that are intended to have double meanings where when read at face value it actually has the opposite meaning of what it has for the part of the audience that is supposed to know it is actually trolling. While somewhat similar to satire, trolling relies on the fact that some of the readers will take it at its literal meaning whereas satire wants all the readers to know it is satire. One of my examples below will explore what this idea looks like to give a better idea of how it functions in this context.

very wide variety, in addition to multiple types, of evidence. For example, I look at written speech, mathematical algorithms, comics, video games (which include sound, video, and an experiential element), just to name a few.

(3) Study interests with fluid boundaries– To be able to complete the study I do have to bound it and have done so by looking at specifically the intersection of science education and *Portal 2* (rather than all games or bigger questions than just science education). However, this bounding is more based on the idea than on a specific setting and, as such, tends to be more fluid in what types of evidence it explores and where this evidence is found.

This is not to say that other strategies cannot address some of these issues as well, but I have found Deleuze and Guattari particularly well suited for handling these challenges as well as providing valuable insights for the particular pieces of evidence with which I am working**.**

Deleuze and Guattari and Chomsky

Suggesting that assemblages require a complete rethinking of how we talk about the world and our research is admittedly a big claim and may seem an exaggeration until that claim is examined more closely. In *A Thousand Plateaus: Capitalism and Schizophrenia*, for example**,** Deleuze and Guattari spend a fair bit of space explaining their issues with Chomsky; this is a good starting point to see how such a simple idea of an assemblage can change how we understand language. They argue:

> We were wrong to give the impression at times that constants existed alongside variables, linguistic constants alongside variables of enunciation: that was only for convenience of presentation. For it is obvious that the constants are drawn

> from the variables themselves; universals in linguistics have no more existence in themselves than they do in economics and are always concluded from a universilization or a rendering-uniform involving variables. Constant is not opposed to variable; it is a treatment of the variable opposed to the other kind of treatment, or continuous variation (1980, pp. 103).

Here is a description which problematizes Chomsky's theory of universal grammar[22]. Since universal grammar relies on the notion of a stable language, if everything is constantly connected and changed through these connections then it makes sense that language would become difficult to describe as an absolute. No longer can our goal be to find a perfect description of what a text means, as this assumes that it exists in exactly one unchanging and universal way. We also cannot address it in the same way authors like Chomsky have done in his defense through ideas such as minor languages, as these still suggest there is a constant that is universal, that the changes are secondary when used in a new context and therefore not part of the universal we researchers wish to describe.

The question arises: why is having this universal so essential, whether it comes up with Chomsky or in our own research field? Being sure of an absolute way of understanding something gives power to the interpretation. No longer is it some researcher simply suggesting that a text means something but now they have some authority to invoke that their reading is absolute. As Deleuze and Guattari write, "the scientific enterprise of extracting constants and constant relations is always coupled with the political enterprise of imposing them on speakers and transmitting order-words" (pp.

[22] Universal Grammar is a linguistic theory credited to Noam Chomsky. With it he argues the human brain is wired to learn grammar, noting what he identifies as common features to all human languages. I mention it here because Deleuze and Guattari spend a good deal of time discussing it in their own work, which makes it an apt example of how their framework can change how we view the world.

101, 1980). The difference with assemblages is that we do not attempt to extract these constants and instead are actually most interested in where these constants do not appear to work, as the ruptures in consistency are far more remarkable and productive than places of sameness.

What is an Assemblage?

While I have provided a bit of a definition and looked at an example of assemblage at work, it will now be helpful to try and identify what we mean by an assemblage. It is important to note that Deleuze and Guattari purposely never directly tell the reader that an assemblage is X because they want to experiment with the idea and let it take different meanings to see what works. To aid with this difficulty, I will also rely on the work of Manuel DeLanda, who has attempted to pull out some ideas he found central to Deleuze and Guattari's concept of assemblage as well as adding some of his own. As DeLanda points out, the process of trying to solidify the concept a little more, although somewhat the antithesis of the goal of the experiment in *A Thousand Plateaus*, is helpful both to be able to encourage more use of the concept by others and to be able to communicate more easily what it is we get from using the concept of assemblage in our own work (DeLanda, 2011a).

Assemblages can be thought of as relations of exteriority. This means that when thinking of assemblages, it is important to consider that parts can be removed from the assemblage and be placed into a new assemblage and perform a new function in that assemblage. Deleuze and Guattari point out that the pieces of an assemblage can be rearranged because "new conditions were necessary for what was buried or covered, inferred or concluded, presently to rise to the surface. What was composed in an

assemblage, what was still only composed, becomes a component of a new assemblage" (1980, pp. 347). In this way, as parts of an assemblage move into new assemblages or even the whole assemblage moves into another assemblage, it brings pieces with it that can now operate in new ways as they become connected to new pieces. This is especially helpful to think about in my own work, as much of education's interest with games involves trying to move part or all of a video game out of the assemblage in which it is working and into a new assemblage in the classroom.

It is useful to consider another common thought on how relationships work in order to highlight what is novel about assemblages. DeLanda describes the work of philosophers such as Hegel as being about relations of interiority rather than exteriority. By this, he suggests that relations of interiority focus on how all the components of an entity work together to create meaning that can only be understood in context with each other. In this case, removing a piece from the network causes it to become unrecognizable as it loses the essence of what makes it function. A common example DeLanda employs would be an interpretation of the genes of the body in which they are viewed as the critical component that defines the rest of the body. Instead, a relation of exteriority would treat genes as just one component alongside a number of other non-genetic components that all are a part of the emergent properties that make up the body (DeLanda, 2006, pp. 16).

Capacities

How much can an assemblage really change and interact with other assemblages? Consider the example of how the internet started, where it is now, and where it may go in the future. A critical early stage of the internet came from ARPAnet, which started with

UCLA and Stanford University and allowed for information to be transferred between the computer networks at these two schools. What started as a way to share information between a few schools mostly as a response to Sputnik has become something that is today used to share pictures of cats, order books over the internet, and do a slew of other everyday activities that have become central to many people's lives. As the internet has grown over time, it has come in contact with a number of new systems with which to interact. For example, initially the internet consisted of only a few networks but over time it became commonplace for the majority of computers to be connected to the internet as well as for more homes to contain computers. Much of what is used today, such as the TCP/IP protocol developed for ARPAnet, was present initially but as it came in contact with new entities it became used in new and different ways that led to an internet today that looks far different than where it started.

This example helps illuminate what a capacity is and how it differs from a property. DeLanda explains that "properties are given and may be denumberable as a closed list, its capacities are not given – they may go unexercised if no entity suitable for interaction is around – and form a potentially open list" (2006, pp. 10). In this way, properties are what traditional qualitative research is usually after. Properties are descriptions that are possible because they are currently actualized, which allows them to be examined. Capacities cannot be seen so simply. It is quite possible for an assemblage to have the ability to interact with other assemblages in interesting ways but for it to not currently be happening in any way which is observable.

Returning to the example of the internet, the original internet had the capacity to allow for sharing of funny pictures, but that was not how it was deployed, so that capacity

was not observable. While this example may demonstrate the difference between a capacity and a property, a somewhat obvious follow up question is what can researchers do then if capacities are not observable in the same way as properties? Here I return to the work of Deleuze and Guattari and use *A Thousand Plateaus* as an example of how it is possible to explore capacities-- experiment. In Massumi's words, from the translator's foreword, "Does it work? What new thoughts does it make it possible to think? What new emotions does it make it possible to feel? What new sensations and perceptions does it open in the body?" (1980, pp. xv). In this way the work I do is going to involve trying out *Portal 2* as an assemblage and experimenting to see in what ways it can interact with other assemblages to generate new possibilities.

When reading through the works of Deleuze and Guattari, I found what they did useful as a starting point for thinking about how I might do my own work with the concept. Throughout the chapters of *A Thousand Plateaus*, much of the work involves Deleuze and Guattari choosing a particular example, such as the Wasp and Orchid, and then seeing what that example can do as they discuss it in conjunction with other ideas. Right now this may sound somewhat abstract still, so I will take it through an example of an area in which I have been trying to use this concept within my own work.

As I have investigated and given thought to the process of playing *Portal 2*, I have become acutely aware there are many possible ways to play video games. One such example that I have been trying recently, after seeing someone do it online, is called "speedrunning." Having by now played through the game a number of times, if I do a complete run-through at a brisk pace, I can complete the game in about seven hours. Speedrunners can finish this same game in a little over an hour. When attempting to

speedrun this game, every effort is made to minimize time including finding ways to "break" the game, such as taking paths that seem not intended by the designers of the game. For most speedrunners, this involves practicing these runs many times to further reduce how much time it takes and having it become second nature to complete all of the puzzles without having to think about them while playing.

What is fascinating about this process is that the game itself does not change. It is the same *Portal 2* that I played when I bought the game and tried it for the first time, with all the same capacities. However, these players have taken the assemblage that is *Portal 2* and plugged it into the new machine of speedrunning. I've noticed when trying to learn to do this, all the parts of the game story I used to notice related to "what science is" disappear from my view as I focus on trying to complete this as quickly as possible, and much faster than until a few weeks ago I thought was possible at all. In this way, speedrunning works as an experiment to see what the assemblage of the game can do when plugged into a new machine and I am interested in further examining this and other ways of changing how the game is played and seeing what happens. From this, I can learn about what made it possible to think about science when playing the game certain ways while in other cases the idea of science seems completely unexplored even with the same game.

Black holes

Black holes are a concept Deleuze and Guattari use to talk about points which bring assemblages together in such a way that they lose their ability to easily change, not to suggest that change is impossible but instead more difficult. They helpfully point out how these black holes behave not like a melding of ideas but instead as resonators. "The

common central point is not where all the other points melt together, but instead acts as a point of resonance on the horizon, behind all the other points" (1980, pp. 224). The black holes do not make all other assemblages suddenly vanish but instead act as a force to pull them together and limit their movement. Deleuze and Guattari use the example of the state to explain this:

> The State is not a point taking all the others upon itself, but a resonance chamber for them all. Even when the State is totalitarian, its function as a resonator for distinct centers and segments remains unchanged: the only difference is that it takes place under closed-vessel conditions that increase its internal reach (1980, pp. 224).

While this description does demonstrate the problems that can occur when getting stuck in a black hole, this does not mean it is always avoidable or even undesirable. As Deleuze and Guattari point out, it is possible for a black hole to lead to something positive as well, if the assemblage does not get permanently trapped in it:

> It is important to bring up this "black hole" function again because it can increase our understanding of phenomena of inhibition, and is in turn capable of breaking with the overnarrow inhibitor-releaser dualism. We saw earlier that an interassemblage could include lines of impoverishment and fixation leading to a black hole but could perhaps lead into a richer and more positive line of deterritorialization… Thus the black hole is a machine effect in assemblages and has a complex relation to other effects. It may be necessary for the release of innovative processes that they first fall into a catastrophic black hole: states of inhibition are associated with the release of crossroads behaviors (1980, pp. 334).

Here again we see what is important is that we become aware of the possibilities in our research. It is possible for these black holes to limit meaning and reterritorialize an assemblage in such a way that it becomes heavily restricted, but at the same time this process of territorialization can lead to positive benefits if used well. In the case of my research on games and science, I see this as suggesting I should not be fearful of the possibility of some explanations and experiments becoming black holes, but instead simply be wary of the possibility and do what I can as a researcher to break this process when I recognize it and try to lead it somewhere else through a "more positive line of deterritorialization[23]." This matches up with Deleuze and Guattari's suggestion of what to do about black holes when they describe their own work. "Find your black holes and white walls, know them, know your faces; it is the only way you will be able to dismantle them and draw your lines of flight" (1980, pp. 188).

This quote references two related concepts that also need to be addressed: white walls and lines of flight. As might be guessed from the similarities between the terms "black holes" and "white walls," white walls are a counterpart to black holes. Rather than acting as resonators that function to pull meaning in and territorialize parts of the assemblage, the white walls are parts of the assemblage that allow for more ease of movement and change. However, neither the white walls nor the black holes are stable. They are constantly changing. As the assemblage changes, new black holes arise that resonate new territorilizations while old black holes may disappear or shrink and become less constraining.

[23] The process of decontextualizing a set of relations.

During this whole process, I utilize the concept of movement in which parts of the assemblage can become more deterritorialized. The pathways out of the black holes and along the white walls that allow for this deterritorialization are described by lines of flight. Lines of flight are ways for different parts of an assemblage or multiple assemblages to connect. This movement from one assemblage to another allows for interesting changes that are not contained by the black holes. These movements are a place for us as researchers to make our work productive. We can help to find these lines of flight to allow for changes to occur. Of course it is always possible, maybe even likely, that in our attempt to find these lines of flight that we create new black holes that resonate meaning in new and possibly unintended ways. It is similarly important that we continue to recognize these changes and respond accordingly within our work to attempt to counteract these restrictions on the assemblages with which we want to experiment.

As an example, one scene I return to regularly in *Portal 2* is when the player happens upon a number of fairly stereotypical science fair projects from a "Take Your Daughter to Work Day" exhibit, including the one shown below:

Figure 3-1: A screenshot from *Portal 2* when the player is exploring part of the science facility and comes upon a number of science fair projects. *(Valve, 2011).*

Many stereotypical elements are present within this example. Players can see the trifold, the expected steps like the hypothesis, and even a somewhat clichéd project with the baking soda volcano. If this is all there were to it, this potential black hole would not be all that interesting. What happens next, however, creates a potential for rupture and the forming of a new line of flight.

The artificial intelligence traveling with the player asks a question which are designed to shake the viewer's perception of the exhibits: "Is this really science?" He goes on to suggest that even if it is science, it is not good science, "even among the child sciences." The game uses humor as a way to get us to try and challenge our view and maybe think a bit differently after presenting a somewhat stereotypical image of a science fair project. Of course what is also interesting is that there are multiple possible lines to take. While I followed along the line of thinking that yes this was quite a silly example of science and that science fair projects that look like this are not really science, this is not the only possibility to explore. Another possible interaction is to reject the AI as being too hard on kids and instead reaffirming this particular view of science. The way the humor is presented even makes this easy for someone that chooses to do so, as the AI goes on to describe the child as inferior to other children: "I'm guessing this wasn't one of the scientist's children. I don't want to be snobby, but let's be honest: It's got manual laborer written all over it. I'm not saying they're not as good as the professionals. They're just a lot dumber.[24]" Of course, all of these assume that some interaction occurs with this

[24] It is also helpful to note that I found the humor in the game, such as this statement, made coding very difficult. Words were many times used in conjunction with tones of voice and images in the game in such a way that trying to create meaning from a transcript of the game becomes very difficult. I have found assemblages do a better job at acknowledging this difficulty and hope this concept will help improve the ability to think about the humor of the game. While there are techniques for coding to try to take into account issues such as tone, it still loses a lot in the process of transcribing and coding.

part of the assemblage. It is also possible the player interacts with this scene in the same way as the speedrunners, spending less than a few seconds in this room as they pass through as quickly as possible to get to the next puzzle and finish the game.

Assemblages and *Portal 2*

So far I've outlined a number of components of assemblages and how they might function but why is it this is a productive choice for my dissertation? To think about this, I went back and reexamined the work I had done previously with *Portal 2*. While there may have been some influence from Deleuze and Guttari, it is quite clear when I reread the work I had been doing that it fits much more closely with other theoretical stances such as hermeneutics, which I have also considered as a possible framework. Since this is true, what was wrong before with my work or what could be improved by changing to this framework?

The first shift is that the questions I can ask with assemblages seem more valuable and productive. My earlier work was focused on the question of what was the message of *Portal 2* and how did it relate to science education. The problem here was it became imbedded in looking at a single interpretation, or maybe triangulating it with other interpretations and looking for similarities, and using these interpretations to develop an explanation for the game's meaning. In the last work I had done, I had sections for the three ways in which the game communicated to players about what science is and listed each of them. The problem here became how did I confirm that these indeed were the messages of the game and not some misinterpretation of it. This is not to say this work has no purpose but that it can be used in a different context to ask a more productive question.

Rather than ask the question, "What does *Portal 2* have to say about the nature of science?" I suggest a more productive question would be to ask, "What does *Portal 2* make thinkable about science?" While for some this may sound like a small question of semantics, I would suggest that this seemingly small change leads to a huge shift in how the work is done and what the question is trying to uncover. The goal is no longer to prove that a specific meaning is one that the game gives to its players but to instead explore possible meanings that it can make possible for players.

The follow up to this is to address how this is different than interpretive frameworks of more traditional qualitative works. While qualitative researchers make claims that they are looking for "an" interpretation and not "the" interpretation, their theoretical constructs for defending their work tend to still be based in proving that an interpretation is correct. For example, triangulation is a commonly used explanation for why work is good, since, if multiple sources provide a similar interpretation, it must be a better interpretation. Another example is looking at how coding of data works, in which themes emerge because they are mentioned many times as opposed to an idea that comes up only once which must be less important. A final example would be to consider the subjectivity statement. In most work it serves the purpose of identifying what I as a researcher am like and using that as a way to try to remove/minimize the effect that has on the research that I do. All of these concerns have in common the desire to reduce the impact the researcher has on the work to prove that it is trustworthy because it is not tainted by these issues that create bias. I would suggest instead that these issues are always present within all work and therefore a post-structural framework, such as the one I plan to use, does a better job of dealing with this by making it part of the work rather

than pretending it does not exist and ignoring or minimizing the impact it has on the work.

When doing a more interpretative type of project with the game, I was having difficulty with proving that my interpretation was "the truth." I had ideas of my own as well as suggestions from others on how to resolve this. It usually involved looking at artifacts such as online created works related to the game as well as interviewing people who played the game. By doing this, it would be possible to see the same ideas come up repeatedly, which would "guarantee" their truth. This is not to say that interviews/artifacts are not useful, but that the focus should not be on using them as confirming or denying truth due to saying the same thing. Instead I suggest that any of these activities I do should be done along lines similar to how Deleuze and Guattari do them in *A Thousand Plateaus*.

For example, Deleuze and Guattari look at a number of examples of space to think about smooth and striated space such as: "the technological model," "the maritime model," "the musical model," and "the mathematical model" (pp.474-488). While they look at these different models to help think about space, they do not do so by finding the similarities between them and creating an ideal model of what a smooth or striated space is. Instead they explore each model and look at what that model can help them think differently about space without focusing on how each model looks the same as the others. In this way the work is about trying to expand ideas and open up possibilities rather than dilute them down to simpler forms by removing all but what is deemed essential.

Portal 2 and Education

Another component to consider with the use of assemblages is how it can better match up with how the game is likely to be used in education. For example, there are already attempts to apply the game to a classroom setting, such as can be seen on www.teachwithportals.com. There is a noticeable change that occurs in the game, however, when it is used this way. The situation is no longer a person showing interest in the game and choosing to play it, but students being required by their teachers to interact with the game. Teachers are attempting to take pieces out of *Portal 2* (not the whole game) and have students play through these puzzles with the intent of looking at the physics involved.

In looking at how *Portal 2* is used in an educational setting, Deleuze and Guttari's ideas on assemblages and what happens when they are plugged in to new machines can be helpful. As Brian Massumi points out, "When you uproot a concept from its network of systemic connections with other concepts, you still have its connectibility" (2002, pp.20). While a teacher might choose to use a single component of a game as an example in the classroom, the rest of the game does not immediately disappear. The piece that is removed still retains remnants of its previous connections (for example, references to other parts of the game) as well connections students will make if they have played the game and connect parts of the example to other parts of the game. It is beneficial when examining the game with the intent of learning something for education from it, to consider how parts of the game may come along with it that we do not intend and become part of the learning process. This makes thinking about the game with this in mind an interesting choice, as it encourages me to consider what happens to the game as I try to

change it and put it in connection with new assemblages. It will take on new possibilities as it comes in contact with new components but it will not lose its previous connections, which is a different way of looking at video games compared to other education work I have seen with video games that attempts to remove or ignore the impact this connectibility might have on the way people interact with the game in a school environment.

Conclusion

At the end of the day, would a study about *Portal 2* set up as a hermeneutic or other traditional qualitative method be possible? Absolutely. While it may be possible, it does not seem to be what would be most beneficial to do. A look at the game from the perspective of what is here and listing how nature of science is present in particular pieces does not get at what would be really helpful for educators. Instead looking at how it becomes possible to think about science while playing a game like this produces a much more interesting thought process. Looking at the assemblages surrounding *Portal 2* as a way to explore its capacities and realize new possibilities is a more productive avenue to explore the underexplored medium of video games in education.

While this chapter has established the foundations for assemblages, capacities, lines of flight, and black holes, little has been addressed about what applications of these concepts actually looks like in research. The next chapter will address this concept by using examples from the analysis done in the work to show specific examples of how these concepts provide unique insights. By looking at specific examples, I hope to help the reader get a feel for what research can get from using these concepts instead of

picking up a ready-made method structure off the shelf with little attention to the conceptual underpinnings of where the methods come from.

Chapter 4 Writing as Method

The truth is, most of us discover where we are headed when we arrive.

-Bill Waterson

Introduction

The previous chapter established that a method using Deleuze and Guattari would not be a prescriptive one that from the outset established what should be done in the same way as in other frameworks (such as doing a survey based study where the exact plan would be outlined from the start). It is still necessary to provide the reader with a sense of how Deleuze and Guattari inform this particular study. This chapter will serve to both guide the reader through what was done throughout the course of this work as well as help establish the connections made between the theoretical framework and the analysis chapters. To help with this, the majority of this chapter will involve using examples from the analysis chapters to demonstrate how I got from the theoretical framework to some of the arguments that I made. This analysis will show how each concept can be used productively as a tool from the Deleuzian tool box since, as Massumi points out, Deleuze calls his philosophy one of "'pragmatics' because its goal is the invention of concepts that do not add up to a system or belief or an architecture of propositions that you either enter or you don't, but instead pack a potential" (pp. xv).

Writing as Method

One way to describe a project like the one undertaken in this thesis would be to simply explain how I built the arguments in each of the chapters by using Deleuzo-Guattarian concepts to think with. First, however, as there are a number of influences which led me to arrive at the point of using Deleuze and Guattari to build this study, I will begin by describing how I employed the concept of "writing as method." The idea behind writing as method is that the work does not come together until, through the process of writing, the connections are made to generate this piece. In the end, while the project involved many more steps and interactions, it is in the writing that the work takes a form that the rest of the academic community can read and engage with. In addition, in accordance with the traditional definition of method, this section will include actions taken by me during the study to find the different evidence that I present in the dissertation.

The justifications for writing as method come from considering how research might be done within a Deleuzo-Guattarian framework. St. Pierre points out that thinking with authors like Deleuze and Guattari cannot be thought "with conventional humanist qualitative methodology because their epistemological and ontological commitments don't align" (2014, p. 3). St. Pierre also points out that data tends to be used in interpretative research in a way she describes as "brute" data. The problem in this case is that data is treated as preexisting and waiting to be collected, but St. Pierre suggests that any researcher using a Deleuzo-Guattarian frame should avoid thinking of the material in terms of the concept of data (2013).

What follows is my work to put together the concepts of Deleuze and Guattari alongside different artistic works and discussions from communities dedicated to *Portal.* [25] It is impossible to have a god's eye view from nowhere and as such this cannot be a representation but instead a production that comes from my time learning about the fan communities related to *Portal*. Writing as method is my acknowledgement that I am an active part of the creation of this work and that the work does not exist prior to it being put together and presented.

Choosing a Starting Point and Following the Lines of Flight

The first order of business was to determine how to start this massive project. When pondering this question I found Deleuze and Guattari had a strong piece of advice on how to think of beginnings to projects:

> Where are you going? Where are you coming from? What are you heading for? These are totally useless questions. Making a clean slate, starting or beginning again from ground zero, seeking a beginning or a foundation—all imply a false conception of voyage and movement (a conception that is methodical, pedagogical, initiatory, symbolic…). But Kleist, Lenz, and Büchner have another way of traveling and moving: proceeding from the middle, through the middle, coming and going rather than starting and finishing… They know how to practice pragmatics. The middle is by no means an average; on the contrary, it is where things pick up speed. *Between* things does not designate a localizable relation going from one thing to the other and back again, but a perpendicular direction, a

[25] While my study focuses on *Portal 2*, this community contains material related to both *Portal* games, although the great majority of it is more closely tied to *Portal 2*.

> transversal movement that sweeps one and the other away, a stream without beginning or end that undermines its banks and picks up speed in the middle (pp.25).

I realized in this way that I was already working on this project even if I had not set a formal beginning and so I worked to figure out how I might start in the middle of where I was.

In practice, what this led to was starting the project by visiting the /r/portal[26]subreddit frequently. There are a variety of reasons for focusing on this particular "starting" point. First, from earlier research, I had come to realize that Reddit was a fascinating resource, as it creates complex webs of connections between disparate sources and people by virtue of being a location for individuals to post links to other websites, thus creating interconnected webs of associations. Second, I had spoken with Leigh Arino de la Rubia at NARST (personal communication, March 30, 2014) and noticed she was also doing work with Reddit, although in her case looking at a different portion of it titled /r/askscience; she had noted there were lots of interesting discussions happening on the site but very little research being done utilizing this underappreciated source material. Finally, people who discuss Deleuze will commonly use the internet as a quintessential example of rhizomes or assemblages. Reddit serves as a form that exemplifies these notions as it allows for lots of jumping off points that could easily lead in unexpected directions. In addition, Reddit also has numerous instances where

[26]Reddit is divided into subreddits which are sections that are dedicated to specific topics. These are denoted by /r/ and then the name of the topic. In the case of portal it is the primary discussion topic of /r/portal.

meanings might get stuck temporarily in a black hole[27], such as when certain memes[28] manage to dominate large portions of the site for a period of time before being usurped by other memes that lead to a new direction.

Where to Go from This Starting Point

Having chosen my starting point, I did not have a specific checklist of where I would go from there. I did, however, have some questions I was considering which could be used to help decide how to follow the multitude of possible paths:

1. How does *Portal 2* contribute and/or lead to discussions of science in online spaces?
2. What can be learned from *Portal 2* and related online spaces that can contribute to our thinking about games and science learning?

These questions[29]served as a way to connect the *Portal 2* community and science education. There were lots of other interesting discussions happening but through these questions it was possible to figure out how to proceed. If I attempted to document or

[27] By black hole, I am referring to the term used by Deleuze and Guattari which is not a literal black hole, as in the astronomical occurrence which can be found out in space, but instead a metaphorical one which acts as a resonator to pull in meaning and reduce the ability for differentiation as discussed in Chapter 3.
[28] In reference to the internet, a meme is a humorous image, text, video, etc. that spreads virally. It can be considered an inside joke, except that in the case of an internet meme, the "insiders" who get the joke number in the millions.

[29] It is important to note that, while the questions are listed here as an absolute and a starting point, in the process of research they also changed in response to what was being found. Originally the work focused on the game itself, but it was quickly apparent to me that the fan communities were more interesting in their own right and would provide a more fruitful research program. In addition, the questions were somewhat narrowly worded at first and had to be reconsidered after I realized that some of the most useful material I was finding did not necessarily align neatly with my initial research questions, even though the material was clearly related to science and the interests of science educators. What remains are the final questions that guide the construction of the work.

discuss everything available online that related in any way to the game *Portal 2*, interesting pieces would likely be lost in a vast sea of unrelated examples.

While these questions have always been a guiding principle for deciding what of the material would go into the dissertation, they could not be the only guiding points for figuring out where to move on. For example, the discussion about sound in "Going Home[30]" could not have possibly come from just having those questions as guides, although the decision to include the discussion of "Going Home" in the dissertation as relevant was guided by the questions. As will be discussed in Chapter 7, I was looking at another video by the same author and chose to watch "Going Home" because I was curious to see what else the author had done, even though I assumed it would be irrelevant to my own study. There was no evidence from the topic or my initial viewing that this would lead to any discussion about any scientific topics, as it just seemed to be a video about some robots from the game trying to find their way home. However, upon reading the comments I found a wonderful discussion questioning the video's depiction of the robots talking to one another in space, with various individual contributing comments related to the fact that sound does not travel in space. This intriguing debate about real-life science, sparked by a fictional video inspired by an online game, is an example of a discussion that would never have been found by a researcher following a more strict definition of study boundaries.

The study focuses on player interactions with the game *Portal 2*. Why have I chosen to focus my study on *Portal 2*, rather than some other game or collection of games? Other science educators have utilized *Portal 2* in a classroom setting to teach

[30] The full discussion of the YouTube video "Going Home" can be found in chapter 7 on p.148.

physics concepts and there are whole websites, complete with lesson plans, devoted to using the game in this fashion.[31] My interest in the game, however, is not related solely to its value in teaching science content, but to its unique ability to inspire and perhaps shape participants' engagement with science more generally. I find this game particularly fascinating because of the paradoxical role of science in the world of the game itself. Science is a central concept in this gameworld, which is set in an abandoned laboratory complex and has a storyline built around the player, whose goal in the game is to escape from the facility, facing situations and obstacles related to the scientific experiments originally conducted there. This setting addresses such details as what an experiment should look like, what a scientist should sound like, even as small of a detail as what a science warning label should look like. At the same time, however, while these details serve as the backdrop, shaping the players' experiences, it is still just that, a backdrop. Most players engaging with the game are doing so simply because of its entertainment value and are focused on figuring out how to complete the next puzzle, rather than on considering the underlying scientific assumptions shaping this game. However, the designers of *Portal 2* have ingeniously incorporated moments when the game smoothly transitions into a vehicle for considering larger issues related to science, bringing science into the foreground through unexpected shifts from player expectations, such as when the owner of the facility discusses human test subjects as if they were objects and suggests doing science involves "throwing science at the wall here to see what sticks."

[31] The website teachwithportals.com also includes a section relating examples of how teachers from various disciplines, from literature to geometry to statistics, have used this game in their classrooms.

To look at how players consider the game, I looked towards fan communities, primarily those which were found as I explored outwards from /r/Portal[32]. For practical reasons, the study is limited to the internet, because research involving offline interaction with Portal players (such as personal interviews or visits to gaming conventions) would require a different set of tools and understandings, which would not take full advantage of the perspectives I was able to develop through the course of my research into how the different online communities interact and are related to one another[33].

While I found a number of different sites and discussions that impacted the study, the primary influences were material from /r/Portal itself as well as material from a variety of sites which hosted art and comics such as imgur and Deviantart as well videos from YouTube. The art and video were found from links from /r/Portal as well as exploring the sites independently[34] of an aggregation site directing me to specific portions and finally through Google searches to see what someone might see if they were looking using search engines. The decisions to use these particular avenues came from being a reader of the /r/Portal community for the past four years. Over time, I learned how different people explored a fan community from my own experiences in trying to

[32] While I could try to draw nice neat lines of /r/Portal led to Deviantart which led to a google search which found something on Funnyjunk or other such lines, this would be an oversimplification of the process. In the process of reading, different sites would come up and I would look at them in time. How related they were to my dissertation questions as well as how often they came up again would contribute towards how often I would return. While the inputs were different, the exploration was somewhat similar to how someone might meander about the internet. Moving from one site to the other due to some passing interest in a way that would be similar to how other viewers might find content to make the project more meaningful then a more strict definition that would be less likely to match how someone might engage with this material (other than another researcher who knew that looking at the top 100 and the 100 newest posts in a page would allow them to claim their data more reliable due to the objectivity of the search criteria).

[33] Follow up studies that look at how people play the game in particular contexts and what types of discussions they have would be a fascinating addition to the work I have done so far.

[34] By "exploring the sites independently" I mean using the sites own infrastructure to explore content related to Portal as opposed to going to the site from links from another site.

learn more about the game as well as through "meta" discussions in which users advised other users on the best ways to find useful or interesting content. This process of coming up with strategies during the study rather than having them predetermined allowed me to take advantage of insights I gained early in my explorations. In this way, I was able to tailor my choices to the particular community of interest instead of trying to apply a pre-prepared strategy such as analyzing a random sampling of posts or looking at a given subset, such as the one hundred most popular of all time[35] or one hundred most recent posts.

Building the Analysis with Capacities

In addition to deciding what to consider, these concepts were helpful for deciding how to do the analysis itself. Delanda's concept of capacities[36](as opposed to properties) comes to mind here. The study itself is focused on what is possible instead of focusing on what is true about these discussions. This is not to say that properties do not come up as well. Many of the examples considered begin with a description of something that occurred in an online space which can be described much like a property in the sense that these specific discussions did occur. What is interesting to me as a researcher, though, is the follow up question of what this shows us as possibilities for this space. What this means is that a different set of questions needs to be asked during the exploration.

For example, when looking at the online commentary dealing with a particular post or image or video, there is a temptation to say that a particular set of statements must mean that the individual contributing those statements feels some particular way. In the

[35] While I did not do this as my primary way of finding material, I did do this as well for an initial idea of what type of content was most popular on the board and to give me some initial bearings although they did not turn out to be the most productive posts to learn from by the end of the project.
[36] A full discussion of capacities can be found in Chapter 3 on p.47.

case of Forehead58, discussed later in Chapter 6, [37] it would have been easy to primarily focus on his physics knowledge concerning momentum. Instead, however, capacities suggest we should be focused on what kind of discussion his creation made possible. That is, the focus should be on what types of discussions were able to arise, rather than what has or has not been revealed about the "true" nature of a particular poster who participated in the discussion. Rarely do the discussions in the following chapters focus on what type of true knowledge must these particular participants have about science. Instead, the focus is on the discussion itself and what it makes possible.

Focusing on the "true" nature of what a poster knows and how that poster will respond is tempting, as it suggests that such knowledge is recoverable and can be used to trigger a desired response. However, this framework does not allow for a deterministic/prediction mindset to drive the exploration; that is, it is not possible to say to that if you create the same set-up of content in a different setting, such as a class website, that the same discussions will occur in response to the content. Therefore, when reflecting on how to use this research productively, it should be seen as a way of considering what might be possible in online spaces and identifying contributing factors that should be given attention when trying to design similar spaces for an educational purpose. While I may not be able to say that making a video like "Going Home" (discussed in Chapter 6) will lead to a discussion of sound waves the next time it occurs, I did learn about the types of events that can occur and what factors to pay attention to in looking for potentially productive mediums that could create valuable discussions of science. There can be no guarantee that a particular piece of content will be productive

[37] This is a user writing about momentum, which is discussed in detail in Chapter 6 as well as later in this chapter in the section on assemblages.

but instead we can work to maximize the opportunities for powerful discussions while still being open to potential new lines of exploration that may unexpectedly occur in the future.

Assemblages

So far, I have discussed how these concepts can shape the dissertation as a whole; what follows is a series of specific examples from the analysis chapters where specific concepts are put into use. Deleuze and Guattari's concept of assemblages is a good starting point since the other concepts tend to tie back into the actions of assemblages. Assemblages disrupt traditional analysis schemes since by their nature they are combinations of many different types of systems that are all occurring at very different temporal and size scales. They are also fairly amorphous instead of nice and discrete atoms that can be built into molecules; they are patchwork and mosaic in nature.

One such example comes from Chapter 6, where it is found in the section titled "When the analogy breaks down"[38] A user called Forehead58 has created a lesson on momentum, which he posted to Reddit, to address why people misunderstand this scientific concept as it applies to Portals. In doing so Forehead58 uses a variety of assemblages which are quite impressive since they are all able to come together and function at the same time even though they come from a number of different spaces which might not normally intersect. The creation involves the intersection of a wide

[38] This section of chapter 6 can be found on p.123. This section focuses on the concept of the conservation of momentum and one user-created assemblage to assist other users in understanding the concept. The portion in chapter 6 focuses on how the different parts of the assemblage work in the discussion. In the current chapter, I will focus on the creation of the assemblage itself, while leaving to that later chapter the analysis of how it functions in a specific discussion.

variety of different assemblages but I am going to focus on just a few to give an idea of the scope.

The lesson on momentum starts with something called an advice animal. An advice animal is a picture, which is assumed to be one the audience will recognize, with text overlaying it, usually with one line on top and one on bottom that are patterned based on norms associated with using the particular image chosen. In this case the author has chosen a picture of Inigo Montoya[39]. This picture serves both to try and create a humorous start to hook the reader as well as to establish the author's viewpoint that other forum goers say the word "momentum" when talking about portals but that they do not really mean momentum.

What follows is a number of examples to help make his point. When going through these examples there are a number of choices related to the diction and symbols that would likely not seem appropriate in a science textbook or classroom. For example, the author discusses "the shitty car" and how "you could be an accurate badass". The author appears to be going for a word choice style that tries to put the readers at ease and make it fit in with other word choices in the forum by mixing in casual statements with the scientific explanations. Another example of fitting in with the forum would be the look of disapproval face ಠ_ಠ. This symbol originated with a user named Look_of_Disapproval, who would only respond to statements with ಠ_ಠ, which ended up

[39] Inigo Montoya is a character from the *Princess Bride*. The text included comes from a line said by Inigo Montoya when responding to another character saying the word inconceivable. Inigo saw the events being described as inconceivable occurring meaning clearly they must be conceivable. He concludes the character must not understand what the word means and makes the statement in a humorous fashion that "You keep using that word. I do not think it means what you think it means."

catching on as a shorthand way to respond to users on the forum with a sense of disapproval. It also evolved in such a way as to have a more humorous connotation than might usually be assumed when someone is attempting to disapprove of what someone is saying or doing.

On top of all of the choices made to fit in as a Reddit post, the user also made use of a number of concepts related to the *Portal* assemblage. For example the author assumes that the readers understand the blue and orange particles drawn on the pedestals on the section on conserving momentum are supposed to represent portals. In addition, the squares going into the portals should be recognizable as the cubes from the game, commonly used in *Portal 2* for solving puzzles based on their shape and decoration. Finally, it is assumed the user already knows that when objects go into one portal they come out the other portal going the same speed, which is what leads to the confusion on momentum in the first place.

What has been considered so far are a variety of creations which have primarily occurred in different internet communities at different times and places. However, none of this would be possible without the operation of the modern science physics assemblage which makes these definitions of physics thinkable and allows the user to denounce other interpretations. Throughout the document, both in the sections reproduced in the dissertation and in the remaining 5/6 of it which were not included for reasons of space, the user ridicules those on the forum who do not understand how momentum works appropriately. In particular, most of the issues presented on page.131 all relate back to other users of the forum not realizing the convention that the direction in which an object is moving is part of its momentum whereas just talking about an object's speed remaining

constant is insufficient for describing the conservation of momentum. Through the authority of science and using everyday situations with which he expects other users to be familiar, such as a moving car, he presents a logical progression showing why changing the direction of movement when an object leaves a portal changes its momentum.

Of course there are many other functioning assemblages happening in Forehead58's post and responses to it that make it work. What is fascinating is the intersection of different communities and concepts to allow for this to work at all. All of the different examples come from a variety of different starting points. They were not developed together as an intentionally functioning system but instead came together somewhat haphazardly. No one deliberately set out to create the look of disapproval face with the intention of having it be adopted as a widely-understood and agreed-upon symbol. Rather, someone used it to indicate disapproval, other posters found it a useful device and began to use it as well, and it became popular as more and more people adopted the practice. The academic setting that has allowed for the creation of physics knowledge has clearly been around a fair bit longer than any of the other assemblages which came about since the internet was invented and yet it still is able to function alongside them.

The way in which considering the assemblage nature of material being examined for this study aids the analysis process is illustrated by considering the example of the discussion in Chapter 7 of a video[40] about sliding panels in the *Portal 2* game. I describe the video about panels as follows:

[40] This is a Youtube video that is discussed in chapter 7. The full discussion and video link itself can be found on page.143.

> When trying to utilize these tools in science education, it is not enough to simply evaluate the parts in isolation but they also must be considered in conjunction since only one piece (either just the words or video) does not provide enough information to see how these videos create powerful interactions (p.149).

There are two competing narratives here, either of which could be easily missed if the video being considered is not evaluated as a whole. The words being spoken throughout the video are those of a concerned scientist trying to sell a product to help other scientists better work with their robot test subjects. On the other hand, the visual element of the video shows his own test subjects being destroyed and impeded by the very product he is trying to sell. The resulting humorous juxtaposition of words and images sparks the viewer discussions that are considered in Chapter 7.

It is significant from an analysis perspective that both assemblages, in this case the concerned scientist and the reality of what happens to his test subject robots, work together to create something new that would be impossible with only one of the two assemblages. One difficulty that arises when discussing these types of juxtapositions is that in the process of moving what was created into an academic document, some of the connecting pieces that make it effective can be lost. This can transform the video into something that no longer functions in the way that made it popular on YouTube, making it hard for those who are exposed to it only in this new setting to understand why it ever worked in the first place**.**

Deleuze and Guattari on Linguistics

In Chapter 6, one of the examples considered is a comic about a watermill that would work to produce infinite energy by using the design of portals from the game[41]. While there were a multitude of different types of responses, one of the most fascinating was a response by spartjoker stating that, "There is nothing wrong the physics here, it would work fine?" (Tralala18). Statements such as these rely on a double meaning[42] in which a portion of the audience assumes that this person should be taken at face value as meaning that everything in the comic works within scientific principles, while the other part of the audience is supposed to recognize this as a joke to poke fun at people. This type of joking does not work without some people taking the statement seriously and responding in a serious manner, thus allowing spartjoker to further agitate them.

Statements such as these were actually some of the first encounters with evidence that I had trouble describing with other techniques. Attempts to code a statement that is supposed to mean multiple things simultaneously seemed quite problematic especially as it so heavily relied on the surrounding responses, thus making strategies to separate it from the text problematic. Deleuze and Guattari helped with thinking about this through their thoughts on linguistics and their criticism of universals in language. They point out the "unity of language is fundamentally political. There is no mother tongue, only a power takeover by a dominant language (1980/1987, pp.101) They discuss a number of what have been called minor languages by linguists as an attempt to contain meaning and prevent those not in power from being able to decide how their language functions which

[41] The discussion about this starts on page 112 of Chapter 6 in the section "The infinite energy watermill".
[42] For a further discussion of these double meaning statements, also known as trolling, see p.116 in Chapter 6.

inadequately deals with the "constant variation" in language. In this case, the statement itself cannot hold meaning alone. It is only once other users respond and engage with spartjoker that the attempt at trolling either functions or not. If no one takes his statement seriously, it does not allow for users to joke about some of the readers taking a statement too seriously. In this way, the statement itself cannot hold meaning until it has been interpreted by others and interacted with, which allows the statement to function.

Black Holes/Lines of Flight

An excerpt from Chapter 7 is an excellent example of how the Deleuzian concepts of black holes and lines of flight can aid a researcher in thinking about what initially is an unexpected result:

> In this case both particularly high quality components as well as components that were deemed inferior served as focal points that overtook any potential interest in the video itself. The remaining discussions primarily consisted of praising the game and the characters from the game. While the video itself comments on "making science," nothing from it seems to have stood out well enough to inspire a response from its viewers that would rival the long discussions of the technical details of the making of the video. [43]

Thus, the comments discussing a video about making science ended up being not about science at all but instead about how the video maker created the animations and who was doing the voice acting for the video. It turns out that by using different tools for animation compared to his previous video, the creator made a new focus point of

[43] Chapter 7, page 147 below.

animation tools the center for discussion. This difference created a resonance like effect which led to the majority of users discussing this issue rather than anything else, such as the concept of "making science" from the video. The structure of the discussions themselves likely helped to encourage this black hole effect since as the discussions began to focus on the animation, other users would respond to these comments rather than making new comments which could lead to a line of flight elsewhere.

Users discussing a particular concept in this case encouraged more discussion on the same topic which both created discussion as well as limited other possibilities. Of course this is not inherently bad. For example, a discussion about a particular scientific concept might have focused on that concept in such a way that it encouraged interesting discussions which might be less rich otherwise. Of course the judgment of good or bad also depends on the goal of the media. In this case this video was not produced, or at least it does not appear to have been, with the intent of starting discussion on science (although I was hopeful as a researcher). What is helpful is to see how a particular event can act as a black hole or resonator and pull in meaning and make lines of flight to other possibilities difficult. As Deleuze and Guattari point out, it is not that black holes are inherently negative but that we must be aware of them to allow us to work to create lines of flight that allow escape and to discourage them from all resonating to the same point which inhibits difference.

Conclusion

After going through this section, a reasonable question to consider is: why do the analysis of the strategies used in the research in this chapter rather than doing it alongside the research analysis in the following chapters? This would indeed address a common

problem in attempts at poststructural research where it appears at the beginning that the research is based in poststructural concepts, but when looking at the analysis section those concepts nearly disappear and the research morphs into some other type of qualitative work. That model is actually what I first attempted when writing these chapters, but the problem was that it negatively impacted the ability to form a story and follow the lines of flight as they moved throughout the different threads of interest on the internet. What happened was that a discussion of how a concept developed would start and then a concept would come up and a description of assemblage would be appropriate to explain how I had gotten to the point I was describing. The problem was by the time I was done with this description it would disrupt the flow enough that the different examples no longer particularly held together particularly well. This chapter is my version of saving those moments that were great examples of the different concepts I used to think with while simultaneously allowing for the analysis chapters to follow along particular lines of flight without being interrupted by lengthy breaks to discuss the impacts of the framework with which I was working.

At the end of the project, Deleuze and Guattari's concepts were tremendously influential in shaping how I was able to think about these online spaces that are discussed in the following chapters. It is impossible to do analysis that is not informed by some type of theoretical framework, although sometimes this framework remains unexamined. Throughout this chapter, I have explored the most prominent concepts used in the analysis through examples that should demonstrate how influential those concepts were in the conclusions that were made. These concepts have been guiding principles in other aspects of the project as well, enabling me to choose a starting point and to figure out

how to move from the entry point throughout the huge network that is the internet. Hopefully this chapter illuminates for the reader how these influences led to the types of discussions about *Portal 2* that arise in the next three chapters.

Chapter 5 *Portal 2* and Reddit

"I know that in America we are supposed to celebrate individualism and everything, but I feel like everything--books, YouTube, whatever--is really a vast creation that we are all participating in. We participate in it by reading and by watching and by making stuff, and the stuff that gets a billion views matters in that process and the stuff that gets 10 views also matters."

– John Green

In this chapter I will explore the question of how the game *Portal 2* is discussed on a portion of the internet known as Reddit. Reddit is a content aggregation site which involves millions of registered users[44] who can publish content that they either create or have found elsewhere on the internet for users to view. This content is organized into many different subreddits which are communities within Reddit which focus on particular areas of interest, such as video games or politics or anything to do with the University of Georgia. Within each of these communities, users can respond to the content they view in two ways: by commenting on that content, thus contributing to a discussion viewable by all users and by voting on the content, which can either increase or decrease its visibility to the community. By looking at the contexts in which *Portal 2*

[44] Registration is a simple process. Users post using screen names, or pseudonyms. Since users are not required to give Reddit their email address for verification of their identity in order to register and post, they enjoy a level of anonymity.

is referenced and discussed on Reddit, I am able to see ideas coming from a number of different sources and communities and see how these different viewpoints contribute to the connections between *Portal* and science[45].

Reddit's Algorithms

Before discussing Reddit content related to Portal, it is necessary to have a basic understanding of the mechanics of how Reddit works. The Reddit website uses an algorithm to assign values to posts, and those values determine what users will see. As a result, the algorithm plays a significant role in determining how discussions unfold on Reddit. I will first explain how the algorithm functions before considering its possible relation to the discussions that occur. By default, Reddit is sorted in such a way that twenty five posts appear per page. These posts are sorted into subgroups called subreddits, which are communities dedicated to particular topics, including a subreddit dedicated to Portal. Many online discussion forums sort themselves by listing the most recent post or the post with the most recent response on top, but Reddit does not do so. Instead, Reddit sorts itself in a unique fashion, using a more complex formula.

The way Reddit sorts can be found, as the source code is open source and can be viewed by anyone who knows how to read it. Below is a copy of what the code looks like written in Python[46] (Salihefendic, 2010):

```
#Rewritten code from /r2/r2/lib/db/_sorts.pyx

fromdatetime import datetime, timedelta
from math import log
```

[45] In this context by science I am referring to science in a very broad sense as perceived by users of the forum. This can include specific science content as well as the nature of science and scientific practice.
[46] The code is actually written in Pyrex when used for Reddit. The Python version is easier to read, however, so I am using Amir Salihefendic's rewriting of the relevant section of code in Python.

```
epoch = datetime(1970, 1, 1)

defepoch_seconds(date):
"""Returns the number of seconds from the epoch to date."""
td = date - epoch
returntd.days * 86400 + td.seconds + (float(td.microseconds) / 1000000)

def score(ups, downs):
return ups - downs

def hot(ups, downs, date):
"""The hot formula.Shouldmatch the equivalent function in postgres."""
    s = score(ups, downs)
order = log(max(abs(s), 1), 10)
sign = 1 if s > 0 else -1 if s < 0 else 0
seconds = epoch_seconds(date) - 1134028003
return round(order + sign * seconds / 45000, 7)
```

Figure 5-1: Computer code used by Reddit to sort the order in which posts are displayed on the page (Salihefendic, 2010).

The code shown here leads to the following set of equations that determines where posts appear on the page for users (Salihefendic, 2010):

Given the time the entry was posted A and the time of 7:46:43 a.m. December 8, 2005 B, we have t_s as their difference in seconds

$$t_s = A - B$$

and x as the difference between the number of up votes U and the number of down votes D

$$x = U - D$$

where $y \in \{-1, 0, 1\}$

$$y = \begin{cases} 1 & \text{if } x > 0 \\ 0 & \text{if } x = 0 \\ -1 & \text{if } x < 0 \end{cases}$$

and z as the maximal value, of the absolute value of x and 1

$$z = \begin{cases} |x| & \text{if } |x| \geq 1 \\ 1 & \text{if } |x| < 1 \end{cases}$$

we have the rating as a function $f(t_s, y, z)$

$$f(t_s, y, z) = \log_{10} z + \frac{yt_s}{45000}$$

Figure 5-2: The equations that are used in the computer code in Figure 5-1 (Salihefendic, 2010).

There are two components in the code above that determine where a post is on the page, which then effects who sees that post, as posts further down are seen by fewer people. The first component of the equation is a logarithmic term based on the number of votes the post has received. The second component of the equation is a term based on how old the post is, which very aggressively favors newer posts over older ones, causing most pages to be dominated by posts which are newer. The age of the material on the first page of 25 posts, as determined by this formula, can vary depending on the size of the community but in the case of the Portal subreddit it tends to be that anything on the first page of 25 posts is from the past few days[47].

The first component of this algorithm has some interesting elements-- in particular how this logarithmic function based on popularity shapes the content that is seen. By using a logarithm the way data is represented is compressed when compared to a linear scale as a way to handle data with a very large range of values. For example log 10 = 1 while log 100 = 2 and log 1000 = 3. For the purpose of voting this means that the first 10 positive votes a post receives will have the same impact as the next 100 votes that occur. Combined with the time sensitivity of the second element of the algorithm, this means that for a post to have a prominent spot for discussion, it is helpful if it quickly collects a few positive votes and it is fairly unimportant if it collects large numbers of votes over a very long time.

I have observed that image-based content appears to have an advantage in getting more prominent positioning on the subreddit. The images that therefore wind up

[47] The subreddit in which I am interested is relatively small at 28,466 members at the time of this writing. For comparison's sake, the largest subreddit has 5.7 million members and their posts are almost always from the same day, as anything but the most popular topics are even more quickly pushed down the list into obscurity.

dominating discussions do so, at least in part, due to the nature of this algorithm. This means that an image that gets a heavily favored position and more discussion is a result of fitting a particular profile, which leads to a quick burst of votes when first seen by viewers to keep it in a prominent position for discussion. To give some perspective on what I mean by saying that image content dominates the discussion, if I sort the forum by newest posts first, the results show that approximately 50% of all posts are text based posts involving questions or opinions about the game or issues surrounding the game. However, when I instead search by "best," which shows the most popular posts of all time, and therefore ones that were discussed longer, it shows that the top 77 posts were all image based content and the 78th post was a YouTube video (not the same as an image but closer in format to a static image than to a text-oriented post.

All of what has been discussed so far only applies to how the links are sorted but not the comments that are made under these links. Randall Munroe was one of the primary proponents for the algorithm which Reddit now uses to sort comments (2009). Randall explains that the primary goal of the comment sorting was for it to not be time oriented. It was important that links be time oriented so people found what was new and more likely relevant to them but once someone found a link and felt it was relevant the time would no longer be an important factor so they could not use the same equation they did for sorting links to make this work. In addition there are a number of weaknesses[48] to using just averages for sorting. Instead comments are sorted using a Wilson score

[48] If you would like to see a further discussion of the weaknesses of simply relying on averages for sorting usefulness of comments you can go to Randall Munroe's blog post which was cited which will both provide additional descriptions as well as provide helpful links for more information.

interval which treats the votes similarly to a statistical sampling with the following equation:

$$\frac{\hat{p} + \frac{1}{2n}z^2_{1-\alpha/2} \pm z_{1-\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n} + \frac{z^2_{1-\alpha/2}}{4n^2}}}{1 + \frac{1}{n}z^2_{1-\alpha/2}}$$

In the above formula the parameters are defined in a following way:

- p is the observed fraction of positive ratings
- n is the total number of ratings
- $z_{\alpha/2}$ is the (1-α/2) quantile of the standard normal distribution" (Salihefendic, 2010)

What is important about this is that it favors posts that have a high percentage of positive ratings to rise more quickly to the top whereas under a system focused on averages a new comment would never overtake a comment with many votes. Once a post is old enough to not be easily visible comments still die off as there are very few people coming back to posts that are more than a few days old but this does keep the comments more fluid if new good comments come up after a post has already been around for a few hours.

Comparison of Reddit's Algorithms to Others

After looking at how Reddit works, does it really differ in approach when compared to how other sites use algorithms to organize material? In the chapter on YouTube content (Chapter 7 below), there is an extended discussion of how YouTube's algorithm works[49] but even without those details, it is possible to look at the differences

[49] While the algorithm for YouTube is discussed it is much more speculative then the one on Reddit here. The reason for this is that Google does not release exactly how their algorithm works. Most of the information about it has been gathered from users and researchers following trends especially when

between the two systems. The first major difference is how older content functions on the two sites. On Reddit, once a post is more than a week old, it is very rare for any new posts to be made or at the very least for a new post to be read or commented on. On more popular portions of Reddit the timetable for new comments can even be shorter with only the first few hours being active. The reason for this is the structure strongly favors newer content in the link sections but not in the comment section[50]. On the other hand, while YouTube may favor new videos on its front page, once someone finds an older video the comments are organized such that age of a comment is given a fairly preferential treatment where Reddit gives no weighting to age of a comment. This means that even a video that is a few years old will commonly have posts from a few weeks ago whereas this is incredibly rare on Reddit.

Of course both of these structures have benefits. YouTube, while it does favor new material for the front page, is better designed to enable users to find older content. Reddit tends to discourage finding older content, as it has a fairly poor search engine and the majority of its tools are designed for prioritizing finding newer content rather than the most relevant content (if that content is years old). This has implications for designing and using web resources in the science classroom. For a class where a teacher wants students to primarily be discussing the material as it is being presented and discussed that year, a structure that is formatted like Reddit would seem reasonable as it would primarily focus on what is being done at the time although it would still be possible to

changes are made to see how it works. While the exact functions are not disclosed Google does publish papers about some of its functions which will be covered.

[50] The structure itself, as shown above, for comment sorting does not necessarily mean that newer comments could not become prominent. The problem is that since newer posts are much more active it is hard for a new comment to get the small amount of traction necessary to become more visible in the discussion even with the Wilson scoring strategy after the link is no longer prominently placed near the top of Reddit.

find older material if a student were sure it was relevant and went to look for it. On the other hand, something like a long standing science resource likely would be less concerned about people only being able to find the newest materials; many questions would still be relevant for long periods of time. In that case, a structure that more favorably treated older but more relevant links would be beneficial, making a structure like Reddit's less useful (although their comment sorting would still work well[51]).

A follow up then is to consider how these algorithms shape the discussions I am exploring and what I am able to find. A first consideration is that the time constant portion of the equation for placing topics forces discussions to leave areas of active discussion fairly quickly--- depending on the subreddit, it could be anywhere from hours to days to weeks (in fairly inactive subreddits). This means that any discussion I find is not the only time a topic has likely been discussed and while it will be some posters' first time seeing the discussion or the particular artifact that is highlighted in the post, other commenters will have a fair amount of experience with this discussion. This becomes visible in cases where commenters will go back to previous discussions and bring up material from them, but even when they do not do so, it does mean that this discussion is very focused around the specific time as opposed to other forums where sometimes popular discussions can last for months[52].

[51] While Reddit currently tends to only have comments that are a few days old, this is likely affected heavily by their favoring of posts being new for people to see them. If older posts were more common, there is no obvious reason within their strategy for comment sorting for new comments that turned out to be more useful not to rise to the top more quickly than something like sorting by averages that other sites use.

[52] This will somewhat depend on the nature of the other forums as well. Sometimes forums are very active and have rules about posting in topics that are too old and will prevent this while others may only have a few very active posts or they may have "stickied" posts that always stay at the top in which discussion can occur over a much longer time span.

While the algorithm for sorting topics shapes how discussions occur, the comment algorithm also plays a role. For example, sometimes users will go back to previous posts, choose the top comment from that post and repost it to the current discussion. While this will not always lead to that comment being equally popular in the current discussion, a comment that was popular a few months ago will usually resonate with people when it is made again. In addition, the comment algorithm works as a confidence interval, attempting to determine how likely it is that what someone said has merit and should be placed high. This means that comments that are fairly uncontroversial, such as humorous comments, are commonly near the top as they will receive mostly positive votes. However, other posts that provide ideas with which some people might disagree are more likely to receive a percentage of negative votes which hurts their confidence interval, causing them to show up lower. This does not mean that these comments never show up near the top, as other factors can encourage enough people to vote them up to encourage them upwards, but it does make it more difficult. In addition, this effect will be dependent on the size of the group viewing the post. A post from the Portal subreddit may only have dozens of comments, making reading even the lower ones more likely, whereas a post about Portal in the general gaming subreddit may contain hundreds of comments, making it much less likely for viewers to see all of them.

How Portal Shows up in Other Discussions on Reddit

The majority of this chapter will focus on discussion directly related to Portal, but it is also instructive to look at an example of how Portal is referenced in a variety of Reddit posts that are seemingly unrelated to Portal, although they are all related to science. For example, while working on this chapter, I stumbled upon a discussion of studies of coffee

drinking that noted that studies have come to a variety of seemingly contradictory results, such as that it both prevents and causes cancer (Toothpaste_n_OJ, 2015). The most popular comments on the post are notably ones that are humorous in nature, such as ColardoScoop's comment that "I'm totally willing to die younger if it means I'll live longer." The trend of humorous comments being popular[53] continues for other comments with one of the higher ones being "when I punch those numbers into my calculator it makes a happy face". Likely that comment does not make a whole lot of sense to readers unless they are familiar with Portal in which Cave Johnson declares that, when his accountants tell him they cannot afford to purchase moon rocks, "I punch those numbers into my calculator, it makes a happy face" suggesting that it actually would be ok according to him (Valve 2011). While it is clear from the high number of votes that this comment resonated with many readers, for at least one reader it did not work so well, leading to the following comment chain:

> How do you punch "coffee" into your calculator
>
> Dip gloves into coffee, put gloves in freezer, wait for gloves to freeze, put gloves on and push the coffee button.
>
> How very science of you.
>
> Coffee 2 Science 0

[53] Humorous content tends to do well on a site like Reddit where people can both vote up or down a comment to make it more/less visible. Humor, at least humor that succeeds well, tends to avoid being controversial while still being interested to people attracting people that want to vote for the content but avoiding people that might be angered by other comments when they disagree with controversial content.

> Wait didn't he say gloves? That indicates two hands so if my math is correct it should instead be… Coffee 3 Science 0 Source: am science person.

This particular chain does reference Portal but it is primarily to continue a fairly simple joke (or series of simple jokes); still, the inclusion provides a few helpful insights. The first is that Portal is enough of a cultural touchstone on Reddit that in a section unrelated in any way to gaming, enough users recognized the reference and responded well to it that it is one of the highest rated comments (and therefore most visible). The second is that while this part of the comments section does not continue the serious discussion of the study, other comments further discuss the merits of the different studies mentioned in the original post. This shows that people find a strong connection between references to science and the content from Portal, enough to mention it and have it work well. While the small section of the discussion thread quoted above may feel like it detracts from the primary goal of the discussion, which is looking at health factors of coffee, it did not significantly detract from rich discussions in the same comment chains. For example, right below this discussion was a discussion of how coffee studies have trouble dealing with the overlap between smokers and coffee drinkers which can cause issues with interpreting the data, which led to a discussion of how studies of the health benefits of vegetarianism should address the fact that many vegetarians share characteristics that make them more likely to live longer regardless of whether or not they are vegetarians, such as higher socioeconomic status. All of these discussions were able to happen alongside the humorous ones related to Portal without it being a negative factor.

The Portal Turrets

One intriguing way science is referenced in reddit discussions is in order to amplify the humor from something that occurred in the game. For example, in a discussion of the game's turrets (robot-style weapons), one commenter pointed out that the way in which the turrets in the game work explains why they are not particularly dangerous to the player. As the commenter observed, the turrets' design does not make sense if you understand ballistics. It started with this image originally posted by bustedbitmap and reappearing within the Reddit discussion posted by jereddit (2015):

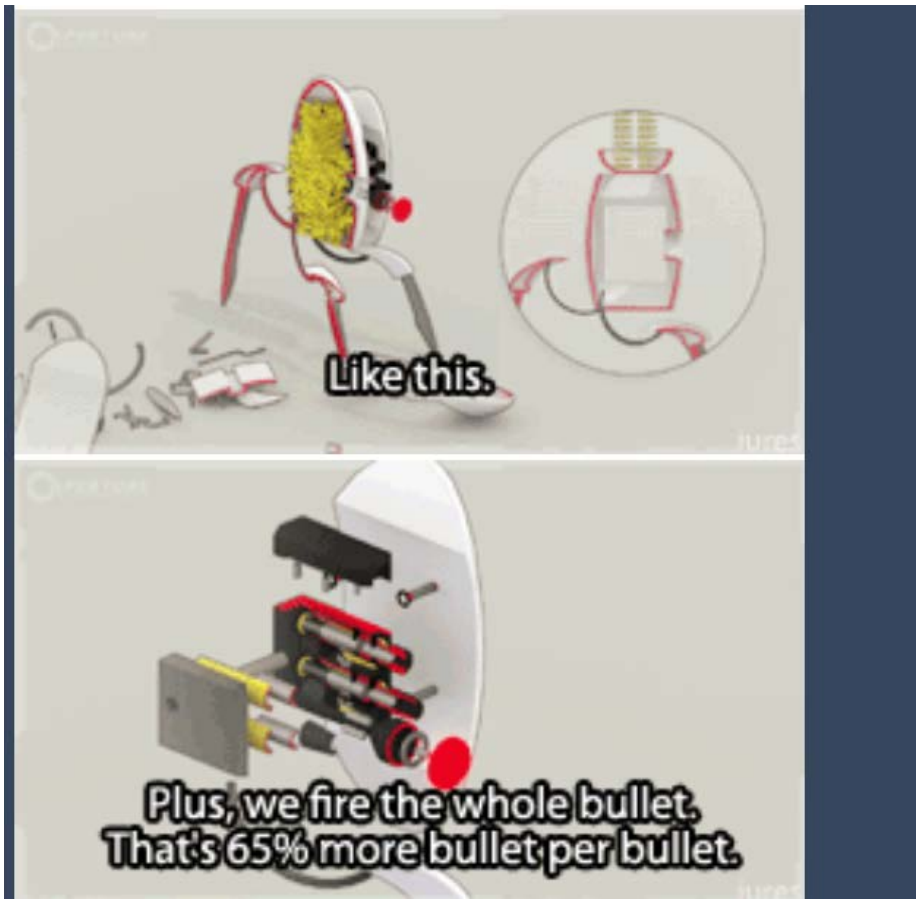


Figure 5-3: An image displaying the turrets from the game along with the speech made by Cave Johnson about why their turrets are superior to other designs (jereddit 2015).

The post includes a link to Portalgifs[54] (2014) who explains the joke as :

> NO BUT YOU ALL NEED TO UNDERSTAND HOW FUNNY THIS IS THEYRE LITERALLY FILLING A ROBOT WITH BULLETS, LIKE BULLETS THAT YOU FIRE FROM A GUN. NOW NORMALLY FIRING A GUN TRIGGERS THE BULLET TO EXPLODE CREATING A PRESSURE THAT CAUSES THE TIP OF THE BULLET TO BE FORCED OUT OF THE BARREL AT A HIGH SPEED.
>
> WHaT CAVE JOHNSON'S TURRET'S DO IS LOAD A TON OF FUCKING BULLETS INTO THE CASE OF THE SENTRY LIKE IT"S A GODDAMN GUMBALL MACHINE AND THEN USE A FUcKIN **SPRING LOADED PISTON** TO FIRE IT THAT IS SO UNNECESSARY AND INEFFECTIVE LIKE NO WONDER CHELL CAN RESIST SO MANY BULLETS THE LIKELIHOOD ITD CAUSE ANYTHING MORE THAN A BAD BRUISE IS LIKE ONE IN A HUNDRED

In the thread of comments that develops, a participant called outadoc notes that, "Valve's humour and attention to details is part of what makes their games so good." Multiple users respond with agreement and their own appreciation of the game developers' approach, which suggests that including that level of rich detail, which is not essential to a player's successful completion of the game but which can be discovered and explored even years after the launch of the game, has value for the game's audience. Mimicking Cave Johnson, the founder of Aperture Laboratories in the game, one of the responses to the portalgifs explanation, from monasticmaestoso, is that "but it's 65% more bullet per bullet" which is part of the line that is used to suggest why clearly this must be a superior method.

Portalgifs response also shows how interesting information can be interjected into a humorous discussion. While he is explaining that it is funny Portalgifs goes through a

[54] On PortalGifs's page you can also find an animated version of this image that is referenced in the discussion on Reddit http://portalgifs.tumblr.com/post/82832868793/no-but-you-all-need-to-understand-how-funny-this.

basic description of how a bullet should normally work since guns are made to trigger an explosion to propel the bullet rather than to be used in a spring loaded set up. Other users also point out inconsistences that mean that, while this is humorous, it still has some issues. One user, mandrilltiger, points out how a spring loaded turret might be a silly design but it would still definitely be dangerous. LordNoodles also points out that what they really mean is they fire the whole cartridge as guns do fire bullets but the bullet is not all there is to what is loaded into a gun. Both of these comments further the discussion though of how do bullets really work while being couched in humor about Portal and are potentially being read by people that would never have a reason to explore this particular question otherwise.

This example demonstrates how important details can be. In addition to providing a rich environment for someone that chooses to explore further, game creators cannot be sure what will spark someone's interest or lead to an interesting discussion. Having read through many Portal-related discussions on Reddit, I can attest that this particular fact from the game, (that is, that the turrets are spring loaded, which makes no sense in terms of real-life ballistics) is not all that commonly referenced, even though it did generate an interesting discussion in this case when someone took note of it. This suggests the importance of looking at discussions to see what can happen and what can resonate with users but realizing that this does not necessarily mean it will happen the majority of the time. Providing a rich environment with lots of possibilities allows discussions to crop up in different places depending on what ends up connecting well at the time.

Combustible Lemons

Before playing this game, I would never have imagined that one of the most memorable moments for me (as well as for plenty of other players of the game) would be a speech about how someone was going to create combustible lemons to burn someone's house down. This striking, humorous speech occurs near the end of the game. It is spoken by the character Cave Johnson, who is the founder of Aperture Laboratories,[55] in the context of explaining an invention that he wants his engineer to make for him. As the game has unfolded, Cave has been shown to be a fallen man, who was once considered a brilliant superstar when he created his research facility but who has since been caught in a downward spiral. Now he is increasingly desperate to hang on to his crumbling lab as well as to battle the cancer he developed as a result of the dangerous scientific tests he encouraged early in his career. This leads to his outburst, a speech that captures his anger and frustration:

> When life gives you lemons, don't make lemonade. Make life take the lemons back! Get mad! I don't want your damn lemons, what the hell am I supposed to do with these? Demand to see life's manager! Make life rue the day it thought it could give Cave Johnson lemons! Do you know who I am? I'm the man who's gonna burn your house down! With the lemons! I'm gonna get my engineers to invent a combustible lemon that burns your house down!" (Valve, 2011)

This speech has sparked many discussions online, both on Reddit and in other forums in the online affinity spaces related to the game, and driven many others that did not

[55] Apeture Labs is the once thriving, now deserted research facility in which the action of the game takes place.

originally begin with a discussion of Cave or lemons or even Portal. Of course, at one level, this rant is simply a colorful variation of the "If life gives you lemons, make lemonade" cliché**.** For example, in a discussion by nadrojmail (2013) about this quote, one user[56] explains it as a way of saying "when bad things happen, don't just accept it, put up a fight." The user goes on to comment on how the joke is that Cave Johnson then gets distracted by the lemons and ends up focusing on them more than the meaning of the idiom.

Much like Cave Johnson's distraction by the actual lemons, the concept itself -- a lemon grenade-- took off for many users. Examples from users on Reddit include the following:

[56] This particular account has been deleted. This leaves the comment but makes the author unknown.

Figure 5-5: Three images created that combined ideas from the safety signs in the games as well as Cave Johnson's idea of combustible lemons (JoshKerky 2014, Shaneredid91 2012, JamRad 2011)

These posters are just a representative sample of the dozens that can be found online. There are also t-shirts, prop lemon grenades, coffee mugs, jewelry, even videos that people create showing their attempts to make an actual lemon explode. The combustible lemon became a commonly recognized symbol for the game.

Discussions of the lemon speech often revolve around how players feel for Cave as he is speaking. For example, there is MRRobers' comment in a discussion thread created by superanth (2011), "the way his voice cracks just a little when he yells 'do you know who I am?' gives me goosebumps" as well as a comment by HarveryDent[57] "…how sad it really is listening to Cave saying it." Even though the idea of making combustible lemons instead of lemonade starts as humor and even though most online discussions of the speech begin by focusing on its humorous ideas, it can lead into a fairly serious thought process that resonates with people about the difficulties of facing challenges in life, particularly those challenges that are perceived as undeserved.

The Long-Fall Boots

Another invention from the game that ends up sparking some interesting discussions is the long-fall boots. The long fall boot is explained in the game as a boot developed to absorb the impact the test subject would receive when landing after falling from a great height, to protect the test subject as well as the portal gun the subject carries. From the perspective of the game developers, it is a way to explain why the player does not have to worry about falls, which are common when trying to complete the physics

[57] If you read the entirety of HarveryDent's comment he/she suggests that people don't recognize often enough how sad it is due to the ridiculousness of it. After having read many of these discussions I have found this to not be true; people do seem to get it even if they start the discussion by bringing up the lemon grenades as a joke.

puzzles that are a key component of the game. Even though the boots might have been envisioned by the game designers primarily to ease the process of solving puzzles, their existence in the game has inspired interesting discussions from players trying to understand how these imaginary devices might work in the real world.

For example, MpegEVIL wrote a post in which she/he asks about how far the player survives in a fall at a point in the game called "The Fall" (2015). The first answer is quite simple and says, in essence, look at the signs the game developer includes in this sequence. There's one at the area where the fall begins that says 4.5 km and another at the ending that reads 2.5 km, so that shows that the character survived a a total of 2km of fall distance. However, other responders are not content to read the signs; they feel the signs are incorrect. For example Jatexi goes into the following description:

> Well, the fall is 59 seconds long and terminal velocity is 200km/h or 56m/s. Chell seems to already be at terminal velocity at the start, probably because some of the fall was cut due to the chapter change, so she can't accelerate anymore. So I'll figure this out with the clips we have.
>
> 200km/h is equal to 56m/s.
>
> 59s X 56m/s = 3304 meters.
>
> 3304 meters = 3.304 kilometers.
>
> So, you fell about 3.3 kilometers. Which is not the 2 kilometers the signs suggest.

While it may have been a question that was not particularly serious in nature it ends up leading to a discussion including science concepts such as terminal velocity as well as

scientific habits of mind, such as determining what approximations have to be used in calculations due to the lack of complete information as well as questioning observations (in this case the signs the players see related to distance). These questions are further explored in comments such as someone asking about why the player's mass matters, since gravity is not dependent on mass, to which another commenter responds with the explanation that air resistance does affect rate of acceleration and terminal velocity.

While the inventions mentioned -- the Portal turrets, combustible lemons, and long fall boots -- may not be real, this does not mean there are not similar real life counter parts that people will connect with the devices from Portal**.** For example, one Reddit discussion begins with a link to a video of people doing acrobatic tricks by jumping over cars using spring-loaded stilts[58]. While these stilts can be used safely, there are a number of safety concerns related to their use, especially if attempting something as dangerous as doing a somersault over a car, a trick that is shown in a video linked in the comment section (RedSquidz, 2013). The comment sections do mention some of the potential dangers with multiple members suggesting that people not try these stunts as they are not as easy or as safe as they might look and another user linking to a video of someone who was jumping over cars on a television program and landed on his stomach and broke his spine. Of course other users suggest the stilts are lots of fun and give people links to websites where they can buy similar boots if they want to try them. What is especially important to note here is how sometimes seemingly unimportant parts of a game, in this case a way to explain away the player being injured from falling too far that is rarely

[58] While the way in which these very real shoes work differ from the ones in the game, they are brought up as connections to the long fall boots likely because they look somewhat similar and both allow for unexpected jumping ability although for different reasons.

brought up, can be connected to other concepts by people that would otherwise not know about them (and in this case this also lacks much of the safety discussion that might be seen when finding them more directly). It is important to understand at a basic level the game that people are playing, so that it is possible to know when they are talking about something from the game and when they have switched to talking about something in real life, which might raise concerns.

What is shared between this and the previous examples of lemon grenades and Portal turrets is the focus on the technologies that science can make available to people. While there are sometimes discussions of how inventions like these might work, it does not bother most of the people when they do not understand how these objects work. This would suggest that the game is at least conducive to a thought process that primarily focuses on the objects of scientific discovery as symbolizing science. It could be argued that the game even somewhat encourages this view by relying on these inventions as some of the primary tools to connect the game to science in players' minds.

The Characters of Portal 2

While there are a number of characters in *Portal 2*, a few in particular seem to connect strongly with the players of the game. First there is Cave Johnson. Cave is the character who created Aperture Science and was the primary person in charge of the laboratory as long as it was still run by humans, before GLaDOS took over. Cheeseburgz describes her/his connection to Cave as follows:

> "I really felt bad for Cave Johnson. As you're playing through the game, you see years go by (on the walls, you see 1978 and other years), you see the deterioration of Aperture

> Science Labratories from an excited upstart with a promising future to a desperate company trying to make ends meet, to an old man's plea for, if not his own life, the life of someone he cares about (Caroline). Specifically, the Lemonade part (while a little hilarious), made it hit home: here's a guy who's seen his company climax and go into steep decline all within a few decades, even though he came up with some amazing stuff" (Cheesburgz, 2011).

In the discussion that follows this post, Legather specifically comments on how Cave is a "lunatic" with his own "take on dedication to 'science'." Legather uses the specific actions of Cave to define the character as having a problematic view of science. These include Cave's plans to use hobos to perform tests by offering them 60 dollars as well as the way he forces employees into "voluntary testing" so that they are not replaced by robots. In the end, Legather describes Cave as a "ridiculous character," which mimics a number of responses from other players who also see him as providing an example of the incorrect way to do science. Others, however, have a different take on the character. Crawdaunt, for example, responds that Cave "may not have always approached things the right way, but he wasn't afraid of the risks." Here Cave is admired for his willingness to take risks; several commenters see a correlation between risk taking and advancing successfully in science (Cheesburgz, 2011).

While Cave is a commonly referenced character in the game, there is no character mentioned more often than GLaDOS. GLaDOS is the artificial intelligence invented at Aperture Science to help run tests in the laboratory who[59] ends up taking over the

[59] The use of "who" over "that" as the preferred pronoun here is intentional, even though GLaDOS is a robot. In the game as well as with people writing on the forums, GLaDOS is mostly commonly referred to using female pronouns rather than non-gendered pronouns. In addition, in the story of the game it is

laboratory and removing the human control as she feels she can test more efficiently. GLaDOS can be described as what might happen to science if it did not contain any human concerns for ethics. While GLaDOS is discussed by far the most of any character in online discussions of Portal, when mentioning Portal, there is much less discussion about the particulars of her position as it relates to science. This seems to be related to the fact that her viewpoint is more unambiguously presented in the game as problematic, whereas Cave is shown as multifaceted, with positive attributes with which players can feel a connection even if his views are also ultimately seen as dangerous.

Another area of interest related to GLaDOS is her connection to Caroline, Cave Johnson's personal assistant, as illustrated in the following image posted on Reddit:

Figure 5-6: An image created by a user on Reddit to describe Caroline's connection to the goals of Aperture Science (LobsterHat, 2012).

suggested that GLaDOS originated from a female game character having her memories implanted into an artificial intelligence, GLaDOS.

This provides one way of interpreting GLaDOS and Aperture Laboratories, and by connection Cave Johnson, as being personifications of science. The first claim, that she was married to science,[60] suggests that her connection to Aperture was also a connection to science. The second statement, that she now IS science, is a reference to the fact that Caroline's memories[61] were transplanted into GLaDOS to help create the robot AI and as such she has now been transformed into "science" itself[62].

In these discussions it is also possible to learn more about how people perceive science when interpreting the Portal story for themselves. For example, in this same discussion from cheesburgz, metaridley18 observes that he/she feels it would be hard for GLaDOS to kill off the main character because "It also seems like an AI specifically built to test and find knowledge would have a really hard time getting rid of a rich and different perspective. If there's anything science does, it shows us that a different viewpoint is often all you need." In this case we can see that Metaridley18 views testing and the acquisition of knowledge as key components of science that are amplified by having multiple perspectives (Cheesburgz, 2011).

Some players also are intrigued by looking for clues within the game that help them learn more about the characters. For example, TeaEyeM is keenly interested in the

[60] Early in the game Cave Johnson explains to employees that Caroline is not available as she is "married to science".

[62] In addition to be an interesting way of viewing the character from the game, this connection between GLaDOS and science will come up a number of times in future chapters such as in Chapter 6 in the artwork "Fuck Science" as well as the wallpaper created combining images from the game, including GLaDOS, and lyrics from "No Church in the Wild". In both of these pieces as well as a number of other references knowing that players make this connection between GLaDOS and science is critical for being able to understand the works.

question of Chell's[63] parentage. In her/his exploration of this question, he/she suggests that Chell is the child of Cave Johnson and Caroline. She/he comes to this conclusion by compiling a number of small hints that do not give complete answers, such as finding Chell's name on a poster from the "Bring your Daughter to Work Day" projects that are present and finding translations for the Italian opera sung by the turrets at the end of the game. During this process she/he also finds that the opera includes lines that roughly translate to "Goodbye my daughter, please stay away, away from science." This continues the trend of the laboratories being perceived as a representative of science that should be avoided.

Interestingly enough Chell, is not often mentioned as a character to whom players feel a strong emotional connection, although she does often show up in the art, which we will look at in the next chapter. One possible explanation for this is that Valve designed the character with the intent that she be amorphous so that players could feel that they *were* Chell rather than simply observers of Chell's story. Erik Wolfpaw, one of the writers of the game, stated in an interview that they purposely did not give Chell much of a personality as they wanted players to feel like they were the character rather than watching the story of Chell (Eurogamer staff, 2011).

Player Identified Favorite Quotes

Another common topic for discussion on the forums is quotes from the games that players found particularly memorable. The quotes themselves as well as some of the

[63] Chell is the name of the female character who is controlled by the player and through whose eyes the player observes the world of the game. Most games using such a perspective are referred to as 'first person shooter" games, but Portal 2 subverts that notion because the player is not shooting things, but rather solving puzzles

responses to those quotes that are chosen can provide some interesting insights. The quotes below were from a discussion[64] started by J3r3myKyle (2015) with a quote from Wheatley, the AI core that travels with the player at the start of the game and acts as a guide: "You might have a very minor case of serious brain damage[65]". The majority of the responses to this initial quote were other users commenting on what their own favorite or most memorable quotes from the games were.

One response to the initial quote was provided by a user who includes the immediate follow up that is provided by Wheatley, "But don't be alarmed, because... uh, well actually, if you do feel alarmed, hold on to that. Because the feeling of alarm is the proper reaction to being told you've got massive brain damage...". While the humor in these quotes is based on the character's inability to speak for reasons unrelated to in-game activity, the quote also suggests a particular view of mental health as being appropriate. In this case, it is the desire to not be brain damaged.

If this were the only case of users engaging on the concept of mental health, it would not provide much insight other than that people would prefer to not be brain damaged. Another example that was quite popular was commenting on a scene that occurs early in the game, where the player is encouraged to interact with art and music in

[64] Some of the quotes provided here are actually off by a few words when compared to the spoken words in *Portal 2*. This is because this was how the members of the forum remembered the quotes. Also while I have chosen to use this particular discussion these quotes were all mentioned in other discussions as well although sometimes with different follow up discussions.

[65] The joke relies on an encounter right before this in which Wheatley is trying to assess the current mental state of the main character. Wheatley asks the player to say "apple" and the game provides a prompt that states "to say apple, press the space bar." Rather than saying apple, however, the player jumps when the space bar is pressed. This is based on a fourth wall break due to the fact that the player knows the character is a silent protagonist and can only interact with the world through jumping/moving/interacting with objects and therefore cannot possibly say apple while Wheatley does not realize this and assumes that the player may no longer be able to speak due to his failure to maintain the character's sleep state appropriately.

the following exchange between the player and an announcer giving directions to the player:

> "This is art. You will hear a buzzer. When you hear the buzzer, stare at the art. [Buzzer, short break] You should now feel mentally reinvigorated. If you suspect starting at art has not provided the required intellectual sustenance, reflect briefly on this classical music. [Classical music plays for a few second and is interrupted by a buzzer].

Here it is possible to see that people responded well to the satire of how the scientific process can sometimes seem foreign to using other forms of knowing, such as art or music. This particular set of statements is funny not only because of how absurd it sounds to suggest that a controlled scenario of staring at a piece of artwork for a few seconds would lead to mental invigoration but also because that particular scenario, while not the norm, is quite imaginable in the right context of a scientific experiment on art[66].

While the discussion thread started with a quote spoken by the character Wheatley, I have found the greatest number of quotes to be from Cave Johnson. For example, when doing a test, the player hears a recording from him that goes as follows, "If you feel shortness of breath or any lung cancer symptoms, that's not part of the test, that's asbestos." Within the discussion thread, the most interesting responses to this particular quote developed into a discussion of asbestos and an interest in what would have been the reality of the situation in the 1950s, when Cave Johnson was said to have

[66] This is not to suggest that players think directly that we test art by looking at it for five seconds and then playing a buzzer but instead that sometimes in an attempt to know and place very strict rules on why something works science can end up destroying the experience and creating a new foreign one divorced from the original experience such as in trying to breakdown the mental processes experienced in viewing art.

started Aperture Science in the game world. On user suggested that no one in the 1950s would have known about asbestos being toxic. This leads to follow up responses such as one user[67] noting that:

> "In fact the first regulation regarding asbestos workers (Ventilation basically) was in 1931.
>
> In fact 1970 court documents proved industry officials knew about the dangers since the 1930s."

A very noticeable part of this discussion is that for the most part it was a person stating with no evidence what they thought about asbestos followed up with someone making an assertion that was somewhat more complex sounding but also included minimal evidence. This is not always how discussions occur, but it can be common for discussions like these that happen somewhat buried in a complex comment structure where significantly fewer people are participating in this specific part of the discussion. In other circumstances, such as will be seen in Chapter 6[68], if a significantly knowledgeable individual happens to be part of the discussion they can provide additional facts that shape the discussion in a positive way.

Another Cave Johnson quote from the discussion was, "They said I couldn't fire someone for being in a wheelchair. Did anyways. Ramps are expensive," another comment which emphasizes Cave's lack of concern for others if it got in the way of

[67] This particular comment was done by a user who has deleted her or his account. This can happen for a number of reasons and while not done by all users is common enough that it is not particularly notable. It is also helpful to note that if the user wished to instead hide a specific comment because they did not want others to see it he or she would be able to delete the comment and it would cease to be accessible.
[68] See discussion of webcomics below in Chapter 6, particularly page 113.

"progress." Throughout discussions about the game which include Cave, people will include quotes[69] from him which emphasize the levels of absurdity to which this character can go as he attempts to ignore any concern for people as part of his program. Critiquing viewpoints of science which ignore the potential human costs of scientific progress through satire seems to have resonated quite well with members of the forum.

Cave's comment on ramps, along with the previous one about asbestos, also shows how difficult it can be to examine these quotes at first. If I were asked to simply analyze his statements independent from the game environment, they would mostly be a list of fairly horrible sounding and/or discriminatory statements which suggest Cave has insufficiently dealt with potential safety concerns in his science set up. However, when looking at these quotes in the context of the game as a whole, it becomes possible to see Cave as a purposely exaggerated satirical character who represents what can go wrong with science if concerns related to the people involved are ignored.

Another character from whom quotes are often given is GLaDOS[70]. For example, one user included a quote from near the end of the game where GLaDOS is talking to the player right before forcefully removing her from the lab:

> "You know, being Carolyn taught me a valuable lesson. I thought you were my greatest enemy, but all along you were my best friend. The surge of emotion that shot through me when I saved your life taught me an even more valuable lesson; where Carolyn lives in my brain." "**Carolyn deleted**" "Good bye, Carolyn."

[69] Another very popular quote from Cave Johnson, about burning someone's house down with a combustible lemon, is discussed in the combustible lemons section of this chapter.
[70] The artificial intelligence who is running the lab at the start of the game.

Other commenters noted that during this portion of the game, the game tone changed in ways other than what might be seen in the words, with 2ndComingOfAugustus pointing out that "The drop in the music, the change in lighting, the change in her voice, everything gets an order of magnitude more threatening."

Conclusion

Portal 2 is a game that is rich in content and that inspires Reddit discussions that reflect a wide range of interests. One topic that many of those discussions address either directly or indirectly is science, both in-game science and "real world "science. Humor is not only an important component of the game but also a frequent component of Portal-related commentary. Examining the wide-ranging topic of Portal 2 and science through the lens of the Reddit community enables science educators to better understand the way members of that community understand and think about science. It also enables educators to gain insight into what aspects of the game, ranging from inventions to background details to characters, resonate with, and inspire reflection from, those who participate in the game and its related affinity spaces. These insights have the potential to improve efforts to create interesting and relatable science-related online content, which can take the form of discussion forums, content aggregation sites, or even games themselves. For the next chapter, I will explore how concepts of science appear in art related to *Portal 2*.

Chapter 6 *Portal 2* and Online Fan Art

Just a heads up: we're gonna have a superconductor turned up full blast and pointed at you for the duration of this next test. I'll be honest - we're throwing science at the wall here to see what sticks. No idea what it'll do. Probably nothing. Best-case scenario, you might get some superpowers. -Cave Johnson

In the previous chapter I explored a multitude of discussions players had based on the game *Portal 2*. In addition to discussions like those, users create art related to the game as well. In this chapter I will examine a number of these creations as well as the discussions that arise around these pieces. Some of the most interesting of these works and discussions are a number of webcomics users have created based on portions of the game.

Portal Webcomics

The image on the following page is a web-based comic relating *Portal 2* to the scientific ideas embedded in the game. To understand this specific comic, you will need to know a few things about *Portal 2* and about web comic conventions. The first is that one of the main concepts of the game is the ability to solve puzzles by using 2 portals[71],

[71] Portals are explained in the game as a way to connect pieces of space. The player has the ability to place two portals-- one blue and one orange-- at a time. The player is then able to move through the portal to the location of the other portal and when doing so they maintain their state such as if they fall

one of which has an iconic blue color while the other is yellow. These portals are one of the most commonly used symbols from the game, and references to them signal to observers that something is related to *Portal 2*. The portals' function in the game is to allow anything that moves into one of them to immediately emerge from the other one with its kinetic energy intact (thus maintaining its momentum).[72]

The infinite energy watermill

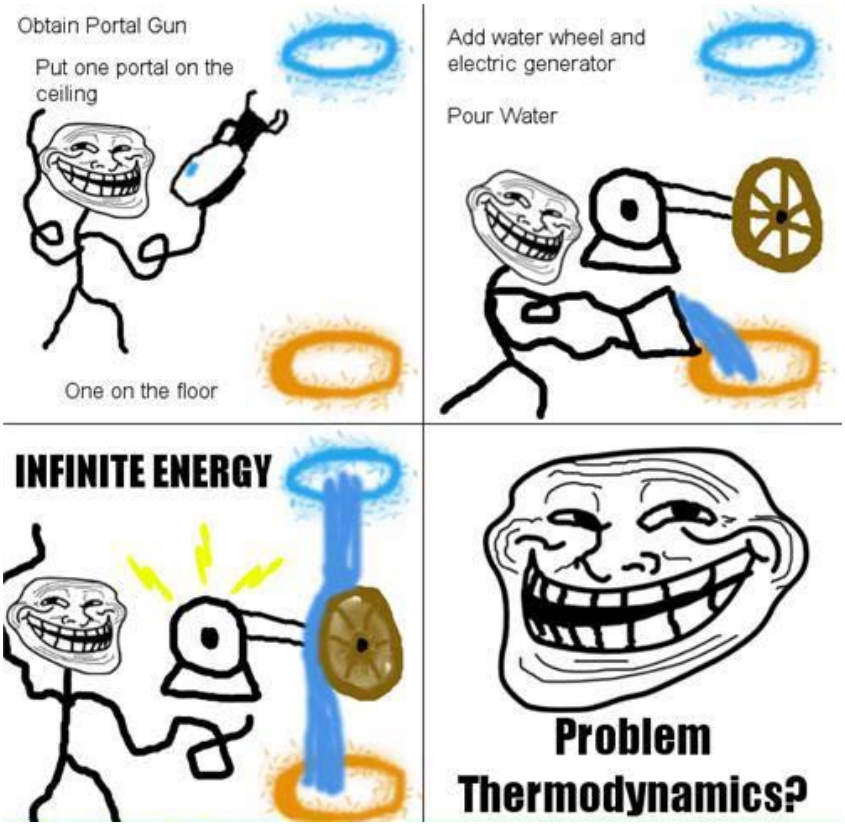


Figure 6-1: A comic in which someone uses portals to generate an infinite energy waterwheel (Tailsfan95, 2011).

through a portal on the floor they maintain their speed as they go through the other portal. This allows the player to complete puzzles by manipulating their trajectory coming out of a portal.

[72] As will be pointed out in a later comic in the paper, this is not exactly true necessarily. Momentum includes direction and sometimes the objects come out of the portal moving a different direction thus actually having a different momentum. The game simply describes the action of portals as "speedy thing goes in, speedy thing comes out".

The large distorted face in the comic is known as a troll face, a character associated with web comics generally, not specifically with *Portal 2.*While the troll face can be used in many ways, it is primarily used to suggest that something the character is doing is purposefully ignoring some common piece of knowledge (in this case how conservation of energy works), usually for the purpose of humor. Additionally, the particular format shown here is commonly referred to as a rage comic.[73]

Below are a few more examples of comics built around the notion of creating infinite energy[74] in this way using *Portal 2* technology. I chose to use this idea of infinite energy from water wheels because it is a common example of the ways in which science comes up in different venues related to *Portal 2*. This water wheel idea is not the only science idea from Portal that is used in comics and other such images, but I think it is interesting to look at a number of similar examples to see how an idea from the game seems to come up in a number of different places rather than just being an isolated incident. Each of these images has its own chat discussion connected with it, which enables us to see how people respond.

[73] Rage comics have a couple of iconic features by which they can be identified, although sometimes one of these features will be relaxed or ignored to improve the effect of the comic. The first is the use of stock faces such as the trollface shown in this strip. These faces tend to represent the tone of the comic and help the reader to know how to interpret it without having to use much space to do so. Other examples include faces intended to show anger, confusion, or frustration just to name a few examples. The other common features include a sparse use of words, a frame setup as shown in the example that tends to involve 4-8 frames read from left to right and top to bottom (this is helpful to know how to read the text inside a frame in addition to the order of frames), as well as usually humorous connotations related to the face used.

[74] These comics are based on slightly changing how a waterwheel works with the game mechanics. The idea behind a waterwheel is that as water is falling down, it has gravitational potential energy that is transformed into kinetic energy as it falls. The water wheel gets in the way of the falling and some of the kinetic energy is transferred to it to move the water wheel. In the case of these comics the portals function to give the water additional kinetic energy by continuously moving it back up. However, there is no provided mechanism for where the energy comes from. If there is no source of the energy this would break the law of conservation of energy (the total energy of an isolated system is a constant).


1-Get a portal Gun.
2-Make a portal in the ceiling and on the floor.
3-Install a tube. Leave a gab.
4-Install a propeler and a motor.
5-Pour 11 of water.
Big Profit ! Make Millions!
During 24 hours it gene-rated 5 GigaJoules of Energy !

Figure 6-2: Two more examples of comics to create infinite energy using the science behind portals from the game (Glampkoo, 2013; Tralala18)

The discussion thread for this image from Tralala18 includes lively exchanges further exploring the science behind portals and how the portals could interact with

waterwheels. For example, a contributor named Armetik suggested that even within the game universe, the waterwheel setup would not work because "the mill would slow the water down thus lowering its velocity and continuing doing it so until it would stop rotating the mill. The gravitation would no longer apply inside the portals, they only conserve velocity (kinetic energy)" (hugelol.com/lol/116060). The thread also contains a question about this concept and wormholes, to which Zenmaster responds "no, you dont understand. a wormhole is simply a warp of spacetime, as is gravity. if a wormhole has disrupted spacetime, gravity will not work in the same way at all. a wormhole is nothing other than an extreme effect of gravity, except that to make one you need huge amounts of matter with a negative mass or energy. we know of no such matter." (hugelol.com/lol/116060). Zenmaster's comment also led to a number of other contributing responses involving discussions of how gravity and momentum both function.

There are also responses that, if I were not already familiar with web comics found on sites like this one, I would have evaluated very differently. For example, spartanjoker responds to the initial image with the response: "There is nothing wrong the physics here, it would work fine?" (hugelol.com/lol/116060). On the surface, it would seem appropriate to state that this person, not seeing any problems, clearly does not understand the implications of the science behind the activity depicted in the comic. However, I believe this person is undertaking an activity people on the internet refer to as "trolling."[75] One challenge for the researcher dealing with trolling is that because it is

[75]Trolling is term used for certain types of speech commonly found on the internet, although it can occur in other places as well. While if something is trolling or not is somewhat context dependent, in general it can be seen as statements that are intended to have double meanings where when read at face value it actually has the opposite meaning of what it has for the part of the audience that is supposed to know it is actually trolling. While somewhat similar to satire, trolling relies on the fact that some of the readers will take it at its literal meaning

impossible to know what another person is thinking, we must determine to the best of our ability whether or not something is trolling by considering our own reaction as well as what other users say in response. For trolling to "work," it requires some respondents to take the statement (in this case, that the physics of the comic is correct) at face value and disagree with the poster while a second portion of the audience realizes it is supposed to be a "troll" and laugh at the people responding to him seriously while he continues to pretend to not understand or ignore the people responding to explain why he is wrong.[76]

Portal Inconsistencies

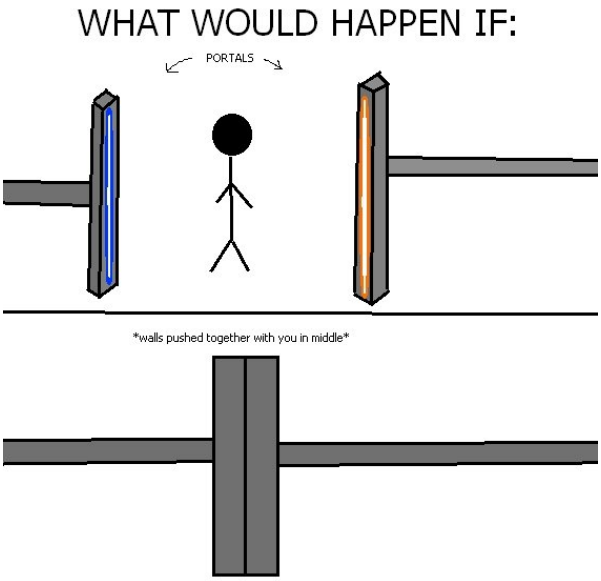


Figure 6-3: A comic considering the question of what would happen if two portals were pushed together with someone between them (Habitat, 2011)[77]

[76] Of course, it is not possible to determine with certainty that someone is trolling, and seeing something as a troll is often a gut reaction. There is no checklist to determine "troll/not troll." I explore these incidents and people's reactions to trolling in part because it is a unique way to look at attitudes toward science, the use of scientific understanding and lack of understanding for comic effect, and the ways that some people attempt to educate others through discussions of these cartoons related to Portal science.

[77] The image above is one posted by a user named Habitat to funnyjunk. From reading and searching a number of sources this appears to be the image that was discussed in the Reddit forum post "A Wild

The above comic is another example of how the intersection of "real" world physics and the physics of the Portal universe can create contradiction leading to both humor and interesting discussions of how to resolve these conflicts. Because this particular comic appeared on a very large online forum shortly after *Portal 2* was initially released, it generated an extensive discussion with 932 separate comments about the image. The majority of the discussion starters that generated larger discussions were users attempting, through a variety of strategies, to answer the question of "what happens."

For example, agentid36 chose to answer that question by providing a fairly serious answer[78]that focuses on making the Portal universe work correctly:

> Nearly the exact same thing is happening here as would be when the two walls didn't have portals on them, just a little differently. No matter what, the volume in between the two portals decreases, therefore once the walls get close enough such that the volume can't contain you, you will be squeezed out the sides. The pistons are not exerting any force on you, the distance between two points/planes is

---

Portal Troll Appears! ANSWER". This particular post though relied on a version of the image uploaded to imageshack which has since removed the image (it is 4 years old and not all sites keep images for long periods of time). The discussion shows the users are discussing an image which involves portals being placed on two pistons and having them come together with a person in the middle and the comic asks what happens. The image is also uploaded the same month as the Reddit post and from previous experiences within this community it is quite common for an image that is popular to end up moving from one site to the other. It is still possible that the users are actually discussing a slightly different version of this comic but this should make minimal difference to the particular discussions highlighted here. The Reddit discussion in question can be found at:
http://www.reddit.com/r/gaming/comments/gzm6h/a_wild_portal_troll_appears_answer/

[78] By serious I mean that the user primarily focuses on answering the question posed by the image. Other users (some of whom are discussed below) will still answer the question but will include significantly more sarcasm in their answer or include jokes and spend less of their writing answering the question.

simply short-cut (think of it like rolling a piece of paper into a tighter and tighter spiral).

edit: the portals probably follow newtonian physics, were they to exist.

This is the most standard answer given for this discussion which seems satisfying to the users of the forum. That is, unlike the next example where many users argued with the response, this one led to very little discussion other than people agreeing with the user. Of particular note was that very few elements about how the stick figure might work are discussed, which leads to fewer points for users to argue about potential different interpretations. In addition, agentid36includes a final remark labeled 'edit'[79] that includes a mention of "Newtonian physics." This may seem somewhat out of place, but one common way that explanations are addressed in such online discussions is to suggest that a particular version of physics rules break down or that it is specifically quantum effects, usually as related to explanations of wormholes, which explain how portals function. In the next comic in this chapter, for example, a number of users address the users' questions by arguing that portals function because of relativistic effects which make them function from the reference frame dictated by the portals but not from any other frame of reference (in that example looking at portals moving on a train).

Another reply to the image led to the following discussion of stick figure movement and specifically torque[80]:

Notabus: You're a stick figure. You don't have width. Turn sideways. You're fine.

[79] Users are able to make adjustments to their comments after they initially post them. One way users let others know that something was changed at a later date is to mark adjustments with an edit label.
[80] Torque is a force that is used to rotate an object.

kamikaz1_k: How would you apply the torque to turn sideways?

saibog38: The real reason a 2-D figure can't exert force in the 3rd dimension is because it doesn't actually physically *exist* in a 3-dimensional world. As in it has zero volume, zero mass, zero thickness. At most it is a *surface*; essentially an idea, or a mathematical equation. And going back to the fact that it has zero mass - well, then the force required to move it is now zero as well. Remember - the moment you give it any thickness of any sort, then it also has the means to generate force in the third dimension, so we're running on the assumption that this is truly a 2-dimensional figure with no existence in the 3rd dimension, and thus no physical reality in the 3 dimensional world.

So how does it move then? Considering it's really just an idea, all that it needs for it to move is for that idea of a surface to change. Now how does that all happen? Fuck if I know. We're talking about a goddamn stick figure in real life. But I think it's fair to say that it don't need no torque to move.

Notabus's reply was the second most popular answer in the discussion and began a fairly lengthy discussion[81] with a simple statement about stick figures simply needing to turn sideways. This leads into saibog's discussion about torque even though the initial question does not require this particular issue to be addressed. This leads to a discussion of what a 2-dimension figure is, with saibog suggesting that the readers think of it like a surface with no mass, meaning that trying to give the stick figure the ability to apply torques to move would not make sense.

[81] There are many other responses to Notabus's post in addition to the other two included here.

He finishes his answer by pointing out the absurdity of the question to address concerns that are brought up when the physics principles get pushed hard because they are dealing with a non-real object and trying to decide how it would move. The social expectations of the users allow people to respond reasonably to a claim to abandon the problem when it breaks down since "We're talking about a goddamn stick figure in real life."

Saibog's response is not the only discussion of how the stick figure might act. The next response[82] is another take on how a stick figure might move:

> The stick figure is two dimensional, but he's in a three dimensional world. He can turn to the side, walk back and forth in the shot, put on ice skates and do a triple axle, basically do anything he wants.
>
> He has no depth, but the world he's in does. There's nothing stopping him from turning sideways, since sideways exists in that three dimensional world.
>
> He can perform almost every physical act you can, except when he turns sideways he goes invisible (or nearly invisible, flat and thin enough that you can't see him except for a line), but it's important to note that **he's only invisible to your perspective**. If he didn't move and you walked over to one of the portals and viewed him from there, he would be similarly invisible.
>
> **Edit:** Whoa, never gotten so many comments so quickly.

[82] As discussed in the last chapter, it is possible for a user to delete her or his account which causes all posts to remain but the identity of the poster is removed. It is also possible for a user to choose to specifically delete a post which will then remove the post without users being able to see it. This post was written by one such account.

> The premise here is that it's a stick figure, so when he turns sideways he disappears. I described it incorrectly when I said he "goes nearly invisible." He would go entirely invisible, since he has no third dimension. My bad.
>
> Still, the premise is that he's a stick figure and the picture clearly shows depth.
>
> Can there be a two dimensional stick figure in a three dimensional world? When you have an answer for that I'm going to ask you how realistic those portals are. We're working inside a premise here. Roll with it.
>
> **Edit 2:** Can we not all agree that stick figures are made of sticks? Not muscles and intestinal tracts? I mean, I thought I was being a little silly with my comment, but Jesus...

This time the user comments on other actions stick figures have been shown to do in the Portal[83] universe by suggesting that stick figures can undertake any human action from the real world, such as ice skating. This response takes a similar tone to saibog's answer and suggests that users "roll with it" since the question is about a fictional universe. This goes even further in the responses to this post where other users have suggested that the answer is incorrect since the stick figure could not have properly functioning tendons to allow movement to work right.

One of the responses about the troubles of tendons and stick figures is shown below by LinuxFreeOrDie:

[83] Stick figures are used in a number of materials created around the game such as advertisements in which they are shown to be able to do actions a person could do.

> I don't think you understand the point he is making. If you are two dimensional your muscles won't be able to pull or push in any way to turn since they won't have any leverage to apply torque to themselves. For example, in the image below, the slanted line is a muscle that contracts in order to turn the straight line clockwise: / / / / ----------
>
> Now imagine those lines converging into a single line, there is no way pulling with either line can turn it. This example works from 2D to 1D, but as you can imagine it is the same principle. You can't apply any torque without an angle which requires thickness.

Here we see an even further branching out of the discussion as LinuxFreeOrDie tries to explain how tendons would need to function in a two dimensional space and why it would be impossible. This response as well as the previous ones help to demonstrate how quickly these discussions can grow and the number of topics that can end up being addressed. What started as a simple comic about squishing a stick figure in between two portals turned into discussions of how two dimensional spaces function as well as the workings of tendons to allow for muscle movement.

When the Analogy Breaks Down[84]

The following is a portion of an even more complex cartoon that appeared on the *Portal* subreddit:

[84] The graphic shown below is actually only one page of the six included from this discussion on why portals from the game do not conform to the laws of conservation of energy and momentum. For the sake of brevity only one of the pages is included although it is helpful to note the other pages since one of the problems that arise here is the producer of this content manages to lose some of the readers. Also this particular page is limited to the discussion of momentum but conservation of energy comes up in the discussion as well.

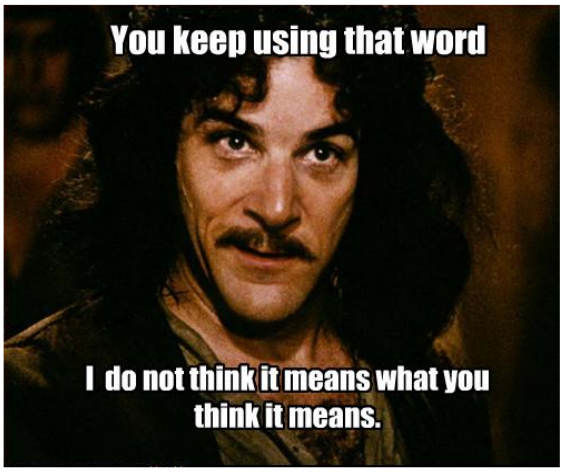
Eviscerated law number 2:

CONSERVATION OF MOMENTUM

Every damn time someone says

"Portals conserve momentum!"

I feel like Inigo Montoya.



DID YOU KNOW?

Momentum is calculated by:

MASS * VELOCITY

You probably know the difference between speed and velocity.

But for the sake of clarity,

VELOCITY IS SPEED AND DIRECTION.

For example,

THIS SHITTY CAR IS DRIVING AT 20 m/s

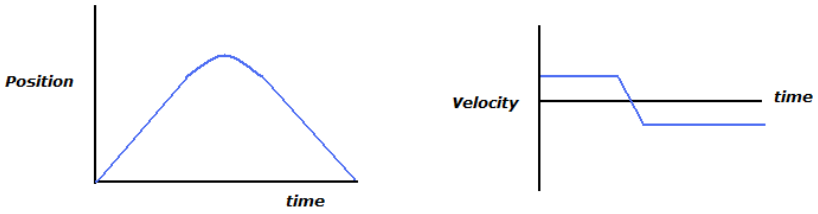
AND TURNS AROUND AT SOME POINT, GOING 20 m/s AGAIN.

You could say:

"That shitty car was going 20 m/s the whole time."

OR YOU COULD BE AN ACCURATE BADASS AND SAY:

"That shitty car was going 20 m/s, and then it was going -20 m/s !"



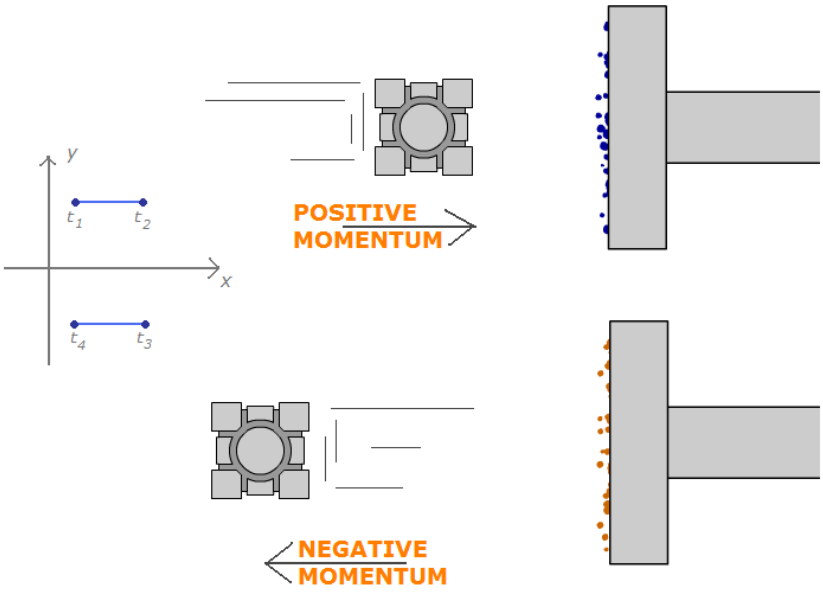
IT'S USEFUL FOR A LOT OF CRAP, E.G. MOMENTUM

"The momentum of that shitty car was not constant! It slowed down at some point, and then built up momentum in the opposite direction!"

AWESOME! NOW YOU CAN USE THAT WORD WITHOUT PEOPLE GIVING YOU THIS:

ಠ_ಠ

So now of course, you realize, portals don't conserve momentum!



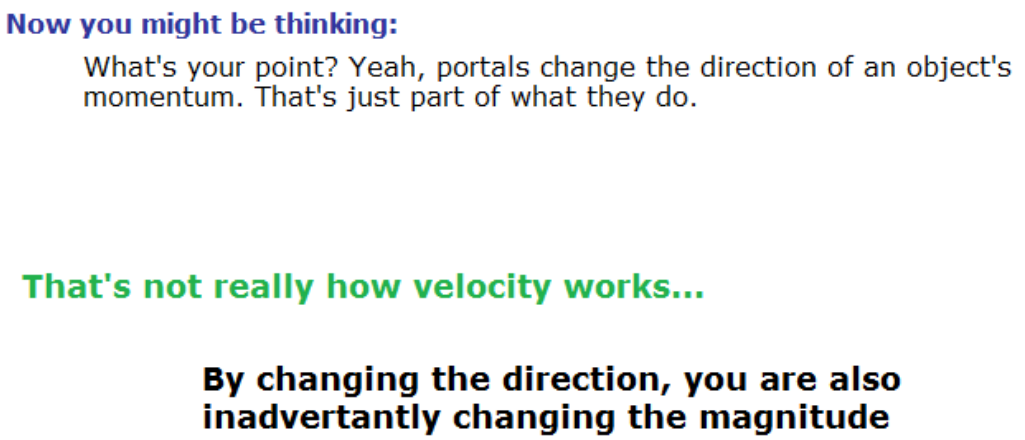


Figure 6-4: One user's image created to try and convince other users that their ideas about how momentum works with portals are flawed (Forehead58, 2012).

One thing that stands out about this particular comic, which includes several other pages that are not reproduced here, is that it involves by far the most explicit discussion of scientific principles of any of the comics under consideration. While other comics might mention conversation of energy in passing, for example, this piece contained a thorough discussion of the problems posed by portals to both the conservation of energy and momentum. One immediately noticeable effect of this was that the amount of detail clearly bothered a number of the readers:

T3hp3trock: My eyes are bleeding.

PossiblyMario: Hm. Very interesting. All of that went in one ear and came out the other.

Evs2012: It's a fun game, the physics don't have to be right or wrong for this to be true.

As can be seen sometimes too much information ends up leading to a situation for some readers where they feel overwhelmed even though the goal of including so much was to improve clarity.

While some readers may have engaged with the material as “one ear and out the other”, others went into some of the issues in significant depth, such as in this discussion of reference frames by Team_Braniel:

> Now the problem with the crushing portal.
>
> The cube's momentum is (P+x) P is zero, the room is not moving, x is zero, the cube is not moving.
>
> The portals momentum is (P+y) P is zero, the room is not moving, y is (Large) the portal is crushing rapidly.
>
> So to find the momentum of the cube as enters the portal you do (P+x)-(P+y) which would be 0-y with y being (large number).
>
> So the cube enters the portal at a high **RELATIVISTIC** momentum. (negative y)
>
> The trick here is that it is the same exact math if the cube is moving into the portal or the portal is moving over the cube, its relative.
>
> "Oh but the portal is just a hole in space and it can't grant momentum!"
>
> You are only half right. It IS a hole in space but it CAN grant relativistic momentum, here is why.

> Because its all relative, one correct reference frame is with the cube stationary. This is initially the frame most people choose, because the cube LOOKS stationary. The trick is the cube stays stationary relativistically even as it is flying across the room with y momentum after it leaves the portal.
>
> See if you choose to look at the equation with the cube remaining stationary, it is space/time that moves away at "y" momentum. As the yellow portal crushes down on the cube, the space/time reference of blue is moving equally at the same momentum (P+y) even tho it appears to remain stationary. So as the stationary cube crosses the portals, as it leaves the blue portal the whole of space/time is traveling away from it (cube still stationary) at momentum "y".
>
> Which from our 3rd reference frame, which has no bearing at all on the math, appears as if the cube is "fired" with force from the blue portal.

Bringing up the science explicitly also leads to discussions of the science mentioned in the comic, in this case the question of momentum. This response highlights one of the challenges that can occur when discussing hypothetical issues. The discussion, as well as the original post, uses a number of interesting science concepts but due to the fictional nature of portals there is not a way for the users to resolve conflicts over what is a "correct" interpretation. Even so, the desire to find the answer is still central for some commenters, as illustrated by this comment from edsq, "I think this post was in response to arguments like this one. As someone who actually knows his physics, these threads are incredibly frustrating, and OP's post is excellent for shutting up some people who just don't get it."

Art Related to the Game

Fuck Science

Figure 6-5: A piece of art displaying Chell sitting on the companion cube (an object that shows up in multiple test chambers throughout the game) in the rain after escaping Aperture Science (Cicierega, 2011).

For those unfamiliar with the way that *Portal 2* ends, the title of this artwork, "Fuck Science," may not make much sense initially. At the end of the game the player has defeated Wheatley, who had taken over the facility, and placed GLaDOS back in charge. At this point GLaDOS kicks Chell out of the facility and tells her never to return. The scene shows Chell being released into an open field that looks somewhat similar to

the one in the painting. The painting then is one interpretation of how to understand the ending, as a sense of freedom of finally being able to escape GLaDOS's experiments. What follows are a number of users responding to Chell's state, and sometimes that of the other characters, upon leaving "science".

CrayolaS7 explains the image and her response to it:

> CrayolaS7: At the end of the game you are released into a wheat field on the surface of the earth. The poster is taking on the mindset of Chell who is saying: "fuck science, I just want to be back in the real world." This is embodied by the feeling of rain on her face after being underground for so long bringing her immense pleasure (CrayolaS7, 2011).

In addition to the image above, the person who posted this discussion had also combined it with music from the game[85] (Nick4753, 2011). For many users, the music combined with the ending reminded them of their own feeling of sadness when finishing the game typified by the top level comment[86] "[NSFED] Not safe for emotional drunks. :'(''' ". While many commenters simply restated in their own words that the artwork made them feel sad, such comments were interspersed with more detailed discussions of the paradox of that moment in the game, the sense that Chell being abandoned all alone on the surface after only knowing the world of Aperture for so long seemed tragic even though reaching the surface, and thus escaping that world, was the goal for the player.

[85] If you would like to listen/look at the combination you can find it at http://rain.nxe7.com/. The site combines the image with "Exile Vilify" by *The National* as well as a video entitled Rain by RainyMood.com. "Exile Vilify" was a song written for *Portal 2* and is part of the *Portal 2* soundtrack.

[86] Comments can be responded to by other users and this will place their comment below the one they are responding to. A top level comment is one that was in response to the original post rather than to a specific comment. In this case this particular comment was where many users discussed the topic of the ending of the game and how they felt about it.

When considering the ending, some players also chose to explore game sound files that are present as part of the game but not heard in the game itself. In particular, the issue of what occurs to the space sphere[87] relies on these extra files that are not used in the game. One assumption of users was that at least the space sphere was happy since he was finally in space. Files from the game show he gets unhappy with space eventually so it isn't necessarily a happy ending for him either, as pointed out by HiddenKrypt:

> not if you listen to the there audio files for him. Star.Star.Star.Star.Star.bored of space.
>
> ...
>
> Earth.Earth.Earth.Wannago home. Wanna go home. Wanna go home. Wanna go home. Space is too big. too big. Wanna go home.

What is most notable here is the lengths to which some players go to learn more about this fictional world. Not only do they play the game but they also do things such as dig through audio files to look for portions that are not used in the final copy of the game in order to learn more about the characters.

The importance of subtlety to making this engagement work so well can be seen in a number of these examples, such as looking through audio files for additional hints,

[87] Near the end of the game the player meets the space sphere. The space sphere is only able to talk to the player about how awesome space is and how much he wants to go there. In the finale of the game the player sends Wheatley and the space sphere to space in the process of removing them from the laboratory.

and is directly acknowledged by at least some users. For example tehphoebus points out[88]:

> Really Portal 2 is a profoundly beautiful story for a video game. From the ARG to the subtle and compelling story that doesn't hit you over the head. To all the small details that you have to seek to find. The community effort with the ARG and sharing our experiences and discoveries. I feel as if it managed to impact many people and engage them on an entirely new level for video games.

Tehphoebus likes the concept of the ARG which involved people coming together to figure out how to use the hints that Valve placed into its game as it was not obvious at first how to access all of them. This sense of depth aligns itself with the design of the game itself as what happens to all of the characters and what is happening at Aperture Laboratories are all hinted at rather than directly explained. This allows the player to gain more as she/he explores and rewards investment with the game.

What's a God to a Non-Believer?

The picture on the following page, which incorporates a number of images from *Portal 2*, was of interest for a number of reasons including: the synthesis of multiple seemingly unrelated works, its quick appearance and disappearance from discussion, and some of the underlying ideas connecting the images and the words displayed.

[88] ARG stands for alternate reality game. In a patch to the original Portal there were a number of radios that were changed that when placed in specific locations would give players messages in morse code. In addition players could find images hidden within the .WAV files associated with each message. These clues led players to additional hints about Portal 2 (which had not yet been released and was in the process of being announced when this occurred).

Figure 6-6: An image created of characters from Portal 2 overlaid with lyrics from the song “No Church in the Wild” (Pyotr_Paker, 2014).

The creation and circulation of this picture illustrates one of the many ways *Portal 2* is referenced in the online discussion of other topics, in this case a popular song which was released around the time of the picture’s creation. The words printed across the four images are lyrics from the hook of the song, “No Church in the Wild” (West and Carter, 2012). The images come from the game: the first is a picture that is scrawled onto one of the walls in the game as part of the history of the facility as depicted by the test subjects; the second is Cave Johnson, the man who ran the facility; the third is GLADOS, the artificial intelligence who takes over the facility from Cave Johnson, and the final is a picture of Chell, the character the player controls while playing the game.

Cave Johnson, pictured second, was portrayed in the story as thinking he could perform science more efficiently by not worrying about the needs of his lab’s test

subjects, who are pictured first. GLaDOS, pictured third, takes this a step further and realizes she can further optimize the process by removing the human scientists and running the lab herself. The song suggests that both kings and gods gather their power from other's belief in them and that the lower end of the chain could resist if they were able to stop this belief, which could be mirrored in the ability of the many test subjects and/or of the scientists employed by Cave Johnson to resist the level above them if they had worked together. The final step in this chain is not made explicit by the game. Chell is the player character and as such the game does not ascribe as many ideas on what her thoughts on the various actors and their power are, as those are decisions for the player to make. In this image, the artists ascribe her as having a role similar to that of the non-believer in "No Church in the Wild". This suggests Chell's role in the story is to realize her ability to overcome the dangers posed by GLaDOS in her attempts to do science by actively resisting through her lack of belief in GLaDOS's superiority.

What is notable here is what can be learned from the connections made within the art itself to learn both what might have encouraged these particular connections and what types of connections could resonate with other viewers. Maybe something like: The view of Chell as a resister of the brand of science that GLaDOS represents can be seen as underscoring the message that science done haphazardly is dangerous, an idea that appears to connect with members of this forum, given the popularity of this particular interplay of music and image. This specific image is also fascinating as it came up rather suddenly and appeared in multiple locations over the course of about a week. Some of the early versions included more blank space as the images were presented in a more horizontal view point instead of a vertical one but the particular version above is the one

that was best able to move through out a number of different locations and be discussed in a variety of contexts.

Conclusion

The responses to the comics and art work exemplify the chaotic nature of these discussions. Many fascinating discussions unfold alongside a number of other discussion that are loosely related at best and that sometimes even run counter to one another. Constantly changing tones, goals, and assumptions of different writers make it impossible to try and attribute a singular direction to these discussions. While this chaos may not match what science educators would traditionally encourage for a science lesson, these examples also demonstrate the value this chaos can have in circumstances that allow this freeform discussion to function. Many different types of readers are all able to engage with the same content in different ways, ways which work well for them, instead of having to adapt in to a smaller subset of acceptable types of responses that might be more easily evaluated/controlled.

While the classroom may not always allow for the chaos of discussions like these, there are still some other notable parts of these discussions that could potentially be harnessed in more structured environments. For one, the majority of these discussions start from humorous beginnings. Humor made for a good hook that got readers initially engaged and allowed for a variety of different discussions to arise from an initial starting event. In addition, when something like Portal is discussed, it helps that there is a significant amount of already created backstory to build on to give the discussions context. As could be seen in each of the art pieces, the interesting discussions related to science that arose from them did not have to spend much time building on the

circumstances that made these discussions significant since they had already been established by the lore of the game itself. The act of choice here allowed for the discussions to be primarily filled with people engaged with the topic already, so the focus was on the discussion expansion of that topic. In the next chapter, I will move from these art based discussions to focus on video based creations that fans have made, to see how the changing medium allows for both similar and different types of issues and discussions to arise.

Chapter 7 *Portal 2* and YouTube Videos

YouTube changed everything about television, from public access to major networks. In one decade, YouTube has developed a culture of its own and is a threat to the conventional business model of television—but not in the way world expected.

-Brian Moylan, *Time* 2015

Introduction

The majority of the content considered in the previous two chapters has been drawn from online discussions related to art either from the game or created by the players. In this chapter, the exploration will move to videos created either by Valve, the company that developed and owns *Portal* 2, or by players. In addition to a change of medium, there is also a shift in location as these videos were all located on YouTube**,** which is currently the most common site by far for uploading videos. This chapter will explore those videos and the discussions they engender with respect to issues and ideas related to science.

YouTube's Discussion Design

YouTube operates rather differently that the other online sites mentioned in previous chapters in terms of how media is found and how discussions are organized. Unfortunately, unlike such sites as Reddit, much of how YouTube functions is

proprietary and so information about the exact ways in which some of the functions operate is not publicly available. However, because YouTube has become such a major social media platform, there are people who study the mechanics of the site and in particular how the site's sorting algorithm functions and their work gives an idea of how YouTube operates even though it is not transparent.

The first question to address is whether something like the design of the algorithms that sort videos really makes much of an impact. One way to get a sense of that impact is to look at what has happened when YouTube modifies how it sorts videos and to see if that change had a measurable effect on some of the most popular channels[89]on the site and whether their viewership changed as a result. One such change occurred in 2012 when YouTube announced that it had changed how videos appeared on the home page for users. Because the change favored different types of content some channels that were previously successful suddenly no longer showed up on many subscriber[90]'s front pages with some channels seeing drops greater than 50% of their viewership on the day of the shift without ever seeing a recovery from this greatly reduced viewership number (Patrick, 2014).

To understand why these algorithms are so influential, it can help to consider what features cause such impacts. One example that helps illustrate why these sorting algorithms are so influential is the way that channels devoted to gaming, including *Portal 2*, became more popular after one such shift in YouTube's process. YouTube realized

[89] Think of a channel on YouTube as similar to a television channel. A channel is created by an individual or group who makes content and puts it on YouTube so that others can view it.

[90] A subscriber is someone who has clicked the subscribe button on a YouTube channel. This button is used for users to tell YouTube what they like seeing and these subscriptions help YouTube shape what videos show up on the front page of the website for any specific user instead of showing the same videos to all users on the front page.

that sometimes videos would have an interesting title or thumbnail, which would encourage the user to click on them, but the viewer would then immediately leave when it turned out that it was not what she or he wanted. To combat this, YouTube adjusted their algorithm to favor videos where users watch more of the video, called retention time, as well as how often the watcher followed to other related videos instead of stopping their viewing and leaving or doing a new search. Such factors were given greater weight in the formula, so videos that had higher retention time and more click-throughs were rated more highly by YouTube and thus got higher placement on the site and were more likely to show up on the front page of YouTube. Videos related to games tended to have viewers who were likely to watch videos to completion and to click on follow up videos of the same game, leading to improved placement on YouTube for gaming videos after this adjustment of the formula by the website (Patrick, 2013).

Clearly how these algorithms are shaped can greatly impact what is popular and what people are seeing and commenting on. In addition to shaping what is popular, both YouTube's algorithm and user culture shape what types of comments are made. Higher placement on the site leads to more views and thus more comments made. In addition, comments beget comments; discussions develop between different commentators, so as the formula shapes the placement of the video, higher visibility leads to more such interaction as well.

The Long Fall Boot Revisited

As mentioned in Chapter 6, the long fall boots[91] were noticeable as an invention from the game that caught players' attention. The long fall boots were also featured in advertisements for the game before it came out, as part of a series of videos produced right before release and posted on YouTubethat presented concepts from the game in humorous ways. "Think of it as a foot based suit of armor for the portal device… Check this out we told this test subject to go ahead and try to land on her head. She can't do it. Good work boots"[92]. In this case, the humor derives from Cave Johnson being more worried about damage to the Portal device than to the human being testing the device[93].

As in the case of the discussions on Reddit, the question of wanting such an item in real life happens again[94]:

> SniperHuntress: i think its such nonsense this hasent been invented yet in real life .....smh .....-__- i dream of walking into class wearing these boots.....someday.....hopefully.....plesae god give me these boots!!!!!!!!!!!!!
>
> Rmo balk: +SniperHuntress tbh look i didn't try to be mean but you got to understand with that shoe you can defy gravity i mean come on how do you make

[91] The previous discussion of the long fall boots can be found on p.98.
[92] For a full version of the video check out Portal 2: Official Boots Trailer: https://www.youtube.com/watch?v=nd1m5_n9P9w
[93] From looking at the comments, the humor is also helped out by the fact that people recognize the absurd setup in the video. In addition it is something that is somewhat believable, although it would likely be put in very different language in an actual situation rather than the somewhat brash presentation that Cave Johnson gives for not being concerned in the slightest about the safety of the human participant.
[94] You will notice some of the names of users will be followed up with a notation that includes a "+" followed by another user's name. This notation is used in YouTube comments to allow one user to direct their comment at another user.

that i don't think you can make something like that just yet and if you can you can't jump from that high up

SniperHuntress: understand i still question the scene where the character wearing it fell through an almost bottomless pic and still survived i guess i think too much of the geniuses of the world and forget its video-game logic but yes i do see and im not saying what you said is wrong

Brandon summerlin: this really wouldn't be that difficult... mind you I don't think we can make anything as effective as this, 500m is just silly, you wouldn't even have the balance for it let alone the durability, but for jumping off a small building? yea that's a realistic goal

Here the discussion again comes to wanting to connect concepts from the game with possibilities in the real world. Initially there is little discussion of the practicality of the long fall boots or how they might possibly function but instead a focus on how neat they might be. The discussion continues by considering the idea by relying on some conceptual ideas about how the physical world works such as the notion that gravity is hard to overcome and that the scenarios the game presents such as falling over 500m are extremes with which it would not be possible to survive. As the conversation continued, though, some more specific ideas arise for how such an invention might be possible:

2012sandokan: I don't think its impossible to make boots like those. In the game they work thanks to shock absorbers. Of course being so small they couldn't possibly bear those heights.. but i think in the portal universe they discovered some bullshit material

to make them off, and be like, indestructible..... But shock absorbers on shoes could really work, and i think free runners would love them.

Here we see that 2012sandokan has begun to fall back on the specifics of how such a device might work by considering the impact of shock absorbers. Both 2012sandokan's response as well as that of Brandon summerlin demonstrate one key way that exaggerations in the game function. While these extreme situations work well for humor, they do not detract from the actual principles involved as both illustrate how these are more extreme setups to make a point but are not representative of the extremes[95] that should be discussed when considering any potential real applications of the principles being discussed. Near the end of the discussion started by SnipeHuntress, the concept of spring-loaded stilts comes up again as well as a real world example demonstrating what is possible when Marting Tang brought up jumping stilts, "Check out 'Jumping Stilts' probably the closest you'll get to these boots ;P". This particular element was interesting as it showed that these intersections between concepts, such as the long fall boots and Jumping Stilts, arise multiple times and are not only a one time connection. While it might not have been obvious that this association would be made, the connection is strong enough that it resonates with different communities posting at different times, suggesting that some of these associations might work well in the future for those found to be particularly productive.

[95] This is an interesting example of the extremeness presented in the game but is hardly the only one. For example, in the previous chapter the watermill example as well as the example of a two dimensional figure being crushed between two portals both rely on taking an idea, such as the conservation of energy, and taking it to an extreme. In both these cases the extremeness also serves a useful purpose of exaggerating the point of discussion to make it more explicit but users are able to pull back from that extremeness when it quits serving a useful purpose.

Panels Trailer[96]

It turns out that the long fall boots were not the only invention- based video from Valve to lead into an interesting discussion. The next trailer to be examined is one for something in the game called a panel, which is an object similar to a floor tile that is adjustable to allow for rooms to be built for the construction of the portal tests in the game. The video describes them as an important part of test chambers as follows:

> Cave Johnson here. This is a test chamber. Four walls, celling, and a floor. Good enough for science [Buzzer sound] not Aperture Science. Gentlemen I give you panels. The planks of tomorrow. Fully configurable. Infinitely Variable. Safe. Aperture brand panels will assist your test subjects every step of the way.

At the time of this writing, over 850,000 people have watched a video which was set up as an advertisement for the fictional building materials of the Portal testing chambers. What is most fascinating here is how interesting some users can find a topic that at first would sound quite mundane. Through the use of humor and the characters of the game world, it becomes possible for large numbers of people to become interested in what would normally be considered incredibly mundane topics, such as this video about fictional building materials for labs in a fictional world. Clearly even parts of the game's universe that many might not think of as important can play a role in establishing these worlds.

By themselves, these words don't fully describe where much of the humor comes from. While Cave Johnson is talking, the two robot characters that the player uses if they

[96]The full video version of Portal 2: Official Panels Trailer can be found at https://www.youtube.com/watch?v=Kyc4JK24EuI

play in the multiplayer version of the game are shown navigating a number of test chambers. During their process they interact with the panels discussed in the video but their interactions create a humorous juxtaposition when compared to what Cave Johnson is saying. For example, when Cave Johnson discusses how safe the panels are, the viewer gets to see one of the robots stuck in a panel that repeatedly smashes him into the wall. In a later frame, Cave Johnson claims the panels will "assist your test subject every step of the way", while the images show the panels removing themselves right as one of the robots is trying to get somewhere so that he falls instead of providing the assistance that Cave Johnson claims will occur. The takeaway from examples like these is that, while a portion of these videos is textual, just looking at the words in isolation does not convey a complete picture. When trying to utilize these tools in science education, it is not enough to simply evaluate the parts in isolation but they also must be considered in conjunction since only one piece (either just the words or video) does not provide enough information to see how these videos create powerful interactions.

Discussions in the comment thread for the panels trailer also illustrate that different portions of the game are clearly not compartmentalized in the minds of the viewers. Within the discussion of the trailer, the following exchange references other items found in the game that are unrelated to the panels being 'advertised' in the video:

> Samuel Baldwin: Imagine if you could Buy everything that they have advertise
>
> tyronextrem: +Andy Gowan turrets too XD
> Princess Luna:+Andy Gowan Nothing is impossible.

As can be seen here the discussions end up allowing for some overlap of topics as users discuss the possibility of being able to buy other products Aperture made. While this particular exchange may only be a few lines with little follow up, it shows how users are able to make comments that demonstrate the interrelatedness of the world of Portal rather than thinking of it as little pieces to discuss independently. This is an advantage that a complex game world like Portal can bring to these discussions, as it allows for the development of a complicated, intriguing virtual world with lots of pieces that interact with one another in an internally consistent way. This gives viewers/players a lot of material with which to think and encourages them to construct their own connections between various objects and ideas from the game as well as between the game experience and the world outside the game.

Making Science[97]

The video "Making Science," a creation of Harry101UK, is a Portal parody of "The Nightmare Before Christmas's" musical number, "Making Christmas". The song's primary characters are Wheatley and GLaDOS and it covers their processes for "making science" primarily by singing about the tests they have developed in the Aperture labs. What was particularly interesting was the focus the video put onto the different technological inventions and their connection to "making science," such as the turrets, the construction of the test chambers, and "Mr. Mashy the spike plate." After my initial viewing of the video, I was hopeful that the comments would include discussions about whether these inventions were what "made science," since one idea commonly expressed

[97]The full link to the Making Science video: https://www.youtube.com/watch?v=HDAFivGsKX4

in public discourse is that the technology developed through/inspired by scientific discovery is the primary purpose of science.

Surprisingly, however, what seems initially like a video tailor-made to inspire commentary about the meaning of science and the interplay of science and technology lead instead of a series of discussions that are, while all connected to aspects of the video, almost entirely unrelated to the concept of the video, that is, to "making science. "When looking at the comment discussion of the top 250 comments, there were a grand total of zero comments related to the topic of what makes science "science" or any discussion of the themes brought up by the characters in the song.

While it might be disappointing to some that such a fertile subject was ignored, an examination of the topics that were instead most common provides insight into what caused discussions to veer away from the theme of the video into other areas. The primary discussions were related to figuring out what software the creator was using to animate the characters in the video as well as discussions of the quality of the voice acting. Some examples include:

Wolf Attack Games: What does he use to animate?

Harry101UK: +Wolf Attack Games Source Filmmaker. =)

Gotham Michael: Really you use that??? Wow thought you used some expensive stuff…

RussoolMishir: The voices are so off, it hurts, sorry.

Shannon robinson: +RussoolMishir He voices all the people and things.

RussoolMishir: But in The Wheatley Song, Wheatley and GLaDOS sound perfect.

Both of these discussions revolved around the form of the video and the process for its construction rather than the content of the video itself. In this case both particularly high quality components as well as components that were deemed inferior served as focal points that overtook any potential interest in the video itself. The remaining discussions primarily consisted of praising the game and the characters from the game. While the video itself comments on "making science," nothing from it seems to have stood out well enough to inspire a response from its viewers that would rival the long discussions of the technical details of the making of the video.

This demonstrates a couple of key points for educators. The first is that it is impossible to evaluate pieces like these videos or art in a vacuum. What may seem most obviously related can lead to discussions that are primarily dominated by what we might evaluate as tangentially related at best. The interests of the audience cannot always be predicted or shaped by the interests of the creator of the content; a video like this example, that would appear to a science educator to be ideally designed to lead to discussions of the main idea it presents, may instead inspire discussions that are dominated by ideas that we might evaluate as tangentially related at best. While material obviously related to science may not trigger responses on subjects that seem to be directly related to its scientific content rather than unrelated discussions, previous examples have

also shown the reverse to be true as well. For example, back in Chapter 6 a comic that showed a picture of two portals being pushed together and asked what would happen led to elaborate discussions on the concept of torque even though there would be little chance an educator would guess that would be the resulting discussion after viewing the comic. This demonstrates how critical it is to look at how these pieces work in action rather than trying to evaluate them and their content alone, as well as how important it is to be open to content that may appear unrelated because it could actually be more helpful than what looks like it should work at first. The following example further illustrates this point.

Going Home[98]

This next video, "Going Home", is also by Henry101UK and functions as a comparison to the previous video, "Making Science." At first it seems like this video would clearly be less helpful to a science educator, as it is simply an imaginary postscript to the ending of Portal 2, consisting of a scene in which Wheatley and the Space core are both found by astronauts and brought back to Earth. However, it turns out not only do videos that seem like they would be clearly useful turn out to not be, but those that do not seem to have such potential often turn out to spark unexpectedly productive comments. In this case, the video leads to a discussion of how sound waves function in space. To be clear, the video, similar in style to "Making Science," also inspired its fair share of comments asking about how the voices were generated and what software was used, but unlike the previous example, the comment thread also included a great deal of dialogue about science, building on material presented in the video.

[98] A full version of the video "Going Home" can be found at https://www.youtube.com/watch?v=LZDUAvrktVg

The most critical component in this case was that the spheres spoke in space and this led to multiple discussions about the inability for sound to travel in a vacuum. For example:

> This Crazy Gamer: you wouldnt hear wheatley since space is vacuum
>
> Adinator: He said “oh good my transmitter still works" so he can hear him
>
> This Crazy Gamer: no if this was real life moron
>
> Adinator: Well it's not real life so get over yourself
>
> This Crazy Gamer: no
>
> Harry101UK: +This Crazy Gamer You're hearing Wheatley's voice over the transmitter. The astronaught and him communicate over it. This is specifically why I mentioned the transceiver.
>
> This Crazy Gamer: oh now i get it

While this particular discussion does focus on the ability/inability of sounds waves to travel in space, the discussion in this example is not particularly deep or insightful. In addition, it serves to illustrate that in such comment threads, not everyone is necessarily respectful of the other users; in this case, The Crazy Gamer and Adinator primarily argue by having The Crazy Gamer call the other a moron while Adinator suggests The Crazy Gamer should get over himself since it is not real life anyway. When Harry 101UK, the creator of the video, joins the discussion with a comment that addresses the issue about which they are arguing, This Crazy Gamer is satisfied with his explanation of how Wheatley’s voice would get to the astronaut despite the fact that, as This Crazy Gamer

had correctly pointed out, sound waves cannot travel in space. Following this exchange, however, other users insult The Crazy Gamer for being “an attention whore” and “stupid” since he only listened when the creator spoke up in the comments although this chain of events is eventually diffused through humor by users writing “SPPAAAAAACCCCCCCCCCEEEE” at each other mimicking the space sphere.

While still not of the same depth as some other discussions examined previously, this next example manages to discuss the issue of sound without devolving into users insulting each other:

> irock296: cough no sound waves can travel through the vacuum of space cough
>
> TheTTVCrew: COUGH transiver hooks to radio COUGH

This discussion continues as different users notice limitations of the story and wonder why things are happening the way they are.

> BaranHekimoglu: +TsujimotoYukaske wait... if they have thrusters built in, why don't they just fly towards earth?
>
> Hannah Holdridge: +BaranHekimoglu because they would go so fast once they were in the earths atmosphere they would literally light on fire
>
> BaranHekimoglu: +Hannah Holdridge what if they fire retrograde to decrease their descending velocity? sorry for not making any sense (unless you know rocket science)
>
> TsujimotoYukasuke: Their thrusters might not be as good, which is why they wherekinda "floating around" It might have enough force to propel them in

space(due to no resistance) but once they touch earth's atmosphere gravity would destroy them

As can be seen here, the discussion ends up not being limited to questions of sound as users realize that the actions of the cores seem strange since they can move around but are still stuck in space for two years for some reason. Commenters attempt to use their knowledge of real-world science to come up with plausible explanations for why the cores' thrusters would allow them to move around space while not allowing them to return to Earth without assistance.

10 Things You Didn't Know about Portal 2[99]

This next video, "10 Things You Didn't Know about *Portal 2*", is another common type of video where the content is information about the game which is produced by other users rather than by Valve, the game creators, themselves. Rather than creating new stories using the tools from the game, such as the previous video which focused on a new story for the personality core Wheatley, videos like "10 Things you Didn't Know about *Portal 2*" inform the viewer about the game to improve their experience. In this case Syyborg Gaming's video provides insights into parts of the game that players could easily miss.

When commenters discussed the video, the majority of the discussion was about whether or not people already knew all ten facts. Even so, there were still some interesting science-related discussions such as this one about whether portals could move or not:

[99]The full video for 10 Things You Didn't Know about Portal 2 can be found at 10 Things You didn't Know about Portal 2

> Shuo L. (dashuo): Maybe the portals can move, they just cannot rotate.
>
> Jack ripper: +Shuo L. well not exactly rotatin but if you create 2 portals on the ceiling and floor, and skydive into it, you'll notice the portal moves slowly anti-clockwise, not ACTUALLY moving but you can tell it changed positions
>
> nawor3565: +Shuo L. The Earth is rotating.
>
> Samrux: +nawor3565It has to do with Einstein's relativity[100], I think. The portals can't change their velocity. They're moving at a constant velocity as the Earth rotates, moves around the sun, and around the center of the galaxy, and through the universe. If the velocity were to change (that is, if the portal accelerated, such is the case of the rotating platform, then it would dissapear). The moving platform that helps you cut the neurotoxin tubes is moving at a constant velocity, so the portals work.

The issue of the Earth moving also arose in other discussions although in more abbreviated fashion, such as:

> Audio Stratus's Music Channel: That whole, "portals can't move" deal would be nice and all if the Earth weren't constantly revolving around the sun.

In this case, it is in the space where there is a discrepancy between the description the game provides vs. the users' understanding of the world that discussion occurs. Since the different users know that the Earth is moving but there is a rule that portals do not work

[100] While this user describes it as Einstein's relativity, from the context of the discussion it seems clear he or she is referring to the idea of a reference frame. In this case it refers to the notion that when determining motion it is necessary to think about what the frame of reference is since, for example, when an object on Earth is discussed as being stationary vs. moving that description relies on ignoring the motion of the Earth rotating.

on a moving surface, they see this contradiction as a problem that they then attempt to resolve in the comment thread. Samrux's answer is particularly noteworthy in that he takes into account the differences between velocity and acceleration and decides acceleration must be the real issue causing the portals not to function. In this case, the game world works for discussion because it is close enough to obeying actual scientific laws for users to try to make small adjustments to their understandings instead of having to respond by declaring that it is just a game so of course it does not have to work.

Infinite Energy Revisited[101]

It turns out that in addition to the "troll physics" comics examined earlier, there are also "troll physics" YouTube videos. The video "Infinite Energy Revisited" actually covers the same topic explored in the comic covered in Chapter 6 --- what would happen if portals were used to make an infinite energy waterwheel? This video even uses some of the same images, so we have two different groups responding to similar materials.

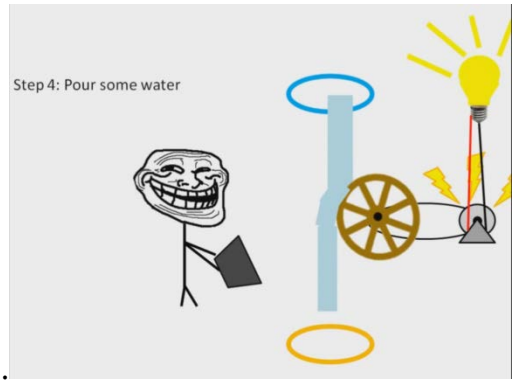


Figure 7-1: A still shot of the infinite energy watermill that was shown in the troll physics video (redpheonix1000, 2012)

[101] The full video for "Infinite Energy Revisited" can be found at https://www.youtube.com/watch?v=vCvRDWv7IeQ

One of the most prolific discussions found in the comment section for this video concerns the topic of magnets, a subject that may not appear immediately obvious as connected to this video, since no magnets appear in the video or are mentioned in the game itself. When considered on their own, the following comments do not seem remotely related to the video:

> TaavieesTheJokuman: Yes, I've got problem. How can I get portal gun?[102]
>
> Jayden Holzhauser: magnets
>
> Zak Jakubiszyn: +Jayden Holzhauser Any other way? I'm out of them and the Magnet store is closed
>
> …
>
> MikeSchmidtofHyrule: +Zak Jakubisyzn Steal neighbor's magents BROTIP: USE MAGNETS FOR FASTER ACQUIRING/STEALING
>
> …
>
> heroicsplendid: Brotip: Use magnets for faster acquiring.
>
> Helen Malone: Use magnets for faster acquiring

These are a representative sample of the numerous comments suggesting that magnets could be used to assist in the procurement of a portal gun or to make the waterfall work better. Only when the broader significance of references to magnets in this

[102] As mentioned previously, the portal gun is used to create portals. The waterwheel is powered by water flowing between two portals. Thus a portal gun would be necessary to set up this apparatus.

community[103]is understood do the comments not only make sense as responses to this video but take on deeper meaning as well. The reference traces back to the 2009 song "Miracles" by the hip hop duo Insane Clown Posse, in which the musicians discuss nature in a way which rejects science. The song celebrates the wonders of the natural world and advocates appreciating those "miracles," while at the same time it expresses frustration with the way that science presents itself, with lines such as, "I see miracles all around me Stop and look around, it's all astounding … And I don't wanna talk to a scientist Y'all motherfuckers lying, and getting me pissed"(Insane Clown Posse 2009).One line in particular, "Fucking magnets, how do they work?" triggered a strong response from many fans and became a widely used internet catchphrase or meme.[104]This line and how it is used helps to demonstrate the tricky nature of sarcasm, since it is used both as in a serious style, such as in the song "Miracles," as well as a way of poking fun at not providing scientific explanations to questions that scientists can clearly answer.

In the comments related to the "Infinite Energy Revisited" video, the multiple references to magnets as a way of acquiring a portal gun is an example of the usage of the term magnets to represent a way to explain away any missing connections in a scientific problem. It helps the users to continue the joke, since simply coming out and saying, "of course portal guns do not exist in reality, but are imaginary objects in a game," stops the

[103] Defining the community here is a bit tricky since internet spaces, at least the ones I am looking at, are incredibly fluid. Not all readers come from the same backgrounds and likely only some of them would consider themselves as part of a community in this case while others think of themselves more of as visitors but without a sense of membership. What is important in this case is that there are enough people that make connections with other "troll" discussions on the internet and therefore understand the joke that is at work with magnets in this discussion (if not the discussion would not be as easily visible and would not have had as many participants).

[104] In reference to the internet, a meme is a humorous image, text, video, etc. that spreads virally. It can be considered an inside joke, except that in the case of an internet meme, the "insiders" who get the joke number in the millions.

humorous flow and therefore the discussion. Being able to determine that this usage of the term “magnet” is intended as humor rather than a serious suggestion is not a matter of being able to apply some sort of checklist, where if enough boxes are marked, then it is a joke. However, there is evidence of the joking nature of the discussions that can be picked up by a reader who does not normally read discussions on YouTube or other internet sites’ comment sections. For one, the term BROTIP is almost always used to denote a silly response in which the writer provides advice in a serious tone that is meant to be seen as clearly absurd. Another example is simply the way in which users continue the absurd seeming discussion without pointing out the illogical nature of such statements as Zak mentioning that the magnet store is out of magnets.

While the discussion of magnets does not have parallels in the Reddit thread about the infinite energy comic, other YouTube comments did cover similar ground to the Reddit comments. For example, the question of the inability to create energy comes up:

> Ninjawa: Wouldn’t the portals require some sort of energy in order to stay open?
>
> Worldofminecraftgaming: It would use the electricity
>
> …
>
> Diamondmyna: +TheROBLOXian Even than, all the power created would have to be divered to cooling as the friction being generated by this could only be equal than or greater to the energy created, and getting a system with 100% efficiency is impossible. Unless you use troll physics.

While the specifics of the discussion are different, the users make similar observations about the fact that energy cannot be created and requires a source.

There is another series of responses that clearly parallels an example outlined in Chapter 6. As described in that chapter, a commenter named spartanjoker asserts that there was nothing wrong with the physics of the infinite energy waterwheel and clearly everything would work just fine. Similarly, in the YouTube comments, another user, Dennis Scott, writes, "I really don't get what the problem is. The water is falling infinitely, at terminal velocity. Which spins the thing. Which makes electricity. Not complicated." The same as in the case with the troll physics comics, the user intentionally ignores a portion of the science that he knows is necessary to continue the trolling[105] joke. When another user calls Dennis Scott out, pointing out that he has no proof, he continues with the faux ignorance stating "We're talking about aperture here. Nothing is impossible. Portals don't need power, as you can sit there and star at one for weeks and it won't disappear."

Conclusion

Similarly to what was noticed about the art discussions from the last chapter, the videos tend to lead to a variety of discussions that are not always easily predictable from the source material, such as the discussions related to the "Going Home" concerning how sound travels in a vacuum even though that fact was a fairly minor part of the video production. When looking at the content of the videos themselves, they tended to have more different components that could spark discussions, such as the different stories suggested by the speaking part vs. the visual part of the "Panels Trailer," due to the

[105]For a further discussion of trolling refer to the chapter 6 section on the infinite energy watermill.

nature of the medium. As was seen throughout the examples, these additional jumping off points for discussions could both lead to interesting discussions of science in unexpected ways as well as lead to unexpected discussions like how does someone do the animation for the video. Depending on the goals of using the content this can be a good result but it can also make it challenging to utilize the content in a situation where a particular goal is desired.

Another noticeable impact of the videos as compared to the artwork from the previous chapter is that the conversations that occurred tended to be more varied. Part of this variation was that any one video tended to have many more parts which could be discussed so this led to a lot of different starting points which different users decided to follow up on. In addition to the medium itself, these videos from YouTube were discussed by significantly more users than the art pieces from the previous chapters. This can be attributed to both the number of users seeing the videos, as many of these videos have had millions of viewers, as well as the format of the different sites. Some YouTube video discussions have had new posts over years of time whereas the discussion posts from the previous chapters tended to be focused into just a few days or a month at most. Clearly this medium provides a rich set of possibilities, but it is clear that shaping the interactions and discussions around them as well as the interests of the viewers plays a major role in what actually gets written about and noticed.

Chapter 8 Conclusion

Let's all stay calm and do some science. -Cave Johnson

Throughout this dissertation I have looked at a number of different online works related to *Portal 2*. While they are all a diverse mix, all share a common quality of being related in some way to concepts of science. Reflecting on this multitude of examples, it is apparent that people can choose lots of different ways to interact with the same game and end up with a number of different views of science and a variety of responses to the same starting material. It does not seem from looking at the responses as well as the original game that the majority of these interactions were planned by the creators of the game but instead grew out of people's interests and the richness of the source material. There were many different possible takeaways from the different projects mentioned throughout the work, but here I will highlight a few of the biggest potential implications for academics, teachers, and policy makers.

Implications for Informal Science Educators

This dissertation most clearly aligns with the concerns of informal science educators. As people increasingly participate in playing video games and use the internet to interact with the world, learning more about how they go about that process is critical. From the different examples in the previous chapters, it is clear that this is not always a neat and easy to follow process. Internet sites are made up of users of varying levels of

interest, backgrounds, and levels of interactivity with the community. These differences between users lead to a multiplicity of different responses to content and to fascinating discussion but also can make predicting what will happen either challenging or impossible. For this reason, I find applying theoretical frameworks like Deleuze and Guattari's particularly helpful for thinking about these areas of interest since it removes the focus from prediction and instead tries to look at what is possible instead of assuming a predetermined response style. Many of the discussions and pieces of user created content will never be exactly replicated even if people later consciously attempt to recreate them. Instead of hoping for an exact recreation of the specific context that led to these exact events, of which some properties are unknown, we can instead focus on some of the features that were most productive and try to harness those, while still being open to differences that will inevitably occur when these ideas are reapplied in new contexts.

There are additional considerations that must be taken into account when doing research in online spaces. While it is still possible to limit research to one site in order to investigate it more thoroughly, it is important to consider how some methodologies may limit what can be learned. In particular, strategies such as examining the top 50 posts on a site or the 50 most recent posts in order to create an objective measure for viewing content from the site actually creates an artificial view that does not match what users of the sites do. A strategy of looking at lists of the most popular posts, for example, can still be helpful in discovering information like content with which people are most likely to interact, but strategies that strive to more closely mirror actual user behavior may end up being more fruitful. When interacting with sites where the researcher has a fair bit of access, such as a site created for a study, it will be especially interesting to see how

different individual users move around the site and how they choose to move between the different parts of the site.

Implications for Science Teachers

For teachers who have shown interest in games, this work shows both potential starting points for using games in science as well as provides ideas on what students can do outside of classrooms when motivated. While classroom settings are different and cannot take advantage of some of the inherent advantages of free choice that occur in play, teachers and students can try to utilize the value that depth can provide which is shown throughout the different examples that were explored. The examples from *Portal 2* worked, in part at least, because, in addition to the surface material that players first engaged in, there was more that could be explored in a variety of different ways. Some players enjoyed going through the unused sound files and learning more about the characters, for example. Others found finding news clippings or small changes in different facility rooms to be the most fascinating even though the game did nothing to require players to engage with these and they could choose to skip by such areas if they desired. This meant that different players ended up with different experiences and could choose when and where they wanted to be careful and when they were less concerned. Of course classrooms are not the same as these online spaces, but if teachers want to use

games for learning[106] and see advantages like the ones demonstrated in this dissertation, it is clear that including spaces for choice and further depth are necessary.

Theoretical implications

Deleuze and Guattari's concept of assemblage provides for a fascinating view to consider for internet interactions. As can be seen throughout the dissertation, rarely are these discussions occurring in a foundational approach style, where everything clearly links to everything else and stays neat and organized. Instead, users will bring discussions from other areas, have mini-arguments that are unrelated to the primary topics supposedly being discussed, as well as add pieces to the discussion that sometimes seem at best tangentially related.[107] In addition to this, the discussions themselves can not necessarily be tied to any single person and there many pieces of information that remain unknown about each person who is taking part. Using poststructural ways of thinking about these discussions, though, allows for the discussions themselves, rather than the individuals participating in them, to be studied. This allows the researcher to focus on what the exchanges allow to happen rather than attempting to use them to draw conclusions about what they supposedly reveal about the people who are participating in them.

[106] This assumes that the goal is to try to harness some of the interest and types of discussions presented here. There are also other reasons to use games in the classroom that would not necessitate the same type of design. For example, using a simple game to help students practice solving chemical equations or some other type of scientific activity would likely not benefit from this hidden depth. Those types of games, however, would likely not see the same types of responses as the ones I have seen here. If the types of interactions seen throughout this dissertation are what are desired then the design of games will require some significant work to allow for this type of exploration.

[107] This is clearly not unique to the internet and occurs in other types of discussions as well, but the internet discussions examined in the dissertation tended to heavily rely on these types of discussions making Deleuze and Guattari particularly helpful in this case.

In addition, the concept of writing as method as used in this dissertation provides an example of a way to utilize postqualitative concepts in science education research. What was most helpful about this method was that it allowed for significant changes in the project in response to the different types of discussions and art I encountered. The original project was heavily focused on the *Portal 2* game itself but the final project ended up being much more about the works people created using the ideas from the game, with only minimal discussion of the game itself except for how it led to these fan creations. While it is always possible to adjust a project's goals and questions while it is in progress, this method focused on developing the project within the process of writing itself; this more open-ended approach made it possible to make such a huge change in response to the new material with which I was engaging. Because of my methodology, I did not begin with a preconceived notion of what I should be seeking in these online communities but instead allowed the process to guide me. Other strategies can focus so heavily on using preexisting tools and questions to encourage more objective measurements that the tools themselves end up shaping the study away from what could have been possible with a method like this one.[108]

When I started this project, few examples of poststuctural work (mostly Foucault) were available in science education and, of these, none utilized Deleuze and Guattari. For this reason, I had no precedents to follow and had to rely on the concepts created by Deleuze and Guattari to guide my decision on how I would proceed in the project.

[108] Any research theory or method will inevitably shape a study and in this one writing as method and Deleuze and Guattari surely put emphasis on certain components as compared to others. With that being said, postqualitative methods like this one tend to allow for a very high level of open endedness and therefore it is easier to move in unexpected directions that can lead to interesting findings that might otherwise not be possible.

Throughout the dissertation, the focus was on how these concepts could help me think about the different situations I encountered. In some ways, however, this work does look similar to other strategies that researchers use. Unlike some poststructural works, the dissertation format itself was fairly traditional, with the analysis primarily consisting of providing examples and then creating an argument using these examples. The primary differences between my work and non-poststructural studies occurred in some of the underlying assumptions, presented in Chapter 4, as well as the way of putting together the evidence, presented in Chapter 3.

If the later chapters, focusing on analysis, are considered in isolation, the influence of Deleuze and Guattari may not always be obvious. This was somewhat intentional with the design of the later analysis chapters, since one of the troubles of doing work using novel theories like those of Deleuze and Guattari can be that the work gets so bogged down in trying to describe the theoretical framework and how it functions that the other topics of the dissertation, in this case *Portal 2* and science, can disappear. To illustrate the utility of utilizing this particular poststructural theory to inform my research practices, I would contrast the results found in previous chapters to two earlier attempts I made to study the topic of the relationship between science and *Portal* 2 using other techniques. My attempts at using traditional coding and hermeneutics both proved to be unsatisfying and unworkable.

Early on in my project, I attempted to code a number of YouTube discussions. This felt somewhat absurd for a couple of reasons. First, a number of the statements were highly interdependent. Attempts to separate these statements in analysis to find the meaning of each individually proved problematic and, if anything, the process obscured

some of the most interesting connections. The next problem was that coding puts a lot of emphasis on how often a phrase or idea occurs, with the assumption that repetition identifies something as an emergent theme. However, with these discussions, the number of times a statement arose did not seem to correlate with its actual impact and thus counting words did not seem a productive exercise. This was especially clear with memes, which resulted in hundreds of people saying the same or very similar statements for effect; suggesting that this repetition made what they said an emergent theme did not match with what I had otherwise observed, especially as the statements themselves tended to have minimal intended meaning, as it was more the effect of all of them doing the same thing at once that created the impact. Additionally, there were the issues discussed in the dissertation about the concept of trolling, in which statements intentionally can carry multiple meanings and that some of these meanings cannot be defined through the statement itself but are instead based on how the statement is received.

After this, I tried a hermeneutic approach to my questions. At first this was helpful as it addressed some of the previous concerns, allowing me to better connect statements together as well as to consider how these different connections could holistically suggest certain ideas or concepts even if no individual statement did so by itself. While my hermeneutic attempts were interesting, they still led to a number of roadblocks. The first was that I became overly focused on the text itself. Gadamer's attempt to reach a "fusion of horizons" led to problems such as needing to know the intention of the creators of the posts and the art. This was important for a genuine fusion of horizons. How could I be sure that my interpretation of what users meant was

genuine, especially when many times what actually happened in the discussion was what was interesting regardless of what the person starting the discussion might have intended. Deleuze and Guattari helped to address this concern and make a more productive project. Utilizing their ideas, I was no longer focused on the intention of the writer but instead on what their writing allowed to happen. This does not mean that what the writer might know or be thinking is never discussed, as it clearly is in some sections of the dissertation, but that it was no longer the primary focus and having times where intentions could not be ascertained was not a problem.

Implications for Policy Makers

For educational policy makers, this research highlights some of the challenges of trying to obtain the educational benefits that games can provide through the process of gamification. As can be seen from the examples throughout this study, these educational experiences were not, for the most part, planned in advance by the game creators but were instead established by users who were interested in the game and decided to create their own content and discussions. Pre-determined strategies such as educational games can still have value, but the potential utility of these games should not be confused for the sort of high level engagement that happens in these spaces of free choice.

In addition to educational policy, the research also demonstrates the importance of a free and open internet. Many of these discussions and creations were made possible due to the nature of the internet, which allows people to create sites of their liking which can attract anything from very tiny niche audiences to audiences of millions. Any changes to the structure of the internet that limit the ability to open new websites or to restrict access in an effort to transform the internet so that it more closely resembles other

forms of media such as cable television would threaten many of the benefits of the internet demonstrated here. In addition, attempts to further complicate copyright law especially through automatic systems which have no practical form of recourse for small time users could eliminate whole categories of valuable content from the internet such as the fan creations shown here.

Future Research

There are a number of interesting directions to be considered to build on the work done in this project. The first potential area for expanding this research is to look into other games that might encourage scientific discussions to see if similar types of content are created in response to them. Would the scientific concepts that are noticed by players of other games be similar to or different than those that interest *Portal* 2 players? For example, Minecraft is another game that teachers have utilized in their classroom, to a greater degree in fact than Portal. It allows for players to build the world in which they play through making different objects by combining materials found throughout the world. The game has been used by both teachers and parents who hope to harness the creativity they see in their children's projects.

In addition, there are other applications of Portal that could be considered. For example, do these same type of discussions happen when people play and discuss these games in physical spaces as opposed to cyberspace? Such research would rely on having access to groups of people who have either played *Portal 2* or would like to begin and who could be studied during their play. Of course, this creates a whole new set of challenges. One of the great advantages of this current project is that it does not require

intervention on part of the researcher; all of the discussions I have looked at would have existed even if I had never found them.

While the area of free play is interesting, many science educators are more interested in what can be done with parts of the game in classroom settings. Studies that investigate the use of portions of the game in the classroom, especially in areas of science represented in the game, such as physics, could be quite interesting. Teachwithportals.com already demonstrates that some teachers are utilizing the game in a variety of ways to present topics such as momentum, so researching particular lessons to see their effectiveness could be enlightening. This would also provide an opportunity to see if different types of players who might not have chosen to engage in the world of Portal normally would interact with it in different ways; if nothing else there would likely be additional scaffolding necessary to aid students who might not be as comfortable with the game world as those who are familiar with playing these particular types of platforming puzzle games.

Finally, outside the realm of games, there are a wide range of online spaces related to scientific topics of free choice that might be interesting to examine further. For example, I am interested in the future in looking at another area of Reddit named /r/chemicalreactiongifs, which contains a multitude of different short clips of chemical reactions. These clips can be shared with others to both talk about how "cool" they are as well as to discuss the science that makes them work. These clips tend to look more like what someone might traditionally think of as being "science" than most of the creations I studied for this project, but at the same time they are still free choice. No one is required to participate in the subreddit, at least until some teacher figures out to assign extra credit

if students write up something they see there. It will be interesting to see, in the variety of different spaces, which ones are most successful at discussing different topics as well as what different assemblages end up playing a role in the different spaces even when they appear incredibly different upon first examination.

The internet is truly a world wide web. It enables people around the world to interact with and access what has become cliché to refer to as a "vast storehouse of information," and to interact with that information in an endless variety of new and exciting ways. It is incumbent upon educators to understand this online world, which plays an ever-increasing role in the lives of our students, and how we can use this remarkable tool to improve the learning environment. The notion that there is a "real world" that is separate and distinct from the virtual world of the internet should be resisted, because for the younger generations, that separation is increasingly meaningless. The internet is part of their everyday lives. Therefore science educators need to be able to engage with it. Research to facilitate such understanding and engagement is critical to the future of science education.

Bibliography

Angelone, L. (2010). Commercial video games in the science classroom. *Science Scope*, 33(6): 45-49.

Barab, S. A., Scott, B., Siyahhan, S., Goldstone, R., Ingram-Goble, A., Zuiker, S., Warren, S. (2009). Transformational play as a curricular scaffold: using video games to support science education. *Journal of Science Education and Technology*, 18(4): 305-320.

Batrack.C. (2013). Going old school: making games with a retro aesthetic. http://gamedevelopment.tutsplus.com/articles/going-old-school-making-games-with-a-retro-aesthetic--gamedev-3567

Beier, M., Miller, L., Wang, S. (2012). Science games and the development of scientific possible selves. *Cultural Studies of Science Education*, 7(4): 963-978.

Bogado, A. (2014). Google's Latino-targeted domain, .SOY, inspires frustration, confusion. http://www.hispanictrending.net/2014/10/googles-latino-targeted-domain-soy-inspires-frustration-confusion.html

Bogost, I. (2011a). Gamification is bullshit: my position statement at the Wharton Gamification Symposium. Bogost.com/writing/blog/gamification_is_bullshit/

Bogost, I. (2011b). *How to do things with video games*. Minneapolis, MN: University of Minnesota Press.

Bohannon, J. (2008). Flunking spore. *Science*, 322(5901), 531b.

Cheeseburgz, (2011). DAE feel bad for Cave Johnson? [SPOILERS!!!...kind of]. http://www.reddit.com/r/Portal/comments/gu761/dae_feel_bad_for_cave_johnson_spoilerskind_of/

CNN Money (2014). Mobile apps overtake PC internet usage in U.S. http://money.cnn.com/2014/02/28/technology/mobile/mobile-apps-internet/

Cicierega, E. (2011). Fuck Science. Originally located at http://emmycic.livejournal.com/716586.html currently found at http://imgur.com/5G4UY.

Daly, J. (2012). Where does gamification fit in higher education? EdTech. http://www.edtechmagazine.com/higher/article/2012/11/where-does-gamification-fit-higher-education-infographic

DeLanda, M. (1997). *A thousand years of nonlinear history: swerve edition*. Brooklyn, NY: Zone Books.

DeLanda, M. (2006). *A new philosophy of society: assemblage theory and social complexity*. London: Continuum Books.

DeLanda, M. (2011a). "Assemblage theory, society and Deleuze". www.youtube.com/watch?v=sZePCx8YUys. Retrieved November 2013.

DeLanda, M. (2011b). *Philosophy and simulation: the emergence of synthetic reason*. London: Continuum Books.

Deleuze, G. (2001). *Empiricism and Subjectivity: an essay on Hume's theory of human nature* (C. Boundas Trans.). New York, NY: Columbia University Press (Original work published 1991).

Deluze, G., & Guttari, F. (1987). *A thousand plateaus: capitalism and schizophrenia* (B.

Massumi Trans.). Minneapolis, MN: University of Minnesota Press (Original work published 1980).

Deluze, G., & Guttari, F. (1994). *What is philosophy*(H. Tomlinson and G. Burchell Trans.). New York, NY : Columbia University Press (Original work published 1991).

Dickey, M. (2005).Engaging by design: How engagement strategies in popular computer and video games inform instructional design. *Educational Technology Research and Development*, 53: 67-83.

Duncan, S. (2011). Minecraft, beyond construction and survival. *Well Played*, 1(1): 1-22.

Duncan, S. (2013). Well played and well debated: understanding perspective in contested affinity spaces. *Well Played: A journal of games, value, and meaning.* 2 (2): 37-58.

EMarket Survey (2013). Social usage involves more platforms, more often: Growing interest in more in-person connectedness. http://www.emarketer.com/Article/Social-Usage-Involves-More-Platforms-More-Often/1010019.

Eurogamer staff, (2011). Portal 2 exclusive interview survey. *Eurogamer*.http://www.eurogamer.net/articles/2011-03-10-win-a-copy-of-portal-2-survey?page=2.

Forehead58 (2012).A response to proposed arguments for portal problems. The laws of physics are broken. http://www.reddit.com/r/Portal/comments/11ssg6/ a_response_to_proposed_arguments_for_portal/

Frankfurt, H. (2005). *On Bullshit*. Princeton, NJ: Princeton University Press.

Franklin, C. (2013). That's no game… .*Errant Signal*. https://www.youtube.com/watch?v=dgu76ql6FSo.

Gates, B. (2005). Prepared remarks. *National Education Summit on High Schools*.

Gee, J.P. (2009). Deep learning properties of good digital games: How far can they go? In U. Ritterfeld, M. Cody, and P. Vorderer (Eds.) Serious games: Mechanisms and effects. (p. 67-82). New York, NY: Routledge.

Gillispie, L. (2011). Energize the curriculum: put game-based learning in the palm of your students' hands. *School Library Journal*, 11: 24-25.

Glampkoo (2013). Troll Physics- Portal Gun! http://www.reddit.com/r/fffffffuuuuuuuuuuu/comments/18c3co/troll_physics_portal_gun,

Green, J. (2015). Iam John Green—vlogbrother, Crash Course host, redditor, and author of *The Fault in Our Stars* and *Paper Towns*.AMA, part 1 of 4. http://www.reddit.com/r/IAmA/comments/32xa0p/iam_john_greenvlogbrother_crash_course_host/.

Hanus, M., Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education*, 80: 152-161.

Harry101UK (2013). [♪] Portal - Making Science. https://www.youtube.com/watch?v=HDAFivGsKX4.

Harry101UK (2014). Portal 2 – Going Home. https://www.youtube.com/watch?v=LZDUAvrktVg.

Hodges, A. (2011). *Crafting fictions and subjects: examining the discourses, practices and communities of adolescent fanfiction writers* (doctoral dissertation). University of Georgia, Athens, GA.

Huizinga, J. (1949). *Homo Ludens*. Boston, MA: Routledge.

IGN (2011). Portal 2: official boots trailer. https://www.youtube.com/watch?v=nd1m5_n9P9w.

IGN (2011). Portal 2: official panels trailer. https://www.youtube.com/watch?v=Kyc4JK24EuI.

Insane Clown Posse (2009). Miracles. On bang! pow! boom! [CD]. Farmington Hills, Michigan: Psychopathic Records.

Jackson, A. (2003). *Images of excess: southern girl subjectivity and small-town education* (doctoral dissertation). University of Georgia, Athens, GA.

JamRad, (2011). Cave Says: Beware of Lemons. http://www.reddit.com/r/Portal/comments/gwyki/cave_says_beware_of_lemons.

Jereddit, (2015). Why the turrets are so weak (Source in comments). http://www.reddit.com/r/Portal/comments/2pa2xn/why_the_turrets_are_so_weak_source_in_comments/.

Johnson, L., Smith, R., Willis, H., Levine, A., and Haywood, K. (2011).*The 2011 Horizon Report.* Austin, TX: The New Media Consortium.

JoshKerky, (2014). Aperture Laboratories combustible lemons, go on, burn life's house down!http://www.reddit.com/r/Portal/comments/1ucwmx/aperture_laboratories_combustible_lemons_go_on/.

Ketelhut, D. J., Dede, C., Clarke, J., and Nelson, B. (2006). A multi-user virtual environment for building higher order inquiry skills in science. *AERA Annual Meeting*.

killedintranslation.com/portal2/ (2011).*Portal 2*: Killed in translation.

Lee, J. and Hammer, J. (2011). Gamification in education: What, how, why bother? Academic Exchange Quarterly, 15(2): 2.

Lenhart, A., Kahne, J., Middaugh, E., Macgill, A. R., Evans, C., &Vitak, J. (2008).Teens, video games, and civics.*The Pew Internet & American Life Project*. http://www.pewinternet.org/Reports/2008/Teens-Video-Games-and-Civics.aspx

Levy, F., Murnane, R. (2004*). The new division of labor: How computers are creating the next job market*. Princeton, NJ: Princeton University Press.

LobsterHat, (2011). Caroline was married to science… http://www.reddit.com/r/Portal/comments/k2z30/caroline_was_married_to_science/.

Massumi, B. (2002). *Parables for the virtual: Movement, Affect, Sensation*. Durham, NC : Duke University Press.

McClarty, K., Orr, A., Frey, P., Dolan, R., Vassileva, V., Mcvay, A. (2012). A Literature Review of Gaming in Education. Pearson. Available online at: http://researchnetwork.pearson.com/wp-content/uploads/lit_review_of_gaming_in_education.pdf

McGonigal, J. (2010). Gaming can make a better world. *TED talk*. Accessed at: http://www.ted.com/talks/jane_mcgonigal_gaming_can_make_a_better_world

MpegEVIL, (2015). [Request] In Portal 2's chapter 6 "The Fall," how far do you fall? https://www.reddit.com/r/theydidthemath/comments/31fy29/request_in_portal_2s_chapter_6_the_fall_how_far/

Muehrer, R., Jenson, J., Friedberg, J., Husain, N. (2012). Challenges and opportunities: using a science-based video game in secondary school settings. *Cultural Studies of Science Education*, 7(4): 783-805.

Munroe, R. (2009). Reddit's new comment sorting system. http://www.redditblog.com/2009/10/reddits-new-comment-sorting-system.html

Nadrojmail, (2013). Knew I had to get it for my dorm. http://www.reddit.com/r/Portal/comments/zea64/knew_i_had_to_get_it_for_my_dorm/.

National Research Council (2009).Learning science in informal environments: people places and pursuits. Washington D.C.: The National Academic Press.

Nick4753 (2011). After seeing the "Fuck Science" Portal 2 drawing/wallpaper I decided it needed background music (Set browser to fullscreen, Requires Flash, Spoiler?). http://www.reddit.com/comments/gzq8g/after_seeing_the_fuck_science_portal_2/

O'Donnell, C. (2013) Inhabiting games well (if not uncomfortably…). *Well Played: a journal of video games, value, and meaning* 2 (2): 5-20.

Owens, T. (2012). Teaching intelligent design or sparking interest in science? What players do with Will Wright's Spore. Cultural Studies of Science Education, 7(4), 857-868.

Patrick,M. (2013). Game theory: how PewDiePie conquered YouTube. https://www.youtube.com/watch?v=EgMqhEMhVV8.

Patrick, M. (2014). Game theory: yes, PewDiePie. YouTube is broken. https://www.youtube.com/watch?v=HLJQ0gFHM8s.

Philippette, T., Campion, B. (2013). On justification: Wow, EQ2, and Aon forums. *Well Played: a journal of video games, value, and meaning* 2(2): 59-78.

Pierce, J. (2014). Teaching technology. *International Review of Qualitative Research*, 7(4), 453-464.

Pittman, C. (2013). Teaching with portals: The intersection of video games and physics education. *LEARNing Landscapes*: 6(2), 341-360.

PortalGifs, (2014). No but you all need to understand how funny this is. http://portalgifs.tumblr.com/post/82832868793/no-but-you-all-need-to-understand-how-funny-this.

Redpheonix1000 – Troll Physics (2012). Troll physics: infinite energy. https://www.youtube.com/watch?v=vCvRDWv7IeQ.

RedSquidz, (2013). Long-fall boots irl? http://www.reddit.com/r/Portal/comments/185khm/longfall_boots_irl/.

Rigby, S., Ryan, R. (2011).Glued to games: How video games draw us in and hold us spellbound (new direction in media). Santa Barbara, CA: ABC-CLIO.

Salen, K., Zimmerman, E. (2004). *Rules of play:Game design fundamentals*. Cambridge, MA: The MIT Press.

Salihefendic, A. (2010). How Reddit ranking algorithms work. *Hacking and Gonzo*, http://amix.dk/blog/post/19588.

Schwartz, R. N. (2012). It's not whether you win or lose: integrating games into the classroom for science learning. *Cultural Studies of Science Education*, 7(4): 845-850.

Shanereid91, (2012). What to do if life gives you lemons. http://www.reddit.com/r/Portal/comments/uam14/what_to_do_if_life_gives_you_lemons/

Short, D. (2012).Teaching scientific concepts using a virtual world – *Minecraft.The Journal of the Australian Science Teachers Association*, 58(3): 55-58.

Steinkuehler, C. (2006). Massively multiplayer online video gaming as participation in a discourse. *Mind, Culture, and Activity*, 13(1): 38-52.

Steinkuehler, C. (2007, July). *Massively multiplayer online games & education: An outline of research.* Paper presented at the ninth annual Computer Supported Collaborative Learning Conference, New Brunswick, NJ.

Steinkuehler, C., Duncan, S. (2008). Scientific habits of mind in virtual worlds. *Journal of science education and technology*, 17 (6), 530-543.

Steinkuehler, C. & Williams, D. (2006). Where everybody knows your (screen) name: Online games as "thirdplaces." *Journal of Computer-Mediated Communication, 11*(4), article 1.

Suler, J. (1996). *The psychology of cyberspace*. Retrieved July 1, 2005 from Sterling, G. (2014). Nielsen: More time on internet through smartphones than PCs. Marketing Land. http://marketingland.com/nielsen-time-accessing-internet-smartphones-pcs-73683

St.Pierre, E. (2013). The posts continue: becoming. International Journal of Qualitative Studies in Education, 26(6): 646-657.

St. Pierre, E. (2014). *Post-qualitative research lecture.* Personal Collection of Elizabeth St. Pierre, University of Georgia, Athens, Ga.

Sundqvist, P., Sylvén, L. (2014). Language-related computer use: Focus on young L2 English learners in Sweden. *ReCALL*, 26(1): 3-20.

Superanth, (2011). Cave Johnson's combustible lemon speech – typographically. http://www.reddit.com/r/Portal/comments/k92hq/cave_johnsons_combustible_lemon_speech/.

Talisfan95 (2011). Troll science: infinite energy. http://tailsfan95.deviantart.com/art/Troll-Science-Infinite-Energy-194006459.

Tralala18. Troll physics (by me). Accessed August 08, 2014. http://hugelol.com/lol/116060

Tromba, P. (2013). Build engagement and knowledge one block at a time with *Minecraft*. *Learning & Leading with Technology*, 40(8): 20-23.

Valve Corporation. (2011). *Portal 2* [computer game]. Bellevue, Washington: Valve

www.teachwithportals.com**.** Accessed October 2013.

Young, M., Slota, S., Cutter, A., Galette, G., Mullin, G., Lai, B., …Yukhymenko, M. (2012). Our princess is in another castle: A review of trends in serious gaming for education. *Review of Educational Research*, 83 (1), 61-89.