Constructing the Language of Science:
Argumentation, Gameplay Environments, and the Diverse Learner

By

Jennifer Dalsen

A dissertation submitted in partial fulfillment of

the requirements for the degree of

Doctor of Philosophy

Curriculum & Instruction

at the

UNIVERSITY OF WISCONSIN - MADISON

2018

Date of Final Oral Examination: 12/5/2018

The following members of the final oral committee:
Richard Halverson, Professor, Educational Leadership and Policy Analysis
Matthew Berland, Associate Professor, Curriculum & Instruction
Erica Halverson, Associate Professor, Curriculum & Instruction
Leema Berland, Associate Professor, Curriculum & Instruction
Aydin Bal, Associate Professor, Special Education
Constance Steinkuehler, Professor, Informatics

Table of Contents

Table of Contents: Figures and Tables

Acknowledgements

It is impossible to name the many students, faculty, and visiting researchers who made a lasting impression on my journey through graduate school. I am deeply grateful to Constance Steinkuehler for introducing me to the Games+Learning+Society and her sage wisdom during my formative years at graduate school. I am equally grateful to Rich Halverson for developing my skills as an educational researcher and thinking critically about narrative. Thank you both for the endless encouragement and challenge. I also want to thank my other dissertation committee members – Erica Halverson, Matthew Berland, Aydin Bal, and Leema Berland – for their advice, support, and feedback.

Thank you to the many students and other faculty that have made a positive impact on my graduate work. I want to especially thank Caroline Hardin, Craig Anderson, Pasqueline Scaico, Jessie Nixon, Majeed Alrabiah, Dorcas Qian, David Azari, Vishesh Kumar, Amanda Captain, Laura Bloker, Sam Graue-Landis, Tanu Rawat, Aybuke Turker, and Vanessa Menschke. I'm glad we could share in many adventures together. Also, a special thanks to Jack Jorgenson, Kurt Squire, Eric Camburn, Bonnie Doren, Andrea Ruppar, and all the other amazing faculty at UW-Madison and beyond.

And finally, to my best friend and partner: Peter. Thank you for the endless support, patience, and encouragement to take this journey.

Abstract

This dissertation investigates the following research question within an informal games-based learning environment: *How do students construct scientific ideas within a games-based learning environment?* In this study, middle school youth role-played as scientists recruited by the Center for Disease Control (CDC) to stop the Raven Virus from reaching global pandemic. Over 10,000 turns-of-talk were collected and analyzed across the games camp. A combination of discourse analysis surrounding scientific argumentation (Berland & Reiser, 2011) and observational data were used to track shifts in group behavior across the five-day period. Three middle school groups (N=12) composed of participants with and without disabilities are documented within this study. Results identify youth as referencing past performance of assessment-based practices in formal academic environments to measure potential success within the camp. However, student-driven inquiry and activities surrounding gameplay afforded participants an opportunity to co-construct a community language based upon learning experiences. In the end, students with and without disabilities took ownership of each other's educational outcomes through multiple means of expression and representation in gameplay. Future research on collaborative learning and scientific discourse within the context of informal learning environments should be studied further.

Chapter 1: Introduction

"What students need to learn and what we know about how they learn have changed, and therefore the learning experiences we provide should change." - STEM 2026

The advancement of educational technologies to support science education has created a rich opportunity to transform the classrooms of the 21st century (Belland, 2010; Collins & Halverson, 2009; Gerald et al, 2009). However, students with disabilities are not passing science-based standardized assessments to the same degree as their peers. The success rate for middle school youth with disabilities in Wisconsin (50%), Arizona (25%), Delaware (20%) and other states across the nation is remarkably low, with scores decreasing as students enter high school (OSEP, 2016). This is without taking into consideration that only five percent of students with disabilities enter the STEM workforce (Leddy, 2010) following graduation. If learning is a social activity (Vygotsky, 1978), and aspects of science education are bolstered by peer-driven inquiry (National Research Council, 2012), then students with disabilities must be active participants in collaborative discussions whenever possible. However, while a Free and Appropriate Public Education (FAPE) affords students with disabilities technological and academic resources to fulfill standardized assessments (U.S. Department of Education, 2016), this policy does not create immediate opportunities for individuals to leverage multiple means of representation (Nelson, 2014), communicate complex scientific frameworks on their own terms, or work alongside their peers to situate meaning to scientific practices. Educational technologies like games-based learning have the potential to empower students with disabilities and fill this gap.

Today, student lives are filled with modern digital technologies that encourage personalized learning opportunities that traditional science classrooms cannot always fulfill (U.S.

Department of Education, 2017). Accessible and flexible technology resources for science education not only support students with disabilities, but develop communities of practice (STEM 2026). These digital infrastructures afford students new opportunities for learning new scientific concepts and constructing scientific arguments within their communities of practice. Importantly, argumentation is not simply the opposition of sides, but a mental exercise where both parties steer their way through the roundabouts of discourse (Cohen et al, 2004) in order to reach a clearer understanding of material. While students in traditional science classrooms will gain academic feedback through standardized assessments and activities, the adoption of interactive technologies creates immediate performance feedback unmatched by other systems within education (STEM, 2026).

Despite research encouraging classrooms to develop collaborative learning projects to build scientific literacy, students with disabilities remain largely disconnected from formal communities of practice. Science education frameworks for students with disabilities remain heavily focused on academic guidance and teacher intervention. Many times, classroom responses are standardized, with students actively looking to arrive at predetermined science-based conclusions based on prescribed activities (McNeil & Pimentel, 2010; McNeil & Knight, 2013; Sampson & Blanchard, 2010). Current research on building literacy in areas like scientific argumentation are heavily situated within classroom and clinical environments (Berland & Reiser, 2009; Erduran, Simon, & Osborne, 2004; Larson & Britt, 2009), but few examine informal settings where technological tools, like games-based learning, have the potential to build this practice. Instead, the fostering of scientific argumentation research for children is focused on explicit instructional techniques (Paretti, 2009, Sampson, Grooms, & Walker, 2011; Schworm & Renkle, 2007) with little reliance on student-driven activities.

The application of traditional assessment-based practices in digital tools is problematic because the flexible systems built to represent multiple means of expression (Cuban, 1986) are narrowed into the formulaic answers that students continue to encounter in classrooms today. The search for pedagogical approaches that shift scientific inquiry onto the student (Lemke, 19) are only possible when these flexible systems exist. Despite this, students with disabilities continue to experience more drill-to-skill activities in educational games that support vocational training, social-emotional skills, and behavioral interventions. What remains largely untapped are opportunities to reshape student agency through gameplay.

Games-based learning has an immediate feedback system that allows educators the ability to track and monitor performance in real time. Just as importantly, games-based learning has the potential to empower the future scientists of the 21st century without direct instruction from educators (Bertrus, 2015; Nell, Drew, & Bush, 201; Gopnik, 2011; Nell et al., 2015). From museums to science fairs, informal learning environments offer the potential for students with and without disabilities to readily explore unknown scientific questions in new, innovative ways.

Informal games-based environments are wholly different because unlike school, where children are required to read, write, and investigate topics in a formulaic way (Gee, 2001), games encourage the opposite. As Trilling and Fadel (2009) argued, rich learning opportunities occur when digital technologies are embedded into well-designed projects. What remains understudied is the use of games-based learning to support science education within informal environments for students with disabilities, and how collaborative learning impacts knowledge gains. Furthermore, few studies are designed to capture and quantify games-based discourse among students with and without disabilities, particularly in the realm of scientific argumentation. This dissertation looks to further this landscape by using mixed-methods to track how students with and without disabilities build scientific arguments within an informal games-based learning environment.

Research Question and Setup

This dissertation seeks to answer the following research question: *How do students construct scientific ideas within an informal games-based learning environment? In addition, I will ask the following sub-question: How do students with disabilities use gameplay to participate and construct scientific ideas within an informal games-based learning environment?* The data collected for this study will reflect the same methodological framework typical of an IEP meeting: a combination of qualitative (*discourse*) and quantitative (argumentation code) analyses. This dissertation also harnesses educational data mining techniques to situate dialogical learning in a quantifiable and scalable way, while preserving the nuances of discussion. In this regard, qualitative and quantitative analyses are carefully considered in tandem with the player's needs.

Literature Outline

This following literature review outlines current gaps in disability studies and games-based learning while underscoring the importance of measuring language beyond standardized assessments. It begins with a brief overview of disability studies, special education, and technology supports with an emphasis placed on games-based learning tools. From there, I trace how the power of individual language and meaning provides educators with an alternative way to track knowledge production. I also discuss argumentation as a way to communicate, consider, and redesign meaning. My literature review will close with a look at how persistent behavior deconstructs common stereotypes and furthers a student's academic goals.

Chapter 2: Literature Review

Learning is a social activity (Vygotsky, 1978) where individuals come together to share interests, collaborate on projects, and participate in a community of practice (Lave & Wenger, 1991). Here, individuals engage in reciprocal apprenticeship, fluidly moving from novice to expert, and thus blurring the line between learning and doing (Brown, Collins & Duguid, 1989). Online game communities are one of several informal learning environments where players contribute to a collective intelligence (Levy, 1999), offer mentorship (Gee, 2012), and co-construct strategies. More recently, these types of interaction are being sought in games-based learning activities within formal learning environments, particularly for students with disabilities. However, social activity is not the primary focus of special education. Educational technologies granted to students with disabilities are less focused on collaborative experiences and more heavily situated on successfully completing standardized assessments.

In order to contextualize how *informal* games-based learning opportunities offer students with and without disabilities a space to actively engage in multiple means of expression, it is first necessary to review the current problems within *traditional* learning environments. I begin with a brief look at the history of students with disabilities in special education and how the current landscape within formal academic environments is not designed for social activity. I also consider the barriers facing students with disabilities using technology in education. From this, I consider the importance of games-based learning in education and how informal environments can bridge this gap. I close with a look at the expanding definition of language, argumentation, and the importance of persistence within these learning environments.

Disability, Education, and Society

There are 56.7 million individuals with disabilities in the United States. This amounts to roughly 19 percent of the country's entire population (U.S. Census Bureau, 2016) with over 20 million diagnosed with a long-term illness or disease (Genetic and Rare Diseases Information Center, 2016). In education, there are roughly 6.6 million children diagnosed with disabilities in the public school system, or roughly 13 percent of the student population. This statistic continues to increase with each given year (OSEP, 2016), meaning the number of students with disabilities served under special education has the potential to increase over time.

The legal framework known as the Individuals with Disabilities Education Act (IDEA) was established to ensure every child diagnosed with a disability receives a Free and Appropriate Public Education (FAPE). Under IDEA (2004), FAPE guarantees *academic access* and *an environment with non-disabled peers*, but does not promise social interaction with other students. Instead, the nature of accommodation services and supports offered to students with disabilities is heavily laden with technical assistance and is less about interpersonal relationships. In fact, students with disabilities are more frequently the victim of bullying (Pijl, & Zandberg, 2004; Norwich & Kelly, 2004; Rose et al., 2011) when compared to their peers. This mindset is an artifact of the social perspective of disability as a whole. Mainly, that society continues to view disability as a medical disorder or something that requires modification or fixing. The elusive normality (Shakespeare, 1998) created and maintained by the "social looking glass" (Wright, 1960) continues to perpetuate the way disability is viewed in society (e.g. *different, oppressed, or sick*). These social beliefs hold strong even today. In a recent study by the National Council for Learning Disabilities (2014), 43 percent of adult respondents believed a specific learning disability was directly connected to a child's intelligence. In addition, 55 percent of adults believed a specific learning disability could be mitigated when a child received corrective lenses.

Similarly, public definitions of disability are not person-first (e.g. an individual with a disability, not a disabled person). While a push to update disability signage is happening in places like New York City, university campuses and other public environments continue to preserve (by default or misunderstanding) language that is no longer appropriate. In other ways, our society has become so used to labels and identifications that we rarely question why these categories exist (Wertsche, 1990). Yet language in culture impacts the way members operate (Cole, 1998) and can ultimately influence student behavior. Figure I represent an example of this continued gap in our society.

Figure I: Disability Signage, at UW-Madison (Left) and New York City (Right)

Language use and misconceptions deepen as we move away from the psychosocial aspects of disability in society and concentrate on education alone. Birch and Johnson (1975) warned that access to education for individuals with disabilities, not from the sterile viewpoint of physical location or equipment, but from the perspective of social opportunity and human rights, would be the biggest challenge our system faced. Over forty years later, the social structure of special education services, while making a tremendous shift to mainstream education, continues to struggle with maintaining inclusive practices.

Social Structure of Special Education

Special education is not designed as an isolated service for students with disabilities, but a department situated within the larger framework of the public school system, where students obtain accommodations and interventions specific to their individual needs (IDEA, 2004). These services continue to evolve as new educational policies take shape. However, the shift to mainstream education is a well-discussed subject with minimal traction. Today, 86 percent of students diagnosed with multiple disabilities, 56 percent of students with emotional behavioral disorders (EBD), and 32 percent of students with specific learning disabilities (SLD) spend *less than* 80 percent of their time enrolled in the mainstream environment. When examined through a wider lens, 40 percent of all students with disabilities in the K-12 public school system are not fully enrolled in mainstream services (U.S. Department of Education, 2016). This statistic is alarming given the 6.5 million students receiving some type of special education service.

Suspension, Expulsion and Dropout Rates

During the 2013-2014 school year, 52,554 children with disabilities served under IDEA (Part B) received out-of-school suspension or expulsion for more than 10 cumulative days. These suspensions were allowed and justified using the very legal framework - IDEA and FAPE - designed to protect educational rights. Under IDEA (2004) and FAPE, students with and without disabilities can be legally removed from class or suspended up to 10 school days if s/he violates a code of student conduct. While originally drafted to ensure students with and without disabilities receive equal discipline, schools are interpreting this framework as a “free” 10-day period to suspend children without legal implications from IDEA. For many students, particularly those diagnosed with EBD, suspensions are inappropriately used as a behavioral tool. This creates a cyclical process where accommodations or interventions services are withheld from students until their return to school.

Many of these accommodations will never include behavioral modifications and multiple suspensions will ultimately lead students with disabilities to expulsion or possible incarceration (National Council on Disability, 2015). Table I shows the number of students (ages 3 through 21) served under IDEA, Part B, who were removed to an interim alternative educational setting and suspended or expelled for more than 10 days per 10,000 children.

Disability	Removed to an interim alternative educational setting[a]		Suspended or expelled >10 days during school year[b]	
	Removed unilaterally by school personnel[c] for drugs, weapons, or serious bodily injury[d]	Removed by hearing officer for likely injury[e]	Received out-of-school suspensions or expulsions[d]	Received in-school suspensions[d]
All disabilities	14	1	80	38
Autism	4	#	14	5
Deaf-blindness	7	0	0	0
Developmental delay[f]	1	0	6	1
Emotional disturbance	50	4	357	120
Hearing impairments	8	#	25	16
Intellectual disabilities	8	#	65	32
Multiple disabilities	5	1	31	10
Orthopedic impairments	3	#	22	5
Other health impairments	21	1	139	70
Specific learning disabilities	20	1	94	52
Speech or language impairments	2	#	13	7
Traumatic brain injury	10	0	47	15
Visual impairments	5	0	24	12

Table I: The number of students (ages 3 through 21) served under IDEA, Part B, who were removed to an interim alternative educational setting and suspended or expelled for more than 10 days per 10,000 children

Students with disabilities who experience ongoing suspension are more likely to dropout of school, with individuals diagnosed with an emotional behavioral disorder or a specific learning disability at the most risk. Table II represents these dropout rates by disability status.

Disability	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14
All disabilities	28.3	26.3	25.7	24.6	22.4	21.1	20.1	20.5	18.8	18.5
Autism	10.8	9.2	7.2	7.0	6.2	6.6	6.3	7.3	7.1	7.3
Deaf-blindness[a]	20.0	9.2	8.2	9.5	9.1	13.3	15.1	14.5	14.6	12.8
Emotional disturbance	48.2	45.0	44.8	43.3	40.6	38.7	37.0	38.1	35.4	35.2
Hearing impairments	13.1	13.5	13.0	11.1	10.5	10.2	10.2	10.2	9.5	9.4
Intellectual disabilities	24.5	22.3	22.2	21.5	19.8	19.2	18.5	18.8	17.9	16.8
Multiple disabilities	21.0	18.6	19.1	17.6	14.9	13.9	13.1	15.8	15.2	14.2
Orthopedic impairments	14.5	11.6	13.3	13.1	13.6	12.4	11.5	11.4	10.7	11.0
Other health impairments	24.7	23.6	23.2	22.4	20.4	19.1	18.4	19.2	18.1	17.6
Specific learning disabilities	26.8	25.3	24.5	23.6	21.4	20.2	19.4	19.9	18.0	18.1
Speech or language impairments	25.2	22.7	20.7	20.5	18.8	17.0	16.0	15.6	14.5	13.4
Traumatic brain injury	18.5	15.1	15.4	14.6	13.2	12.5	11.4	12.3	11.1	12.2
Visual impairments	11.3	11.5	11.2	9.6	9.6	8.4	8.5	7.3	8.0	6.4

Table II: Dropout Rates of Students with Disabilities by Category (OSEP. 2016)

In general, every disability category has decreased in the number of students who dropped out from school. While a decrease in dropout rate for students with disabilities is most notable for emotional behavioral disorders (-13 percentage points between the years 2004-2014), this category nevertheless maintains a lead from year to year.

School-to-Prison Pipeline

The disproportionate representation of culturally and linguistically diverse students in special education, particularly African American males, is promoting the school-to-prison pipeline (Tulman & Weck, 2009). African American students make up 18.7 percent of the entire special education population. However, nearly fifty percent of these students are in correctional facilities. In addition, while students diagnosed with disabilities account for 12 percent of the student population nationwide, one-fourth of students qualified for special education services are subjected to school-related arrests. Today, 85 percent of students enrolled in juvenile detention centers are identified with a disability (National Council on Disability, 2015). Table III breaks down the statistics of students with and without disabilities (by race) under suspension each year.

Race	**Students with Disabilities (%)**	**Students without Disabilities (%)**
All	13	7
African American	25	16
Latino/Hispanic	12	7
Native American	11	8
White	9	4
Asian	2	3

Table III: Suspension Rates (see: National Council on Disability, 2015)

The massive number of students dropping out of school, in suspension, facing expulsion, or entering juvenile detention centers represents an unresolved problem in special education. Over the past twenty years, special education research has focused on strategies to counteract this effect through intervention and academic design. However, as made clear by the statistics listed above, culturally diverse students with disabilities continue to experience a climate of social isolation and separation. The following paragraphs will closely examine the current state of the disability research agenda and how technological tools may serve as a potential catalyst for transforming the learning environments of the 21st century.

Disability Research Agenda

Special education research is an interdisciplinary field focused on supporting the whole student. Through research, educators can better understand how to accommodate students with disabilities in achieving academic and social milestones. In the past twenty years, major research in special education has included self-determination (Wehmeyer, Agran & Hughs, 1998;

Wehmeyer, 2005; Carter et. al, 2006; Shogren et. al, 2007; Shogren et. al, 2013; Carte, 2013; Shogren et. al, 2014; Wehmeyer & Shogren, 2016), culturally responsive practices (Hays, 2001; Klinger & Edwards, 2006; Brown, 2007; Cartledge & Kourea, 2008; Bal et. al, 2014; Trainor & Bal, 2014; Bal & Trainor, 2015), independent living (Kennedy et. al, 2014; Mason, Dempsey & Fodstad, 2009; Smith, 2015), universal design for learning (Fowler et. al, 2014; Marino et. al, 2014; Nelson & Rose, 2014 Gargiulo & Metcalf, 2015), behavioral interventions (Cheney, Flower & Templeton, 2008; Sutherland et. al, 2008; Horner et. al, 2009; Lewis et. al, 2010; Brosnan & Healy, 2011), technology services (Edyburn, 2013; Okolo & Diedrich, 2014; Kennedy et. Al, 2015) and postgraduate life (Wagner et. al, 2005; Gregg, 2007; Artiles et. al, 2010; Hosp et. al, 2014). However, the changing and broadening landscape of special education research remains fixed on what the President's Commission on Excellence for Special Education (2002) described as schools following a too-narrow culture of compliance.

Technology and Learning

The above sections of this dissertation outlined the current landscape of students with disabilities in formal learning environments and the challenges facing academic success. While changes to policy afford more students with disabilities accommodation services, the tools and research surrounding this support is heavily focused on traditional approaches to learning. Today, technology plays a key role in giving students with and without disabilities additional opportunities to communicate, express, and represent ideas (Nelson, 2014). However, I argue that current structures in formal education restrict technology availability and use. Therefore, before turning the discussion to how informal learning environments and alternative technological tools (e.g. games-based learning) can provide rich experiences for students, the gaps surrounding formal education and technology must be explored further.

The following paragraphs deconstruct technology in learning by first examining how current definitions within formal environments potentially detract from richer experiences in education, particularly for students with disabilities. I compare assistive technology to educational technology in schools to further illustrate this barrier, along with challenges to teacher training. From there, my discussion focuses on universal design for learning and technology use within the context of informal learning environments. I also look at how games-based learning, an activity leveraged within both formal and informal learning environments, could open the doorway for science education. I close with a look at how games-based learning could transform the way students with disabilities understand and engage in science.

Assistive Technology vs. Educational Technology

Assistive technology devices are designed to support students with disabilities in various aspects of everyday life. These devices can range anywhere from Augmentative and Alternative Communication devices (ACCs) to wheelchair switches and braille. Researchers have created various evaluation models to help guide educators on the best technology to use (see: Bryrant & Bryant, 2003; Lahm and Morrissette, 1994; Bryant, Bryant, & Raskind, 1990). However, the match between student needs and technology is sometimes interpreted as a pressure to conform rather than express differences in learning. For example, while some parents see Cochlear implants as opening the door to their child's academic future, members of the Deaf Community may view this technology as oppressing a linguistic minority (Goggins & Newell, 2003). In determining accommodation services for a student, educators are not prioritizing whether the technological tools offered will encourage advancement or academic challenge. Instead, the focus aims to fulfill the requirements of a Free and Appropriate Public Education (FAPE). The push to level the metaphorical playing field within these formalized learning environments

(Dalsen, 2017) means children are likely missing opportunities to grow beyond the prescribed frameworks offered to them.

The U.S. Department of Education (2008) defines informational[1] technology as "computers, devices that can be attached to computers (e.g. LCD projector, interactive whiteboard, digital camera), networks (Internet, local networks), and computer software" (pg. 12). While educational technology is marketed as the great equalizer for underachieving students (Passey & Rogers, 2004; Reynolds, Treharne & Tripp, 2003; Perotta, 2013) because it allows individuals to learn at their own pace (Nelson, 2015) and access a wider variety of resources (Perrotta, 2013), definitions surrounding this tool varies significantly between public, private, state and federal agencies (U.S. Department of Education, 2008).

Importantly, different interpretations of assistive and educational technology have led to further challenges in supporting students with disabilities in school. In the next section, I highlight where gaps in formal learning and technology exist, and why informal environments play a critical role in encouraging student growth in ways traditional settings cannot.

The Gaps in Formal Learning and Technology

Educational technology is cited as showing positive results in literacy, math (Cheung, & Slavin, 2013), and science. However, scholars continue to question the effectiveness of technology in education (Duncan, 2010; 2012; Machin, McNally & Silva, 2007; Greaves et. al, 2010; Karich, Burns & Maki, 2014), with some citing concerns of student distractibility (Bowman et. al, 2010; Hembrooke & Gay, 2003; Sana, Weston & Cepeda, 2013; (Lenhart et al., 2010). The ongoing challenge surrounding all these studies is a simple one: as innovative

---

[1]Informational technology and educational technology used interchangeably in the document cited

technologies continue to buckle under traditional means of instruction, what learning supports are being measured and to what degree (Rose & Meyer, 2002)?

This problem runs parallel with assistive technology services. Educators are measuring how effectively assistive technology supports students when compared to traditional views of classroom success. As successful intervention and assessments are rooted in traditional instruction, and because assistive technology is meant to promote learning, students with disabilities are measured with the same standards as non-special education peers without taking into consideration alternative learning needs. However, this frustration deepens for special education students, as unsuccessful assistive technology products lead to abandonment. Reasons for abandonment include: financial stress (Wehmeyer, 1998), lack of appropriate evaluation of student needs (Parette, 1997) and learning preferences (Judge & Parette, 1998), portability of device (Scherer, 1993), student embarrassment of the device used because it stands out (Bryant & Bryant, 2003), untapped resources, and unrealized need for advocacy by caregivers (Jary & Jary, 1995; Flippo, Inge & Barcas, 1997). In addition, a lack of knowledge in designing technologies to accommodate a specific disability need (Edyburn, 2000), like visual impairments (Alper & Raharinirina, 2006), impacts academic outcomes.

Both assistive and educational technology support for students with disabilities have entered a familiar crossroad, cracked by a digital divide (e.g. Bucy, 2000; Luke, 2000; Attewell, 2001; DiMaggio et al., 2001; Jung et al., 2001; Bonfadelli, 2002; Ekdahl & Trojer, 2002), As not every child is afforded the same resources due to legislation and/or legal interpretation, a lack of technological access in schools means children risk being left behind (Attewell, 2001; Wenglinsky, 1998; Kozol, 1991; Lenhart et al., 2010; Siegler & Ramani, 2008; Cheung & Slavin, 2012; Van Dijk & Hacker, 2003).

Another hidden risk of access inequality for students with disabilities in schools is the level of technological training and instruction given to educators (Lim & Chan, 2007; Tondeur et al., 2008). Hermans et al., 2008). This is not to place blame on the teachers, but to acknowledge how rapid advancements in technology (Ivanoff, 2006) are creating a “cat and mouse game” wherein professional development opportunities are unable to showcase the newest or most effective technologies on the market. Teachers learning to balance assistive technologies with educational technologies (Ludlow, 2001; Lee & Vega, 2005; Anderson & Pelch-Hogan, 2001; Hasselbring & Glasser, 2000) cannot always recognize opportunities to consolidate resources into one program. For example, a student with speech-to-text software may use Google Docs to complete his/her assignment. Another teacher, not realizing that Google Docs has text-to-speech built into its programming structure, may unknowingly advise the student to use the assistive technology software.

Summary

Schoolwide collaboration on technology initiatives can boost knowledge in computer use while recognizing assistive technology as part of this larger endeavor (Hirst, 2010). Such a plan does not need to be exclusively coordinated by the school. Students, parents, policymakers and community members are part of the educational process and are encouraged to contribute to the discussion (Ito et al., 2008; National School Boards, 2007) in order to represent students of diverse backgrounds. The next section will briefly discuss the benefits of games-based learning within informal environments, the benefits of data capture when examining player activity, and strategies for implementing this tool as part of a formalized learning environment for science education.

Games and Learning

Like other instructional technologies, games are sociotechnical artifacts (Bijker, 1995) where educational impact is dependent on context and use. Today, many educational games are designed to track and monitor student achievement within the classroom environment. These measurements typically include assessment-based practices and the collection of clickstream data to measure what academic progress was made and to what degree. However, while educational data mining techniques create a broader look at player activity overall, motivations behind in-game behavior are not always captured in full. The following section examines how educational researchers measure learning in games and the role of quantitative analysis. In addition, I discuss what data channels researchers can potentially use to capture data beyond standardized assessments (Marion et al, 2012), particularly for students with disabilities. I close with a look at how games-based learning is measured in science education.

Informal Environments and Games

Informal learning communities can range from museums to after school programs and clubs. These "middle spaces" (National Research Council, 2011) are less formal and rigid when compared to traditional educational environments, but nevertheless contain some structured activities. As play is primarily a social and recreational activity, Ito (2009) argued that educational games must consider the informal environments surrounding structured content. Current research shows that informal environments that use educational technology can bolster expertise in various subject areas (Resnik, 1998; Squire, 2011), foster collaborative experiences among youth (Steinkuehler, 2004; Stevens, Satwicz & McCarthy, 2008; Nardi, 2009), and develop a community of learners (Klopfer, 2008; Squire & Patterson, 2009).

Gameplay within informal learning environments creates a chance for children to cultivate interests, formulate personalized learning goals, and connect with others (Squire, 2011). This includes additional opportunities for social integration (Ito & Bittanti, 2009). While games have the potential to motivate students to investigate and pursue science (Dede, 2009), the implementation of games-based learning for students with disabilities is largely focused on tracking measurements within formal environments. In short, educators focus heavily on "what" students are doing with regards to performance rather than "why" or "how" they are accomplishing these goals.

The following paragraphs deconstruct the importance of measurement within games-based learning and ongoing challenges facing researchers as they look beyond "what" players are doing in order to understand "why." From there, I examine special education and games. I close with a look at science education and games in formal environments, along with existing gaps regarding the building of scientific ideas.

Measurement

Research surrounding games-based learning frequently concentrates on asynchronous connections and less frequently on synchronous experiences (Gee, 2004; Gee & Hayes, 2010). As a result, games-based studies rarely track and report on simultaneous activities that occur during moments of play. Instead, research focuses on player decisions based on clickstream data collected and analyzed internally (Owen et al, 2014). This information-rich approach offers research scientists a massive volume of data about gameplay behavior (Romero & Ventura, 2010), especially in the context of playability in the commerical industry (Asthana, 2011; Kohavi, Longbotham, Sommerfield, & Henne, 2009). Data mining techniques in non-commercial, educational games is also important when studying task-based strategy (Weber and

Mateas), spatial reasoning patterns (Drachen & Canossa, 2011), and design pathways (Gagné, El-Nasr, & Shaw, 2011). Beyond using large scale data exhaust to determine player activity, educational scholars use pre/post assessments to measure knowledge gains. Less frequently captured is discourse surrounding games-based learning experiences at a broader level. The use of qualitative analyses to support games-based learning is found through ethnographies and case studies (Steinkuehler, 2004; Nadir, 2010). However, additional work is needed in the games-based learning field to disentangle player motivation (Gee, 2005). Specifically, while internal data structures designed to capture in-game behavior support researchers in determining design pathways (e.g. "what is happening"), the *why* behind these activities cannot be easily deciphered through quantitative analyses alone.

Qualitative feedback from players within games-based learning environments is frequently captured but never analyzed beyond self-reported measures. As a result, leveraging qualitative data to demonstrate the impact of learning in play is largely unclear, particularly in the realm of disability studies (Marino et al, 2012). Many times, games-based learning ties for students with disabilities focuses heavily on score improvements over the co-construction of artifacts or individualized expression of the player. To better understand the advantage of harnessing qualitative and quantitative data analyses in games-based learning, the following paragraphs look at disability studies in games.

Special Education and Games

Games allow students with disabilities to participate in alternative vocational training initiatives (Kwon, 2012), develop self-monitoring skills (Buggey, 2005), gain digital literacy (Israel et. al, 2015) and become more engaged with academic material (Marino et. al, 2014). Many times, this progress is measured through quantitative analyses, with standardized assessments and drill-to-skill practices (Koran & McLaughin, 1990) routinely used to study learning gains. For example, using data collected from 366 adolescent students with and without disabilities in 18 life science classrooms, Israel, Wang, and Marino (2015) investigated the link between demographic data, gameplay, and reading proficiency. The study's design was focused on knowledge gains (e.g. quantitative assessment) in reading and less on the co-construction of language development during moments of play. In another study conducted by Marino et al., 2013), students with disabilities reported collaborative discourse during gameplay activity. However, data collection was focused on behavioral patterns in clickstream data. As a result, the scholars concluded that student decision-making was not fully tracked or analyzed within their study.

A further dilemma that arises from studies like those of Israel, Wang and Marino (2015) is the assumption that assessment and motivation are easily paired. This is problematic for students with disabilities, as most assessments are not readily designed to recognize differences in communication, expression, or learning. These observations mirror concerns outlined by Gee (2013) in his book *Good Video Games + Good Learning*. Specifically, that several obstacles remain *before* games-based learning can be leveraged as an assessment tool. This includes the need to find ways to accommodate changes in curricula and foster critical thinking skills in students while considering assessment-based practices that are not designed as fixed tools.

At the same time, disability scholars continue to classify games-based learning opportunities as a type of intervention tool (Torrento et. Al, 2014) with pre/post assessments serving a s a key data channel for tracking student knowledge across time. As a result, opportunities to study social interaction among students with and without disabilities in a games-based learning environment are currently limited. This barrier is amplified when taking into consideration how academic subjects like science education leverage social interaction to build critical thinking skills. In science education, children are taught to coordinate their world views, develop hypotheses, and carry out experiments to verify claims. These skills are critical for preparing the scientifically literate citizens of the 21st century. The following paragraphs briefly describe the current landscape of science education, games, and social activity.

Science and Games

Many times, games in science education place students at the center of the learning process (Barab, 2007). Through this process, students practice scientific literacy while educators track and monitor knowledge gains (Bransford & Schwartz, 1999). From addressing hypothetical outbreaks in-game (Miller et. Al, 2004) to developing high-level reasoning and alternative modes of expression (Alexander et al, 2008; Clark et al, 2011; Bardar & Edwards, 2017; Kirikkaya, Iseri, and Vurkaya, 2010; Squire, 2011), games offer educators innovative ways to track and monitor student progress. While some games in science education encourage community engagement (Barab et al, 2005; Dede, Ketelhut et al, 2004), quantitative analysis is frequently used to assess player activity (Owen et al, 2013; Fu, Zapata, & Mavronikolas, 2014).

What is less studied are ways students arrive at scientific answers (Bransford & Schwartz, 1999) during moments of play. As video games continue to evolve and become increasingly adopted by educators in a classroom setting, the conversation surrounding games is *not* whether they are used for learning, but under *what context* (Squire, 2006). In science and elsewhere, situated understanding between and among student groups may occur through games-based learning experiences, particularly when a hidden curriculum (Gee, 2004) bolsters expert problem-solving skills. In essence, helping students to learn by doing within a larger community, and through routes of their own choosing. Yet students with and without disabilities continue to be measured by assessment-based practices and activities that may not always represent multiple means of expression or representation (Nelson, 2014). The next section will explore language use within informal and formal learning environments, along with the impact of standardized language in schools.

Language and Literacy

There is no universal manual to language. In English, adjectives will precede a noun (e.g. “red” before “house”) whereas in Spanish, the words would be “casa” [house] “roja” [red]. The pitch of your words will determine the meaning in Chinese, and for individuals who use American Sign Language (ASL), communication requires no sound whatsoever. How information is communicated, and how many verbs, nouns and adjectives are conveyed, depends on language and culture (see: Tardif, Gelman, Xu, 1999; Bernstein et. al, 2004; Malvern et. al, 2004; Hoff, 2006; Hoff, 2013). In essence, language is what we make of it. Words are powerful, moving, fluid, empty, and meaningless. From culture to culture, and from community to community, the way we communicate differs. The subtle nuances attached to communication are also important - the voice, the body language, the emphasis on vowels - all these factors create a sentence interpreted as happy, sad, sarcastic, etc.

Take the following sentence: *There is no room for error.* A supervisor’s intonation could make this sound aggressive or serious. However, two college roommates could exchange the same sentence in a lighthearted way as each meticulously shaves a balloon. In both situations, there is no room for error. A worker will succeed or fail, a balloon will survive or pop from existence. It is the context and meaning that makes the difference.

This section illustrates the (dis)connection between formal and informal language. Specifically, how the construction of language at school can vary significantly from the conversations exchanged at home. Through this literature, I argue that school environments constrict the way individuals build and interpret language, which ultimately leads students to become victims of the 4th grade slump. I argue that informal dialogues - language constructed and exchanged outside the classroom environment - holds enriching and needed experience for all students, regardless of disability type.

From Home to School

Language begins at home. Like seeds, an enormous amount of time and energy is needed before activity is discovered. Language grows from experience, introduction, correction, expansion and experimentation. Children continue to expand and grow their vocabulary while mastering grammatical structures, correcting spelling errors, and pushing new words into familiar sentences in an experiment that *sometimes* goes right but *often* goes wrong. As these children enter school, experimentation turns into drill-to-skill activities (Foucault, 1975; Labov, 1982). Herein a paradoxical belief is born: that mastering school literacy will lead to social mobility. School literacy does not celebrate differences in dialect or openly acknowledge differences in the way individuals communicate. Rather, the working blueprint of education is to provide a unified (and standard) language (Collins, 1989).

In the classroom, a student's language structure is boiled down to a correct or incorrect response. Every child is asked to communicate their thoughts in a formulaic way. Here, the celebration of difference is extracted from school in exchange for creating a single academic standard that is tested, re-retested, and recited through weekly activity. However, the 'normalization' of language within the school system causes an enormous challenge for many individuals with and without disabilities. For better or worse, school assessment leaves no calculated room for students to stretch their minds and experiment with language itself. Under this premise, children from culturally and linguistically diverse backgrounds are raised with the 'wrong' language structure that must be corrected through intervention and remedial services.

Here we enter a two-fold problem. While some families have the resources to provide their child with the tentative tools needed to succeed academically in the classroom environment and other families are not afforded this same luxury, there is only so much preparation a child can undertake in order to secure an otherwise moving target in education. Even then, there is no guarantee that s/he will succeed once in the school system. As Shirley Heath (1983) writes in her ethnography on two communities: "For Roadville, the written word limits alternatives of expression; in Trackton, it opens alternatives. Neither community's ways with the written word prepares it for the school's ways." (pg. 235).

Hence, even children from varied backgrounds, those introduced to alternative ways of communication, individuals with many books, or few books, or many writing activities, are not necessary prepared to enter a system where the response is filtered down into "A" or "B." The way students communicate information, and the way sentences are structured, come under scrutiny as individuals decipher what another person is saying. Such an example is shown in *Alice in Wonderland*, where the March Hare and Mad Hatter become miffed by the way Alice is communicating with them. Thus, the following exchange:

> "Then you should say what you mean," the March Hare went on.
> "I do," Alice hastily replied. "At least - at least I mean what I say - that's the same thing, you know."
> 'Not the same thing a bit!' said the Hatter. "Why, you might as well say that 'I see what I eat' is the same thing as 'I eat what I see'!"

The scrutiny that students with and without disabilities face during their early years in school are meant to redirect sentence structure in a way that corresponds with weekly assignments and standardized assessments. Just as a parent may correct a child's labeling of an item at home (e.g. “Ball” and “Yes, that’s an orange.”), teachers may undergo a similar practice in an attempt to guide students to the appropriate call-and-response. Until 4th grade, much of this training is exclusively focused on structure. This instructional practice, though helpful in propelling students into a state where they can pass the necessary exams, creates a circumstance where children with a limited specialist language falter in later grades.

The Achievement Gap

Active differences in language is where the divide in school begins. Students who are unable to master standard English become victims of the 4th grade slump, where vernacular language drops away in text and classroom environments (Gee, 2015). Many students who successfully passed coursework in earlier grades find themselves left in the lurch, unmotivated and stressed because the academic rules have changed on them. From 2003-2008, the level of reading proficiency between special education and mainstream students was significantly different from 4th grade onward (OSEP 2016). Figure II shows a comparison of student proficiency.

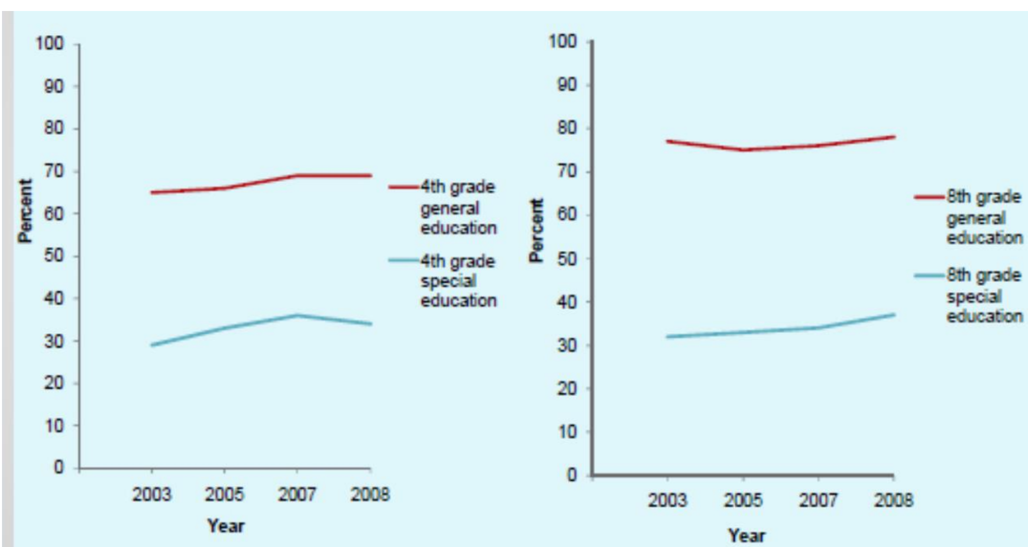

Figure II: Proficiency Rate in Reading (Special Education vs. Mainstream)

Today, students with disabilities continue to fall behind in reading proficiency, even when a student is provided accommodations or an alternative assessment altogether. In reading, the median percent of students proficient in their grade level continues to decrease after third grade. By the end of high school, only 25 percent have a reading level that is competitive to their peers. With modified standards, this percent increases to 54 percent. However, modified and alternative methods are not measuring the same grade-level standards. Table IV gives an overview of reading proficiency based on regular vs. alternative assessment during the 2013-2014 academic year.

Content area and student grade level	Regular assessment (grade-level standards)[a]		Alternate assessment[b]					
			Grade-level standards[c]		Modified standards[d]		Alternate standards[e]	
	Number of states	Median percent students proficient	Number of states	Median percent students proficient	Number of states	Median percent students proficient	Number of states	Median percent students proficient
Math								
Grade 3[fg]	48	36.1	0	—	9	49.1	52	71.1
Grade 4[hg]	48	34.4	0	—	10	56.1	52	71.2
Grade 5[ij]	48	27.4	0	—	11	56.8	50	72.6
Grade 6[kj]	48	20.1	0	—	11	51.9	52	70.6
Grade 7[ig]	47	18.5	0	—	10	46.5	51	70.2
Grade 8[kg]	47	16.8	0	—	11	37.5	50	70.6
High school[kl]	48	18.7	0	—	8	35.7	50	70.4
Reading[m]								
Grade 3[no]	48	32.1	1	—	9	62.2	52	71.0
Grade 4[po]	48	29.0	1	—	10	59.0	52	73.0
Grade 5[qr]	47	29.1	1	—	11	59.8	51	74.1
Grade 6[sr]	48	25.0	1	—	11	43.4	53	71.7
Grade 7[qr]	47	23.1	1	—	11	55.0	51	72.1
Grade 8[sr]	47	23.3	1	—	11	56.5	50	75.7
High school[st]	49	25.0	0	—	7	54.5	48	71.4

— Median percentage cannot be calculated.

[a]*Regular assessment based on grade-level academic achievement standards* is an assessment that is designed to measure the student's knowledge and skills in a particular subject matter based on academic achievement content for the grade in which the student is enrolled.

[b]*Alternate assessment* is an assessment that is designed to measure the performance of students who are unable to participate in regular assessments even with accommodations. The student's individualized education program (IEP) team makes the determination of whether a student is able to take the regular assessment.

[c]*Alternate assessment based on grade-level academic achievement standards* is an alternate assessment that is designed to measure the academic achievement of students with disabilities based on the same grade-level achievement standards measured by the state's regular assessment.

[d]*Alternate assessment based on modified academic achievement standards* is an alternate assessment that is designed to measure the academic achievement of students with disabilities who access the general grade-level curriculum, but whose disabilities have precluded them from achieving grade-level proficiency and who (as determined by the IEP team) are not expected to achieve grade-level proficiency within the year covered by the IEP.

[e]*Alternate assessment based on alternate academic achievement standards* is an alternate assessment that is designed to measure the academic achievement of students with the most significant cognitive disabilities. This assessment may yield results that measure the achievement standards that the state has defined under 34 C.F.R. section 200.1(d).

[f]No students in this grade were assessed in math by the Federated States of Micronesia, Kansas, or the Republic of Palau.

[g]Some students participated in a field test version of an assessment test in math in the following states: California, Connecticut, Idaho, Illinois, Maryland, Massachusetts, Mississippi, Montana, Oregon, South Dakota, Washington, and Wyoming.

Table IV: Reading Proficiency Based on Environment, OSEP (2016)

In summary, the reading proficiency for students with disabilities in special education services is largely unchanged. Students continue to be taught a prescriptive way of speaking and reading. This is confusing as there are many forms of standard English (see: Milroy & Milroy, 1985) which complicates who is being taught *what language* and under *what circumstance*. Once more, there is the question of what is truly right vs. wrong. In school, language is more clinical and straightforward. But in everyday conversation, the waters become murky.

Informal Dialogues

Foucault (1975) characterized schools as institutions of recruitment and divide, where knowledge is only transferred to specific populations and groups (Lasche, 1984). Thus, literacy has become stratified and divided into acceptable and unacceptable methods at work. It is the language beyond school, the informal environments of learning, that allow the necessary room for simultaneous growth and error. Beyond school, through play, activity, social interaction and community, students can find their own voice, their own language, and own way of expression.

The use of standard and non-standardized language in conversation is neither right nor wrong. Rather, language is formed based on circumstance and interaction. For example, a person who says *followin'* will regard the recipient of language as friendly and without need of deference. In contrast, the word *following* implies more formality and distance. While neither of these words are inherently wrong to use, they are viewed as inaccurate when situated in a specific context (Gee, 2015). Another example comes from the pronunciation of 't' vs. 'd.' Take the word coldcuts. Some individuals will pronounce this as [kolkats] while others [koldkats]. In school, the colloquial use [kolkats] is corrected for the standard English (Collins, 1989). However, outside of school, this expression is more widely accepted without correction. These differences in language may be subtle, but signify a major shift in the way children perceive their preferred way of communicating ideas. For students with disabilities, who already are placed in a position of social segregation and intervention services, the correction of expression only further drives apart the promise of inclusive practices.

From Dialogue to Reasoning

Informal dialogue sparks experimentation as children work together to establish common definitions (e.g. referring to a sea urchin as a "spike ball") and explore how these definitions take shape in their world (e.g. a sea urchin's behavior). The structure of language represents the metaphorical root of learning, where communication and words sprout into new ideas. Argumentation, the exchange and debate of what is communicated or believed, represents the first promise of growth. In this respect, argumentation is fighting both inward and outward, making sense of the world while communicating with the world, all while finding reason within it. An individual needs more than a standard task (e.g. an assessment) to form reasoning. When a problem is placed in an argumentative setting, such as when a single individual is prompted to express their own thoughts, reasoning, and ideas to others, argumentation forms (Mercer & Sperber, 2011). Thus, language and meaning are not enough. A deeper look at argumentation and how children not only communicate information using language, but mutually deconstruct information in order to make sense of their surroundings, is crucial to understanding how students situate their own thinking with others.

Argumentation

The building blocks of language set the foundation of argumentation. Children begin by learning information and parroting back what was learned (e.g. "That's a dog." and "Dog!"). From there, adults question declarations and ask children to provide examples of their case (e.g. "How do you know that he's a dog?" followed by "He barks!"). This is no different from the practices children see and respond to within their classroom community (Braaten and Windschitl, 2011). We ask children questions early and often to prepare them for the educational system and to strengthen language development. Thus, just as language development begins at home, so does the justification of expression and ideas.

The meaning behind our words are interpreted (and reinterpreted) by our past knowledge (Berk & Winsler, 1995; Tippett, 2009). The mutual understanding of material becomes truth. For example, individuals will identify a *cup* as a vessel that holds water. However, bowls technically hold water. The difference between these words is situated in the shared definition and meaning. As Nietzsche (1980) writes:

> What then is truth? A moveable feast of metaphors, metonymies, and anthropomorphisms; in short, a sum of human relations which have been poetically and rhetorically intensified, transferred, and embellished, and which after long usage, seem to a people to be fixed, canonical, and obligatory. Truths are illusions we have forgotten are illusions; they are metaphors that have become worn out and have been drained of sensuous force, coins which have lost their embossing and are now considered as metal and not as coins. (p. 20)

These structured thoughts become important as society builds, counters, and reconsiders another person's claim. Claims serve as the beginning root to arguments, and arguments are central to shaping any specific discipline or field (Andrews, 2007). The word *argument* is defined as an interactive process and communicative act, where a person is putting forth a claim, thought or belief. This is different from *argumentation*, a social process where individual *arguments are chained together*. Arguments are a way for individuals to engage in cognitive conflict and immerse themselves in the negotiation process. This cognitive conflict is resolved when individuals come together to actively voice their (dis)agreement. The (dis)agreement becomes a learning experience (Baker, 2003) that strengthens argumentative behavior through the process of social interaction. The goal of argumentation is not to necessarily end in agreement. Rather, to build a mutual understanding of the issue(s) at hand. Argumentation, dubbed by Duschl, Ellenbogan, & Erduran (1999) as the language of science, gives rise to conceptual growth (Wegerif, & Sams, 2004; Nussbaum & Sinatra, 2003). The following review briefly describes the role an educator, student and school play in the activity of arguments.

Argumentation and School

Duschl, Schweingruber, and Shouse (2007) described the interpretation of scientific explanation of the natural world, the evaluation of scientific evidence, the understanding of scientific knowledge, and the participation of scientific practices and discourse as key elements for students to master in classrooms today. When students choose to engage in these scientific practices, their ability to construct, evaluate, and reconsider declarative statements becomes stronger. For example, in scientific classrooms where a student makes a declarative statement about something (e.g. claim), classmates may question, defend, or otherwise revise it (Berland & Reiser, 2009; Osborne & Patterson, 2011). Similarly, students will come together to resolve inconsistencies in the explanation, identifying weakness in arguments and drawing from multiple sources of information in order to arrive at the explanation that best fits the evidence before them (Berland & Reiser, 2009). In school, educators must build an environment that does not motivate students to seek accuracy, but to reconcile differences and search through multiple options (Reiser, Berland & Kenyon, 2014) to understand material (Sutherland et. al, 2006). From this, argumentation is not simply a verbal exchange, but a culmination of information gathered by discourse and action. For example, students who individually construct models will come together to evaluate and revise them as a collective. Figure III**,** taken from Reiser, Berland and

Kenyon (2014) demonstrates how argumentation - the debate of whether "coldness" is an actual word - ultimately led to a consensus of how to best articulate their findings to others.

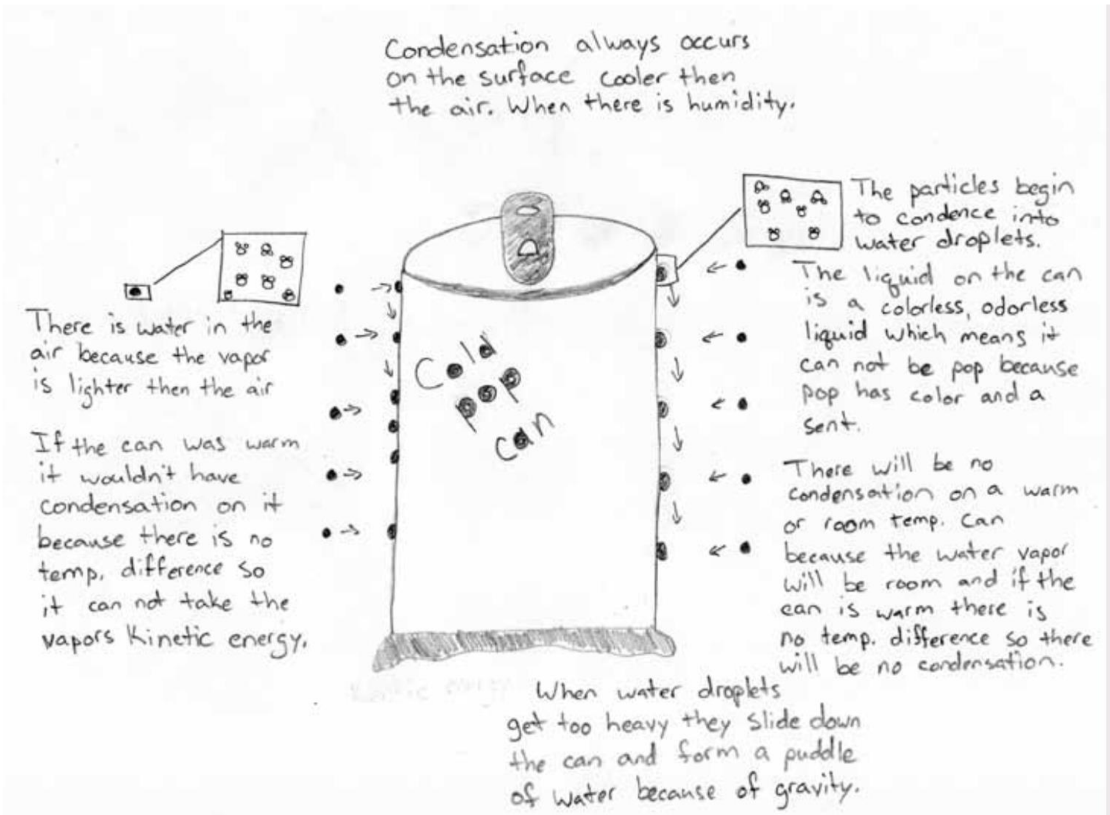

Figure III: Model to Construct a Scientific Idea (Reiser, Berland and Kenyon, 2014)

Argumentation holds a natural connection to science education (Newton, Driver, and Osborne, 1999) because it requires students to seek evidence and collaborate on activity. Kuhn (1999) saw argumentation as a gateway between the informal thinking of students and the formal thinking of scientists. The ability to strengthen argumentation skills, neutralize social status through argument discourse (Mercer et. al, 2004), and deepen knowledge in scientific matter (Nussbaum & Sinatra, 2003) represents why scientific argumentation has become popular in recent years. However, the role students play in this activity is highly dependent on both instructor and classroom environment. While the opportunity to engage in peer-to-peer debate can lead to constructive feedback of material learned, the demand for completing science standards can run counter to such activities. For example, students asked to write a letter to scientists may structure the assignment to reflect what s/he believes the teacher wants (Spinuzzi, 1996), rather than what may persuade a scientist (Berland & Hammer, 2011; Coffey, 2003). In short, student argumentation is influenced not by the application of their own scientific frameworks or ideas, but through explicit instruction and anticipated outcomes for academic success. The following paragraphs take a closer look at the teacher's role in scientific argumentation in classrooms today.

Educator's Role in Argumentation

Scientific argumentation is supported by psychologists and educational researchers (Kuhn, 1993; Siegel, 1995; Driver, Newton & Osborne, 1999; Berland & Reiser, 2009; Berland & Reiser, 2011) as a needed activity in school. Argumentation is important to encourage because a) learning is a social activity and b) it encourages students to coordinate their own perspectives with another party. This process, sometimes known as 'mutual bootstrapping' (Kohlberg, 1998) leads to the construction of new ideas and meanings. However, argumentation in the classroom setting is not an easy process and often depends on teacher involvement (McNeil & Pimentel, 2010; McNeil & Knight, 2013; Sampson & Blanchard, 2010) or driven by explicit instruction (Grooms, & Walker, 2011; Schworm & Renkle, 2007). In science and elsewhere, peer-to-peer interaction becomes secondary to algorithmic textbooks (Chinn & Mailhorta, 2012) and teacher-driven curricula (Lemke, 1990; Simon, Erduran & Osborne, 2006). Many educators continue to sidestep argumentation activities because they feel unprepared to change their classroom practices (Sampson & Blanchard, 2012) or have the leeway to embed argumentation activities within the context of standardized material. In the wake of national assessments and exams, the time, energy and resources needed to invest in argumentation is little.

Educators, now realizing argumentation is on the back burner of classroom preparation, are working to design professional development opportunities to help teachers rejuvenate conversations of debate. These opportunities include teaching educators about explicit strategic questioning (Gillies & Haynes, 2011), strengthening communication skills (Gillies, 2004), creating more open-ended tasks (Cohen, 2004), and facilitating cooperative learning opportunities (Gillies & Boyle, 2008). In doing this, our system hopes children will become more critical thinkers as they are introduced and immersed in challenging material.

However, there is *no requirement* that argumentation be teacher-driven. The proposed structures of argumentation largely assume teachers will maintain a leadership role in their classroom environment. Educators who rely on traditional forms of instruction (e.g. lecture) could overlook possible opportunities for students to engage in peer interaction and feedback. Only now are teachers, particularly those who forfeit their leadership role in exchange for more cooperative learning opportunities, recognize the power of small group activity (Slavin, 1995). Mainly, that children can and will learn from each other.

Student's Role

The interaction and learning experience elicited by open dialogue in peer-to-peer conversation has proven effective across many subjects, including mathematics (Kramarski & Mevarech 2003), psychology (Peterson & Miller, 2004), and history (Deaney, Chapman & Hennessy, 2009). By encouraging students to work collaboratively to understand material without the formal guidance of an educator, schools provide an open space where students can be critical agents of learning (Freire, 1970). As one student explained (Ahn, 2011):

> "Working in a group to construct knowledge for all of the participants changed my assumptions about the learning process in general and students in particular. I began to realize that everyone could be successful when we worked as a team and that each of us had something unique to contribute. Some were strong question writers, others had near photographic memory of details in the text, and everyone brought different vantage points to bear in synthesizing the course material. I am a strong student, yet I learned as much, if not more, from my peers as I did on my own during the activity." (pg. 30)

While not every person walks away from an experience with shared learning outcomes (Crowley & Jacobs, 2002), the tinkering and exploration (Halverson & Sheridan, 2014) of artifacts encourages individuals to re-think dialogues.

The initial team interaction is crucial to providing members the opportunity to establish commonalities, understand expectations and adapt to group behavior. Over time, team members use implicit communication and action to accomplish tasks. This shift "frees up" cognitive energy (Johnson, Khalil & Spector, 2008) that is otherwise devoted to creating new channels of group understanding. By achieving shared cognition (Sales & Cannon-Bowers, 2000), group members work more smoothly and efficiently in their environment (Guzzo & Salas, 1995; Cannon-Bowers & Salas, 1998).

Argument construction is not an automatic process learned. Like the shift from vernacular to specialist language, argumentation represents a skill discussed widely in academic circles but rarely fostered in academic environments. Even in higher education, students who have mastered vernacular language and the academic system struggle with finding ways to appropriately structure an argument. As Anderson (2007) writes:

> "In such a system, it is assumed that something magical will happen in the student's mind and that it will be expressed in perfect argumentative form in writing submitted for assessment. The argumentation is assumed to inhere in the very nature of the discipline;

> that it to say, the way disciplines are constructed, with debates and inductive reasoning taking place in Literature studies about, say, the treatment of Ophelia by Hamlet." (p. 5)

The question here is not whether argumentation is happening in schools per se, or if good argumentation is happening for that matter, but how argumentation is being assessed by the academic system. In school, arguments must be structured in a specific way, with specific words and topic sentences used to guide the person's idea. For example, a child who says "It moves because that pull-y action makes the earth move" is referring to gravity. However, because the correct definition is not offered, their argument is perceived as insufficient. The following section briefly outlines current research on scientific argumentation in formal learning environments.

Argumentation Research in Formal Environments

The application of scientific arguments within the classroom environment by students is surprisingly rare (Banilower et al., 2013; Osborne et al., 2016) due to limited opportunity (Roth et al., 2006), particularly when assessment-based practices are used to measure success. The difficulties in learning how to build an argument are further compounded when science education is taught as a series of facts and figures, not ideas to be coordinated and argued upon (Weiss et al., 2003; Nasir et al., 2006). As a result of using standardized practices to track student progress in argumentation, some educators have limited pedagogical knowledge of how to build and encourage authentic scientific argumentation through inquiry. Students are therefore not actively engaging in curricula that generates critique. Henderson et al. (2015) argued that if the construction of scientific critiques by students is expected in school, then curricula must be restructured to support the building of this skillset. This may explain why research on scientific argumentation in schools is largely focused on the educator's role in cultivating this skill (Kelly

& Chen, 1999; McNeill & Krajcik, 2008; McNeill & Pimentel, 2010; Simon et al., 2006) and less on student-driven construction.

Literature that focuses on scientific argumentation among students within formal learning environments concentrates heavily on language construction or educator-driven practices to strengthen argumentation discourse at school (Rodriguez & Duschl, 2000; Sampson & Clark, 2011; Sandoval, 2003; Sandoval & Millwood, 2005). However, some literature also considers community differences in interpretation and design. For example, Berland and Reiser (2009) found that student groups placed different levels of emphasis on elements of scientific argumentation that were internally coherent but nevertheless different from group to group. That is, some groups approached arguments as standalone discussions, while others approached them as connected ideas. The co-construction of these arguments and how they shifted over time ultimately varied by group dynamic and discourse.

While the landscape of scientific argumentation in formal learning environments continues to grow, how youth tackle and engage in scientific argumentation outside of schools is less known. The following section briefly describes argumentation within informal environments along with modern studies.

Argumentation Research in Informal Environments

Arguments happen in everyday life (Toulmin, 2003), between groups, between individuals, inside and outside of school. Cognitive elaboration as a strategy for understanding and communicating material (Slavin, 1996) is not bound to a particular environment. Despite this, how students learn about argumentation is largely school-based (see: Berland & Reiser, 2009; Berland & Reiser, 2011). One location where research on the building of scientific reasoning and argumentation within informal environments can be found is in the virtual world.

In a study by Steinkuehler and Duncan (2009), game communities used discourse to form arguments, offer counterarguments, and propose new models. Other scholars see the formation of communities as a way to create a "collective intelligence" (Levy, 1999), where individuals collect and distribute information to a larger community for consideration without actively engaging other members in argumentation. However, the role scientific argumentation plays online or through recreational means is largely unknown.

This is not to suggest that scientific argumentation is inactive outside of classroom environments. In fact, scientific content is easier for students to understand and construct arguments around when the subject matter is situated in an everyday context (Osborne et al., 2004; Osborne et al., 2016). As Dewey (1897) noted, good education comes through life experience and is not confined to one location. This is why bridges between home and school to encourage academic play (Steinkuehler, 2008) are needed. Just as importantly, the behaviors and actions surrounding argumentation outside of traditional environments are also key. Whereas argumentation and language are building blocks to learning material, persistence helps to reshape, redefine, and reorganize this material for an individual's purpose. The following section will highlight the inherent benefits of persistence in education, particularly for students with disabilities.

Persistence

Social emotional learning (SEL) is a process through which individuals gain competency in self-awareness, self-management, social awareness, relationship skills and responsible decision making. High SEL is linked to increased emotional resilience, reduced aggression and stronger academic performance (Zine et. al, 2007; Elias et. al, 1999; Ross, Powell, & Elias, 2002; Wilson, Gottfredson, & Najaka, 2001). Today, SEL is a growing topic in schools (Elias, 2004;

Elias et. al, 2000; Zins, 2001), with the fostering of positive development in youth serving as a focal point for individuals with disabilities. Students with specific learning disabilities (SLD) experience increased anxiety, more depressive symptoms and have difficulty with social problem solving (Teglasi & Meshbesher, 2004; Al-Yagon, 2007; Lackaye & Margalit, 2006) as well as trouble managing SEL skills (Bryan, Burstein, & Ergul, 2004; Elksnin & Elksnin, 2004; Gresham, Sugai, & Horner, 2001; Kuhne & Wiener, 2000; Romasz, Kantor, & Elias, 2004; Elias & Tobias, 1996). Thus, finding ways to build SEL skills and persistence is crucial, particularly for students pushed against a system that does not conform to their natural way of expression and communication. This literature review briefly describes how students with disabilities encounter an educational system that does not always fit their needs and how these same students must persist in the wake of social isolation, repeated failure, and attempted success.

Motivation

An individual who attributes a successful outcome to their own abilities will have positive motivational consequences. In contrast, an individual who attributes an unsuccessful outcome to their own abilities will have negative motivational consequences (Weiner, 1985). The self-assessment of capabilities (Marsh, 1989) and expectancy of how someone may perform on a subject (e.g. math, music, art) can impact children as early as 1st grade (Eccles et. al, 1993). In fact, an individual's perception on performance outcomes in an academic domain - like math - can strongly predict whether someone will (or will not) choose to pursue that subject long-term (Wigfield & Eccles, 2002). Successful individuals will continue to work in domains that require them to overcome challenge and build upon their current skills. However, an unsuccessful individual with a fixed mindset will forgo environments of challenge and instead situate themselves in a routine that leaves their talents largely untapped (Schmitz & Skinner, 1993). This impact is not only a tremendous stress on the student, who begins to fall behind in their studies, but becomes a point of contention for the educator, who may perceive the lack of effort on the student's part as a behavioral problem (Skinner & Belmont, 1993).

Motivation is fueled by engagement. Emotional engagement (e.g. enjoyment, enthusiasm, vitality and zest) are pinned against emotional disaffection (e.g. boredom, anxiety, frustration and self-doubt). These two spheres have a strong relationship with academic outcomes and school retention (Connell et. al, 1995; Roeser, Strobel & Quihuis, 2002). Hence, student interest and emotions sustain their participation in learning activities.

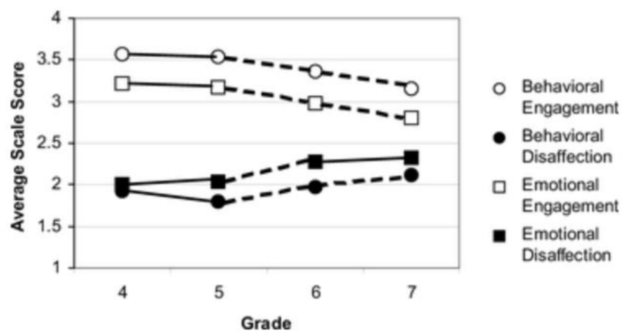

Figure IV: Behavioral and Emotional Changes by Grade Level (Skinner et. al, 2008)

As such, our schools need active and innovative strategies for engaging students that does not rely on traditional methods of instruction. Based on the educational system's current trajectory, traditional methods may amplify self-doubt in the very students who are already struggling to maintain their academic career in the system (Skinner et. al, 2008). At present, many of these individuals do not feel like achievers, but are surrounded by feelings of doubt and failure.

Failure and Defeat

Children learn when they are challenged, when there is social activity, and when they have the opportunity to practice self-discipline. The mainstream environment is a place of challenge and encouragement. While not perfect, mainstream education does offer many of these characteristics on a regular basis. However, mainstream education is also driven by standardized assessments. A student who cannot regularly complete homework assignments and/or pass standardized assessments will experience an academic career filled with repeated failure (Whyte, Saks & Hook, 1997), deficit mindsets, and learned helplessness (Margolis, McCabe & Alber, 2004). The ultimate consequence of underachievement in today's academic system is being placed in remedial services (Elliot & Dweck, 2005), an environment that does not resemble or remind students of the mainstream education they left behind.

Students within the special education system feel the ill-effects of repeated failure, undergo constant surveillance, become documented, tracked, corrected, and in many cases introduced to an academic toolkit that is viewed by educators as immensely helpful, but to students wholly foreign. Our schools ask these same students to then prosper under conditions where challenge and expectation are rare, but the imitation of academic success is high (Tabassam & Grainer, 2002). This is not an environment design to instill confidence or foster motivation. Rather, we have developed a system that removes self-driven interest, belonging, and passion, thereby guaranteeing an outcome of academic struggle (Dweck, 2000). Ironically, special education perceives this environment as free and appropriate as dictated by IDEA.

Special education (and remedial coursework, for that matter) is not a system designed for self-discipline or tenacity. Remedial support is not even about creating a high-performing student in the mainstream setting. Rather, remedial coursework is designed to provide students with the bare minimum. That is to say, students with disabilities, those from culturally diverse backgrounds, and students who cannot successfully pass exams, find themselves in a position where talents and pursuits are exchanged, in many cases barred away, for the sake of developing a student who is like everybody else (Dalsen, in review). Growth mindset and tenacity is not about success time and time again. Tenacity grows from challenge. Remove this, and educators are creating a fixed mindset environment (Dweck, 2010).

Educators want to encourage students to succeed but are placed in a position where academic measurement works against academic tenacity. As Chicago teacher Will Okun (2008) writes:

> While remedial classes do enhance basic skills, few students sufficiently progress academically to ever return to their appropriate grade level courses. As a result, students enrolled in remedial classes rarely achieve the course requirements for graduation. Plus, I believe that hardworking students like Etta are capable of greater academic advancement in grade level classes with high(er) expectations as compared to the low standards of remedial programs.

Dweck (2010) acknowledged the struggle surrounding achievement and grades. She stressed that grades represent the handwork and effort students put forward in their assignments, and are not meant to be a ‘consolation prize.’ Meaningful work, where the student is aware of their own actions and the actions of those around them - promotes learning not only in that immediate situation, but creates a stronger resilience in each child long-term. However, this means academic tenacity cannot be centered on self-esteem *or* the reward of high grades. Instead, something more needs to drive children to independently pursue the next level of their academic career.

Building Academic Tenacity

A student is not guaranteed academic success simply because they feel good about their abilities in school. The failed self-esteem movement of the 1990s demonstrates how building tenacity requires a student to move past their comfort zone and actively engage in challenges that require strategic effort, endurance, and ability to persevere in the wake of failure. Academic tenacity is not about accomplishing an assignment or resolving a short-term challenge. Instead, academic tenacity is looking ahead to the future and understanding that long-term goals demand effort and dedication.

The key characteristics and behaviors of a student who is academically tenacious include but are not limited to the following: someone who feels they belong academically and socially in school, someone who postpones immediate pleasures in exchange for work, a person who remains engaged, someone who seeks out challenge, and an individual who will continue to work despite setbacks (Dweck, Walton & Cohen 2011). This is the environment described in mainstream education but hidden from special education services. As Dweck, Walton, and Cohen (2011) wrote:

> "*Two students with equal academic abilities can respond in remarkably different ways to frustration, with one relishing the opportunity to learn and the other becoming demoralized and giving up*."

Dweck (2015) is concerned that educators are linking academic tenacity and growth mindsets (see: Dweck, 2000; Blackwell, Trzesniewski & Dweck, 2007; Dweck, 2008; Chan 2012; Yeager & Dweck, 2012; Boaler, 2013) to feeling good about yourself. This is the not the case. A student who feels good about their abilities, or is confined to an environment where their abilities are tested but not challenged, will end up having less tenacity when compared to the student who actively struggles in a more complex environment (Mueller & Dweck, 1998). At present, special education is not challenging students but instead following a too-narrow culture of compliance (Special Education Commission Report, 2002) that substitutes the learning of students for the obligation of framework.

Literature Review Summary

Students with disabilities are historically disconnected from academic and social participation in school. This academic landscape has resulted in higher expulsion rates, behavioral interventions, and assessment-based practices. In the classroom, a student's language structure is boiled down to a correct or incorrect response. Here, learning as a complex process is embodied by assessments over discourse, action, and differences in expression. Language variation is substituted for academic standards that are tested, re-tested, and recited through weekly activity. Students who cannot meet academic objectives and goals are ultimately separated from their peers. These same students are asked to build academic persistence under a framework of isolation while simultaneously combating pre-established activities and beliefs.

Standardized assessments leave no room for experimentation in the special education world. Instead, educators operate on a deficit mindset where academic measures take priority. The ability to communicate and demonstrate skills is largely untapped within this current structure. But imagine an alternative place where students with disabilities can express their thoughts, demonstrate their knowledge, and build persistence. In this place, experimentation and collaborative activity serve as a valuable platform for learning. Today, games-based learning provides educators with an alternative way to monitor progress while affording students the opportunity to build new skills - like argumentation - outside the confines of academic language. The critical building of new skills and strategies is important for all students, particularly those diagnosed with disabilities, in their academic journey. Thus, creating an alternative environment where language construction, expression, and joint activity builds persistence is key.

This dissertation examines the co-construction of scientific concepts among students with and without disabilities within the context of an informal gaming environment and how gameplay is used to build scientific arguments. The data collected for this study will reflect the same methodological framework typical of an IEP meeting: a combination of qualitative (*discourse*) and quantitative (*argumentation code*) analyses. This dissertation also harnesses educational data mining techniques to situate dialogical learning in a quantifiable and scalable way, while preserving the nuances of discussion. The following paragraphs describe this data collection and analysis in detail.

Chapter 3: Methodology

This dissertation seeks to merge qualitative and quantitative data streams from middle school students with and without disabilities during gameplay in order to better understand the construction of scientific ideas. The following paragraphs outline the designed curriculum, game, and logistics of the study in further detail.

Design Background

The Games+Learning+Society (GLS) is an organization where researchers, video game developers, and industry leaders meet annually to discuss the social impact of gaming culture. Located at the University of Wisconsin-Madison, GLS has partnered with local and national organizations to forge relationships with academic leaders, leverage practices from academic-based research, and translate learning goals through gameplay experiences.

GLS researchers collaborated with curriculum designers and local educators to enhance games-based learning opportunities. Here, the objective of game and curriculum design was not to regurgitate facts, but to immerse students in a learning environment where one can explore and express their voice further. GLS also worked closely with the Learning Games Network (LGN) to design multiple educational games. Games developed in-house included Anatomy Pro, Econauts, Fair Play, and Virulent. Virulent represents the first game developed by LGN and GLS on iPad and was center of a 1.5 million dollar NSF grant awarded to the organization in 2011.

Virulent

Virulent is a game designed to introduce players to virus and immune system behavior. Roleplaying as the fictional Raven virus, players must attack the immune system and steal precious resources in order to invade the body. Each level becomes increasingly complex as players are introduced to new aspects of the microscopic world. Verbal instruction (from the perspective of the Raven Virus) and written instruction (located on there right-most corner of the tablet screen) provide players with feedback on their next course of action. If the player goes too long without making a move, or completes an action that is required, the voice over will provide additional guidance. Figure V shows an example of instructions that accompany a level.

Figure VI represents a screenshot of the game in action. The first panel shows the vision exiting the budding site in Level 1. The second panel shows an advanced level of *Virulent*, where the player is completing virus replication.

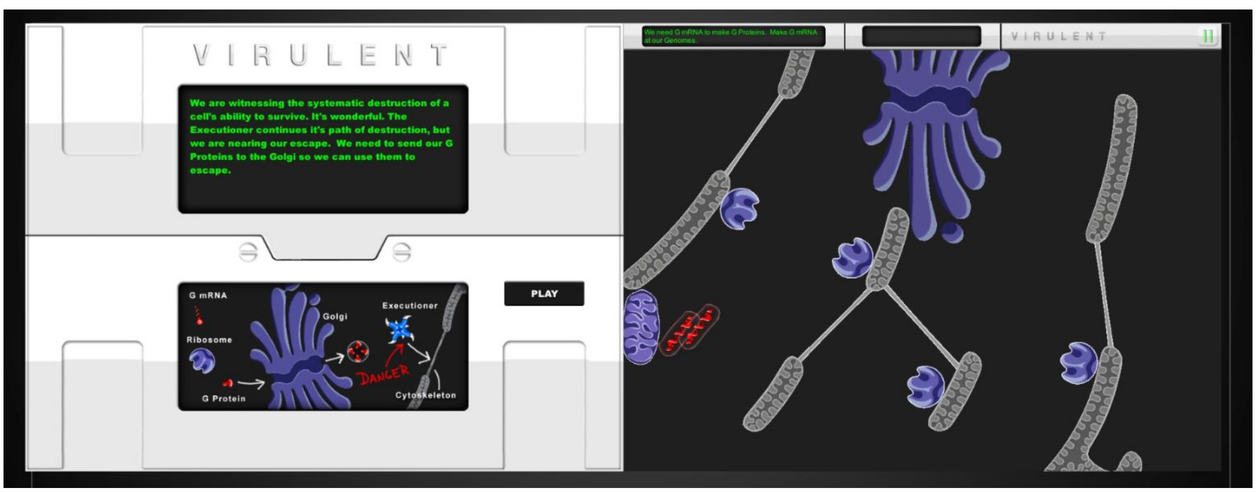

Figure V: Screenshot of the Game *Virulent* (Right Side) with Directions (Left Side)

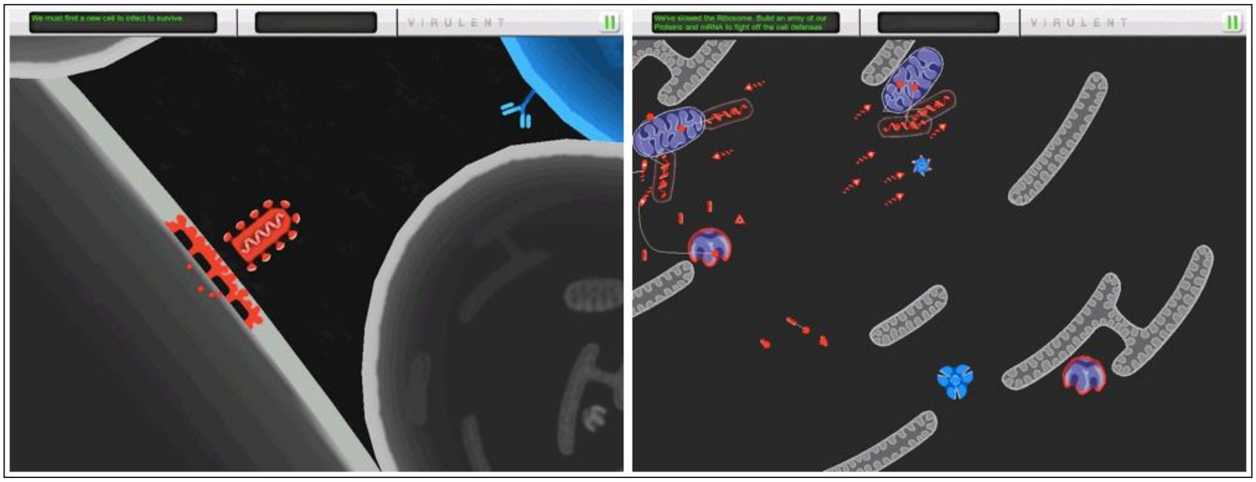

Figure VI: Screenshot of the Game during Level I and Level VII

A main goal of Virulent is to demonstrate virus replication. In order to accomplish this, the game developers designed the levels to represent a cyclical process. At the end of the final level, the player finds their virion is once more back at the budding site, thus linking all their actions throughout the game back to the first level. Figure VII is a screenshot of the levels.

Figure VII: Virus Replication as shown on the Level Screen

A graphical encyclopedia of virus and immune system components - named the Almanac - allows players to reference items as they go through each level. A component would only be accessible if the player has seen that item before during gameplay. To make information easier to understand and identify, the game developers made virus and immune system components different colors. Red represented anything linked to viruses whereas blue represented anything linked to the immune system. Items that are purple, gray or black are considered "neutral" and are therefore placed in the "other components" category. A screenshot of the almanac is found in figure VIII.

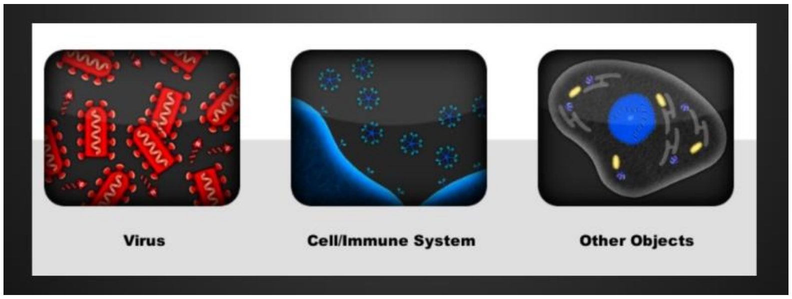

Figure VIII: Almanac Guide Example

Curriculum Structure

Gameplay is a designed experience (King & Borland, 2003; Squire, 2006) where situated understanding, identity, and the coordination of ideas has the potential to grow (Gee, 2004). Games are also sociotechnical networks (Squire, 2004) where different players come together to share in an experience. The following paragraphs highlight the various elements used to construct these communities within the informal games-based learning camp. These include forming a roleplaying activity where students become scientists, an outline of each day's events, and room setup.

Roleplaying Activity

Participants role-played as scientists recruited by the Center for Disease Control (CDC) to stop the Raven virus from reaching global pandemic. Participants in each cohort were divided into "research teams." Each "researcher" was given a tablet or "digiscope" to investigate "microscopic slides" (game levels). In addition, every participant was given a labcoat and clipboard with scratch paper to record their scientific observations along the way. All created artifacts and projects were peer-driven with the underlying context that synthesized information would help inform their group and the CDC on virus behavior. Before the start of each day, cohorts watched pre-recorded Skype videos sent to them from mock CDC scientists. These videos provided participants with key information on virus behavior and development. Figure IX is a screenshot of one of the pre-recorded Skype calls. On the right, a map showing the infection rate of the Raven Virus on a global scale is shown. This infection rate climbs with each passing day. By Day 5, the CDC becomes infected by the virus, thus adding another level of urgency to finding a cure (see: Appendix A).

Figure IX: Mock CDC Scientist Skype Call

In order to add a more realistic twist to the CDC Skype calls, the curriculum actors tailored their messages to reflect information that specific group members discovered during the day. For example, the scientists would note “X group” had observed a particular behavior of the Raven Virus and had shared this information the previous day to the larger cohort. Only information that was previously shared by other groups to their larger cohort was communicated, with the remaining information kept private until each of the “research teams” chose to report their findings.

Day Events

The first day of the curriculum was spent introducing our participants to the *Virulent* game. Participants watched a Skype video from mock CDC scientists, investigated “microscopic slides” as a group and wrote down preliminary findings on their worksheets. Each participant was given a labcoat, clipboard, and a “digiscope” to support their investigation. All participants also received a unique “research badge ID” or QR code to log in to their device. While the facilitator offered preliminary guidance to participants in terms of device setup and narrative, all activities were student-driven. On the second day, participants constructed paper-based models of virus and immune system behavior. Available resources for model making included markers, crayons, coloring pencils, tape, and sticky notes. However, individuals could use other resources (e.g. colored paper) and reference gameplay strategy to inform their model-making process. There was no template for participants to work from in this project, and no requirement that groups needed to restrict their model to paper. Group models were revised and shared through self-produced videos on the third day. The fourth day was an opportunity for groups to share results with other “research teams.” The cohort presentations required each group to present a 5-8 minute showcase of what they had learned so far. All audience members were given scratch paper to write down what they liked best about the model and what questions (if any) they had following the conclusion of the group’s work. At the end of each presentation, other cohort members were given an opportunity to share their thoughts on the model. The day ended with an “emergency” call from the CDC scientists, who were now infected with the Raven Virus. On this day, the CDC scientists reiterated the importance of finding a cure, before the video abruptly ended. Participants were briefly asked what they believed was happening at the CDC, however no further information or verification of a Raven Virus infection was announced. On the final day of the curriculum, participants were offered three hypothetical solutions for stopping the

Raven Virus from reaching global pandemic (create a vaccine, an RNA inhibitor or Mitochondria inhibitor). Participants read and analyzed information from fictional excerpts as a way to better inform their decision. Each group chose a single option and presented their case to the larger cohort. The day ended with a cohort vote on which option they believed would end the Raven Virus altogether. A complete list of curriculum activities and structure is located in Appendix A.

Room Setup

Each group had their own room in which to play *Virulent* and create artifacts. A separate room was chosen for each group to minimize noise, create an opportunity for students to engage with group members in a "research lab space," and to control for possible group members overhearing or copying the conceptual frameworks of other groups early on. Each room had six chairs, a round table, and office supplies available for the participants to use.

Game and Curriculum Choice

I chose to use games-based learning for this dissertation because it provides students with and without disabilities an equal platform for learning without the pressure of academic performance within the confines of a pre-established school system. I selected the game *Virulent* for several reasons. First, the game and curriculum adheres to current science and other academic standards.[2] This is important as games-based learning opportunities should be connected to present day policies and academic standards. Second, the curriculum requires players to apply knowledge from the game through hands-on activities. In this research setup, gameplay serves as a tool for encouraging the production of scientific artifacts, discussions, and ideas. Third, the curriculum and game are designed to elicit social interaction among peers. Finally, the overall curriculum and game requires students to learn new scientific terms. However, these terms are

[2]Standards met: (MS-LS1-1), (MS-LS1-2), (MS-LS1-3), CCSS.ELA-Literacy. RST.6-8.8), (CCSS.ELA-Literacy.RST.68.9), (CCSS.ELA-Literacy.RST.11-12.3)

not taught to students from the beginning. Technical words are introduced over the span of several levels, and while facilitators may pose questions about the vocabulary to players, there are no direct instructions or assessments that require individuals to memorize these words. Thus, students must independently process, articulate, and determine each word, each meaning, and each action, within the context of play. This environment allows students the opportunity to shift freely from vernacular to specialist language, from claim to argument, and from follower to leader, without being instructed to do so.

Facilitator Role

A main facilitator was pre-selected for each group in the camp. The facilitator held three primary responsibilities. First, to ensure all students were equipped with the necessary resources to participate in the session (e.g. working tablet, QR code). Second, to briefly summarize the information students learned following the call from the CDC. Third, to monitor the learning environment for any unexpected challenges (e.g. two students fighting). Facilitators also gave students a time check roughly every 25 minutes and offered guidance on time management when the session was nearing an end (e.g. “You have ten more minutes before the cohort debate. Has everyone decided what option is best?”).

A secondary or “floater” facilitator was also available for each group in this study. The second facilitator would move across different groups in the camp and stay within any given room for roughly 5-10 minutes. The two primary responsibilities of the secondary floaters were to check on whether the group ran into any technical issues that required assistance (e.g. no charger available) and to communicate camp-wide messages that may affect the group (e.g. “Everyone needs to meet in Hall C for the cohort debate”).

Both the primary and secondary facilitator could support a student during moments of play by asking them what strategy or approach they were planning to take. However, facilitators were instructed not to provide scientific definitions, tell the participant how to complete a level in the game, or grade students on scientific accuracy. All facilitators went through a 60-minute training prior to the event to outline these responsibilities and expectations in detail.

Positionality

Research is a shared space, shaped between researcher(s) and participant(s) (Bourke, 2014; England, 1994). It is therefore important to discuss my identity and its potential impact on the research conducted in this study. During my K-12 education, I always participated in mainstream classroom discussions and occasionally in extracurricular activities. However, many of my friends with disabilities did not share in this experience, either only participating in mainstream classrooms for a couple hours or being separated from their peers for the entire duration of the school day. This shaped my perspective on how formal education addresses student needs. I found that students with and without disabilities only interacted during brief moments in the day, many times during assembly or play. It was play that resonated most deeply with me because it was informal, peer-driven, and without the same structured labels that educators had placed upon students in the building.

Following graduation, I continued to seek opportunities to support students with disabilities. However, many students felt disempowered to pursue postgraduate experiences because they were uncertain about their ability to work alongside others and/or did not share the same social support as their peers. When put together, these experiences shaped my initial thoughts on disability, social support, and education.

In this study, I served as both the primary data collector and a group facilitator. I do not have a formal undergraduate degree or certification in teaching. I also recognize my background knowledge and experience in disability studies could impact my observations. It's possible that my expertise affords me an opportunity to both identify and address disability needs within a group. I also have the background knowledge to help address disruptive behavior, such as giving a student space or recommending an alternative activity. However, this knowledge was not shared widely with other group facilitators in the camp. As a result, my direct interaction with students would likely differ from other facilitators.

I took steps to check for accuracy of the dataset throughout data collection and analysis. I conducted member checks with group facilitators at the end of each day through a 30-minute debrief session. I also verified information by comparing facilitator notes and checking with group leaders to verify information about a participant's activities during analysis. I also helped transcribe the talk audio, which helped strengthen my understanding of the group's conversation and its changes in dialogue over time. As a researcher and disability advocate, I acknowledge bringing my own beliefs about education into this dissertations study. I also recognize how these beliefs shaped my approach, interpretation, and analysis of the dataset. Further limitations regarding this study are discussed in Chapter 5.

Data Streams

A pre-assessment of biology content and scientific interest was administered to every participant prior to gameplay. The biology pre-assessment took place online and the scientific interest assessment was done through paper-and-pencil. All individual, group and cohort conversations were captured using lavaliere USB recorders. Photographs of model construction were collected and scanned following Day 2 - Day 5. All paper worksheets (Day 1, Day 4, Day

5) were collected and scanned into a secure BOX file. This collection included all scratch paper and student notes. Facilitator observation notes were collected at the end of each day. The lead facilitator, along with a handful of volunteer participants, independently completed recall interviews. A post-assessment was administered at the end of the final day to determine scientific gains in biology content. A further description of the data streams is found in Figure X and Table V.

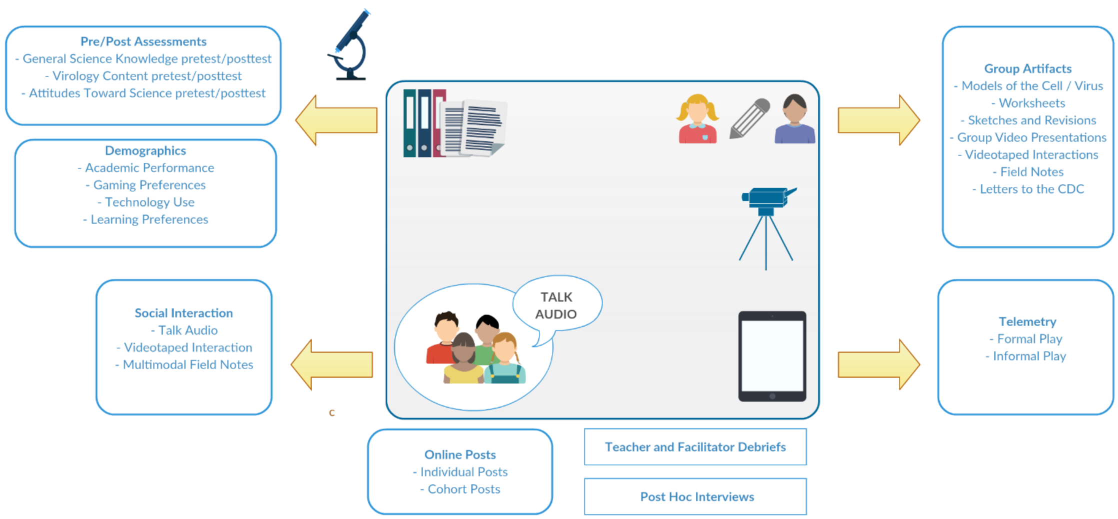

Figure X: Setup of the Curriculum Room

Day	**Activity**	**Description**
1	Virus Worksheet	Label virus and immune system components as they emerge in the game.
1	Letter to the CDC	Each research team wrote a letter to the Center for Disease Control to present their initial proposal on how to stop the Raven virus from global pandemic.
1-5	Online Portal	An online portal allowed students to access, write and post messages to each other outside of structured activities.
1-5	Telemetry	Each participant received a unique QR code. In order to access the game, participants needed to scan the code and login. All information from gameplay was recorded (e.g. number of levels attempted, number of levels completed).

Day	Activity	Description
1-5	Talk Audio	All participants received a USB recorder. Each day, participants turned the recorder on at the beginning of the session. The portable nature of the recorder allowed students to move it freely around with them as they transitioned from one activity to another, or one conversation to the next.
1-5	Facilitator Debrief	Every facilitator recorded observation notes and debriefed with the lead educator that day. Observation notes included student behavior during gameplay, peer interactions, use of tablet, conversation during model making, and other observations specific to the group's dynamic / progress.
3	Video Presentations	Every group recorded a 5-minute video for the CDC. In this video, group members explained what they had learned thus far about the Raven Virus, showcased their model, and proposed any new solutions they had for stopping the virus in its tracks.
4	Peer Feedback	All participants provided peer feedback on group models via a worksheet. Participants were encouraged (though not required) to identify something they liked and thought should be improved upon for each group.
2-5	Model Construction	Participants constructed, updated and revised their model of virus and immune system behavior.
5	Cohort Vote	Every cohort took a vote at the end of Day 5 to decide the best way to stop the Raven Virus from spreading further.
5	Post Assessment	All participants completed a post-assessment of the game. This assessment was on biology content and scientific interest. Questions reflected the same ones asked in the pre-assessment.
5	Recall Interviews	Roughly 2-4 weeks following the event, participants were asked questions about what they remembered from the overall game, what they liked about the curriculum, what they disliked, walked through the model of the Raven Virus, and reflected on activities completed. Individuals were also asked questions about biology (e.g. "What is a budding site?") in order to gauge information retained.

Table V: Data Streams Collected

The multiple streams of data collected for this study is akin to the IEP process that students with disabilities undergo in school. Through a combination of qualitative and quantitative analyses, special education teachers determine what current learning trajectories exist for a student and what strategies should be taken to improve upon current needs. The combination of qualitative and quantitative data is useful for capturing a more complete picture of learning, which I aim to mirror in this present study.

Finally, it was important to allow participants the opportunity to move freely from one task to the next. While some semi-structured activities occurred on each day (see: Appendix A), participants had the chance to move between gameplay, model making and discussion. As such, participants could explore their interests and investigate material in a way that made the most sense to them. Figure XI represents a snapshot of the room setup.

Figure XI: Group Video Recording, Referencing Tablet, and Model Making

Recruitment

Participant recruitment occurred over the span of three events: a spring break activity entitled Game-a-Palooza (GaP), during an after school program at a local private school, and through the summer program at a Boys & Girls Club (BGC). Participants received information via flyers and e-mail correspondences. The outreach coordinator for GLS served as the main point of contact during the admissions process. During the initial phase, prospective participants filled out basic information in order to ensure contact information, demographic data, and allergy/medication alerts are on file. Those participating in the event were notified via e-mail or by phone with updated information on the event/time.

Group Selection

All participants were assigned to a group on the first day using a list randomizer. If a participant signed up with a family member or friend, they could make the request to switch groups. Each participant would remain in their selected group during the 5-day period. However, if participant behavior escalated (e.g. fighting, the lead facilitator would assess the situation and determine whether a change was necessary.

Data Analysis

Learning is a complex process shaped and re-shaped by numerous factors (e.g. peer interaction and mediating tools). Thus, my data analysis must merge qualitative and quantitative data streams in order to capture the learning environment as a whole. The following paragraphs outline my data analysis. First, I examine each data stream separately in order to better understand its structure and behavior. I then combine qualitative and quantitative data streams together into a master log. Through this approach, I hope to connect argumentation and biology content in order to track shifts from vernacular to specialist talk. Further, to clearly trace differences in learning on the individual, group, and cohort level.

Step 1: Establishing a Coding Scheme

Framework Rationale

This dissertation adopts Berland and Reiser's (2011) argumentation coding scheme to examine in-room and on-topic discourse (i.e. any conversations that are related to the game, the curriculum, or session activities). I chose this argumentation framework because it looks at classroom communities as a way to transform student practices to engage in scientific argumentation. The design of this framework also considers different claims that emerge from diverging interpretations, different tactic definitions, and how members come together to resolve conflicts in their worldview in order to make progress (Reiser, 2004). Similarly, this coding structure gives more context behind the rich questions posed by students along with the coordination of ideas resulting from these statements and critiques. Finally, this coding scheme not only deconstructs part of scientific argumentation but recognizes that the co-construction of arguments requires individuals to attend to others in-group. The following paragraphs briefly outline the definitions of each argumentation code.

Argumentation Codes

The definitions of argumentation structure are divided into five areas: claim, evaluating, question, defense, and revision. In order to begin an argument, a *claim* (defined as a declarative fact) is spoken first. Participants who *question* a claim are asking for clarification. *Evaluating* occurs whenever a participant agrees or disagrees with an idea, but provides no evidence to support this statement (e.g. “Yes,” or “No.”). *Defense* is providing evidence to support or negate a claim. A participant who revisits and restructures a claim based on discussion is *revising* it. Table VI provides an outline of each coding definition with corresponding examples.

Utterance and Definition	**Example**
Construct a Claim - must happen first to create an argument - is stated by a participant as a declarative fact	“Slicers are bad.” “A virus is alive.”
Defend - can only occur after a claim is made - is stated to justify why a claim is true or false - justification is needed in order to classify this as a defense item	“Viruses are not alive. They just randomly act things. They do not have a brain.”

Utterance and Definition	Example
Question - can only occur after a claim is made - must be asking a question directed at the claim	“What do you mean?” “Why?” ‘How is that possible?”
Evaluate - can only occur after a claim is made - participant is confirming or denying whether a claim is true without giving justification as to why	Yes.’ “No way.’
Revise - can only occur after a claim is made - when the person making the claim, or the person defending the claim, decides to revise it from its original, declarative fact	“Maybe a virus is alive.”

Table VI: Scientific Argumentation Coding Scheme

Under Berland & Reiser’s (2011) framework, claims, questions, and revisions are separated into a “sensemaking” category. In contrast, defense and evaluation are separated into the “persuasion” category. In the middle of these two categories is the label “attending to others.” Thus, both sensemaking and persuasion within a dialogue are needed for strong arguments to occur. Figure XII provides a visual of this example.

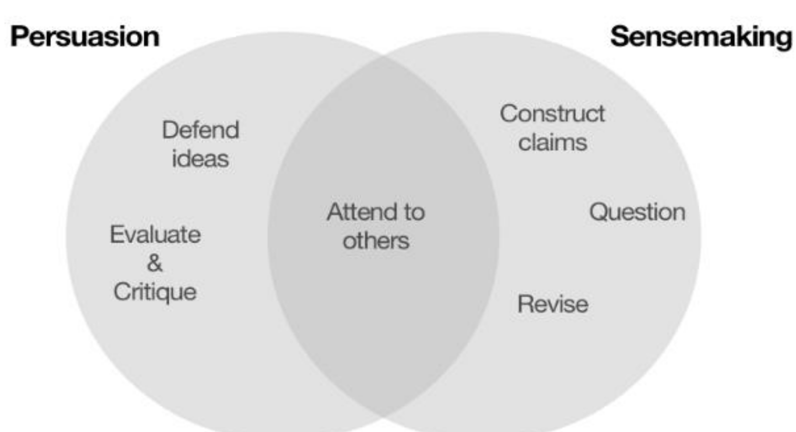

Figure XII: Sensemaking and Persuasion (Berland & Reiser, 2011)

Biology Coding Scheme

In order to trace biology content, the research team developed an inclusive coding scheme based on all terms that appeared in the game, the in-game almanac, and curriculum materials related to viruses (e.g. virion, antigenome, mRNA) and cells (e.g. nucleus, cytoskeleton site). We coded explicit use of each term as well as synonyms, metaphors, and misstatements (e.g. mispronunciations). For each instance of use, we coded for correct use of the concept (*implicit* vs. *vague*). A vague statement would occur when a participant identified a biology component without its label (e.g. “thing” or “it”). Appendix B provides a complete list of biology words and corresponding names.

Establishing Inter-rater Reliability

First, team members came together to construct coding definitions. Once definitions are established for each item (e.g. claim, revision), team members independently coded 5 sample transcripts as a trial-run for inter-rater reliability. All codes were documented through MAXQDA and uploaded onto a secure UW-Madison BOX account. Each transcript represented 10 minutes of talk. Questions with regard to coding structure and definitions will be discussed by team members. After completing the trial-run, research team members randomly selected transcription files (n=1600 turns of talk) for each person to code separately. Our team then examined the results for inter-rater reliability. All codes were compared using Fleiss’s kappa.[3]

Step 2: Demographic Information and Data Selection

Demographic Data

---

[3]Biology: 93% agreement, kappa .83; argumentation 94% agreement, kappa .093

The completion of argumentation coding must happen *before* selecting group data for analysis. This helps prevent biases in the demographic data (e.g. skewed coding). Demographic information connected to each of the participants was not organized until after the curriculum activity (Day 1 - Day 5) was complete. As such, participants were not identified with a disability before the start of each session, and every group was created not based on academic need or ability, but through randomization. This point is crucial for three reasons:

1. Knowing which participants were identified with a disability could alter the way facilitators or group members addressed them.
2. A blind review of argumentation patterns and biology content during the coding phase ensured no research bias would happen during the process.
3. Third, students with and without disabilities should serve as collaborative partners without the fear of labeling. By not having disability status at the forefront of the learning exercise, we are treating each and every student as an equal participant.

Step 3: Proportions and Frequencies in Argumentation

Frequencies and proportions help capture the preliminary landscape of argumentation talk. For example, argumentation patterns may identify an increase in questions from Day 2 - Day 4. Knowing the similarities and differences between and across groups provides a snapshot of what discussions are taking place in the form of argumentation, to what extent, and whether these patterns are for (or against) central tendency. Importantly, scientific argumentation requires more than simple proportions and frequencies to track student learning.

Step 4: Emerging Themes

I will identify emerging themes and strategies (Creswell, 2013) used by participants to construct scientific ideas through gameplay activity. These emerging themes will be coded within argumentation discourse and paired with observational data. For example, a group of participants may use *biology definitions* to construct a claim (e.g. “The purple thing is the mitochondria.”). Alternatively, participants may use gameplay strategy to predict scientific hypotheses and apply them to real-world ideas (Dewey, 1928).

Step 5: Merging Data

The learning process is a culmination of multiple interactions and activities. For example, we cannot look exclusively at facilitator notes *or* discourse in order to establish how students interact with material. Here, gameplay serves as a tool for learning and experimentation. By merging the qualitative and qualitative data streams together, I can better examine how individual groups construct scientific concepts through *both* verbal expression *and* gameplay action. When finished, my analysis will trace individuals, groups, and cohorts through argumentation discourse and action. Quantified discourse from MAXQDA will be paired with assessment scores and telemetry data into a “Master Log.” From there, I will analyze results using SPSS.

Step 6: Case Studies and Thematic Analysis

This dissertation uses a multiple case study approach (Creswell, 2009) to illustrate the co-construction of scientific ideas among groups. Each case was selected to show different perspectives (Creswell, 2012) of students with and without disabilities working together. Multiple data channels, including participant discourse and facilitator observations, are used to construct each case (Yin, 2009). In addition, each case study documents the chronological events of single groups across the five-day period (Stake, 1995) and thinks about how participants used various linguistic and technological resources to communicate meaning (Coffey & Atkinson, 1996). Similarly, a critical examination of gameplay and digital media as a space (2012) creates an opportunity to see how students, particularly those with disabilities, use this environment to generate, question, and drive scientific discussion. As a result, the case studies presented in the next chapter will examine the environment, tools, and individuals surrounding the co-construction of scientific arguments while emphasizing the diverse relationships shared between and among different group members. Case study analysis (Patton, 2005) will evaluate coded discourse and observational data to compare in-group activities (Yin, 2009). A within- and between-case comparison on argumentation discourse was conducted (Strauss & Corbin, 1994) along with a thematic analysis (Creswell, 2009). This offers additional insight on how students with and without disabilities interacted with each other, the tools (e.g. game), and formulated scientific frameworks over time.

Chapter 4: Case Studies

The following case studies investigate the interaction between middle school participants, gameplay, and the construction of scientific arguments within the context of an informal learning environment. Each case study begins with a vignette of small group activity. From there, the description moves to each individual in the group, their interests, and interactions with others. These interactions illustrate how group members come together to situate meaning and language over time. All of the excerpts are linked to argumentation dialogue. Each case study is then followed by a brief description of scientific argumentation statistics. This includes a look at sensemaking vs. persuasion patterns across the five-day period.

Demographics

A total of 12 middle school students were studied over the five-day period. Half of the participants identified as male (N=6) and half female (N=6). The majority of participants identified as White, Non-Hispanic (N=7). Table VII-IX provide a description of each group's demographic information ahead of time.

Group I: Pink Fluffy Squids			
Participant	**Gender**	**Ethnicity**	**Age**
Adrian	Male	White, Non-Hispanic	13
Daniel	Male	White, Non-Hispanic	13
William	Male	White, Non-Hispanic	11
Henry	Male	White, Non-Hispanic	11
Facilitator: Graduate student in the School of Education, C&I			

Table VII: Demographic Table for Group 1

Group II: Bill Nye's Minions			
Participant	**Gender**	**Ethnicity**	**Age**
Mia	Female	African American	14
Linda	Female	African American	11
Hanna	Female	African American	13
Leah	Female	African American	12
Gail	Female	African American	12
Facilitator: Undergraduate engineering student at UW-Madison			

Table VIII: Demographic Table for Group 2

Group III: The Narwhals			
Participant	**Gender**	**Ethnicity**	**Age**
Ellen	Female	White, Non-Hispanic	13
Dylan	Male	White, Non-Hispanic	13
Paul	Male	White, Non-Hispanic	13
Facilitator: Graduate student in the School of Education, C&I			

Table IX: Demographic Table for Group 3

Case Study 1: Pink Fluffy Squids

The following case study investigates how students with and without disabilities use gameplay strategy and mentorship to navigate their way through complex scientific frameworks. In this case, two sibling groups worked together to determine the best way of stopping the Raven Virus from reaching global pandemic. In one sibling group, both brothers were diagnosed with ADHD. Adrian, the older brother, used gameplay strategy as a way to communicate his scientific ideas to others in the group. The other sibling pair was composed of two brothers without a diagnosed disability. Daniel, the oldest brother in the second sibling group, used the scientific method to communicate information to others. While both communication styles were different, their combined efforts supported their younger siblings in learning virology. This mentorship not only created a strong bond between group members by the final day, but allowed the younger siblings an opportunity to confidently argue and revise the group's work.

Introduction

A tense silence filled the room as four middle school boys tackled an infamous challenge within the Virulent game: Level 5. In order to win, players must sacrifice one of their genomes in order to sustain control and conquer the impending onslaught of slicer enzymes. None of the participants were able to come upon this gameplay strategy during the morning session. Quiet whispers were soon replaced with brief moments of frustration as each of the participants struggled to defend themselves against the strengthened immune system. Participants zoomed their way around the slicer enzymes and created diversions, but nothing worked.

Adrian

Adrian, a thirteen-year-old boy and self-described gamer, released a frustrated sigh as the last genome was obliterated under his watch. Soon after, he discarded his tablet and wandered over to the window overlooking the street below. No words were exchanged as he began this impromptu break. Nevertheless, such breaks were highly important to Adrian's routine.

Adrian was a middle school student diagnosed with ADHD.[4] He disliked school because classrooms lacked the action-packed adventure he craved. Adrian reported little autonomy in class and a growing sense of isolation among peers. For this reason, games served as an alternative way for him to express, communicate, and act upon the world. As he explained:

> *"[In games] there is like always something happening… you are doing things, and you can try stuff, like blow things up, or crush things, like [makes an explosion sound], or you can do whatever you want. And like… that's okay, because it's not about me doing what's wrong… there's no wrong… okay well… there are things that go wrong, but nobody is going to say anything 'cause you make the decisions. I get a choice. I do something wrong, yeah okay, whatever. I can try again."*

Daniel

Daniel was a thirteen-year-old boy with a competitive spirit. He was also a self-identified math whiz, wannabe chemist, and a tinkerer with computers. Daniel hoped to someday run his own experiments and build robots that zoomed across the galaxy. He loved roleplaying a scientist because it created an opportunity to try new things. Daniel wasted no time vocalizing observations and prompting feedback from others in the group:

> **Daniel**: And the cell also needs the actual skeleton inside the cytoskeleton. And they also need slicers. So if we straight those we know the cell which is where we have that slicer and proteasome. They both need the mitochondria and the…?
> **William**: The ribosome.
> **Facilitator**: The ribosome.
> **Daniel**: Ribosome.
> **Facilitator:** Okay.
> **Daniel**: And the virus needs the budding site. So I'm not getting anything new but I think if there's any parts I'm missing people could tell me.

[4]It was important for me not to begin the description of Adrian as a boy diagnosed with a disability. A disability is merely a factor and does not define an individual. Thus, ADHD is mentioned in the second paragraph in order to help accentuate this awareness.

Daniel took frequent notes and periodically consulted his younger brother, William. These conversations were filled with banter and laughter. However, Daniel sometimes appeared troubled upon realizing his younger brother ignored his sage advice. This divide became the subject of many debates in the days to come.

William

William was a highly social and energetic middle schooler. He introduced himself to everyone at the camp and memorized many of the other participant's names without pause. William outwardly admired his older brother's knowledge of science, and many of his earliest notes, drawings, and recommendations mirrored Daniel's activities. William referred to himself as the "research assistant" and Daniel as the resident "scientist." However, like many sibling relationships, the competitive nature of the two brothers was clearly demonstrated in later days. Frustrated by Daniel and wanting to share his own suggestions to other members of the camp, William sought another ally in the group: Henry.

Henry

Henry was Adrian's younger brother and a middle school student diagnosed with ADHD. He spoke rapidly, moved chairs frequently, and switched projects without announcement. Henry left many personal belongings scattered across the room: the tablet on the floor, his backpack in the corner, and his clipboard under the table. Some days, it took several minutes for him to collect these items. Adrian said his brother had long ago earned the nickname "tornado" at home because of this whirlwind-like behavior. However, Henry was among the most enthusiastic when discovering new information about the Raven Virus. His positive attitude and encouragement ultimately served as a strong social support, particularly for William.

Day 1-2

The entire group sat around the table during the first and second day of gameplay. The table was a spacious area filled with construction paper, colored markers, crayons, and various other office supplies. Daniel and William liked having the supply bin near them because it allowed for easy access to all available materials. The first day of gameplay was largely a discussion between Daniel and William concerning the Raven Virus. The third participant, a middle schooler named Leroy, was more distant when discussing scientific facts. The facilitator noted the social divide and hoped the three boys would build a stronger rapport in the days to come. However, Leroy was unable to attend the remaining days of the camp due to a family emergency, leaving Daniel and William in a potential lurch in terms of their team. Fortunately, Adrian and Henry enrolled on the second day and filled this vacancy.

Adrian looked nervous after spotting the various office supplies on the table. What did a *video games* camp have in common with construction paper and markers, after all? It reminded him of school, at least in the vaguest sense, because his class recently completed a puzzle-making project in math. It was not his favorite activity because the directions were confusing and too prescriptive for his taste. Anxious, Adrian approached the facilitator and asked whether anything would be graded. He looked visibly relieved when the facilitator said no.

“Oh good, I thought you were a teacher.”

Daniel volunteered to brief the new members on yesterday’s events. He told them about the Raven Virus, the story of their recruitment by the CDC, and how each of the “research teams” needed to find a solution for stopping the virus from reaching global pandemic. Henry listened with fascination and delight at the story. Adrian looked slightly bored and bounced his knee impatiently, wondering when the game would begin. After the group formally introduced themselves and sat down, everyone charged ahead with the game.

William and Daniel continued the game from yesterday's session. The two boys spread their observation notes across the round table and thought about ways to construct the virus model. Henry became uncomfortable sitting at the table and soon rolled over, laying on his stomach across the chair. Adrian was also growing impatient in his seat. He quickly sunk to the bottom part of the chair and raised the tablet above his head. The facilitator explained once more this was a camp - not a classroom.

"You don't *have* to sit there."

Adrian blinked. "I don't?"

"No."

The realization caught the participants off guard. At once, everyone but Daniel scattered from their spot. Henry flopped on the ground and Adrian found a chair near the window. In minutes, the room filled with a tense silence as everyone fought slicer enzymes, free antibodies, and evaded B cells. William came over to help Henry with one of the levels. However, his attention was drawn back to the table at the request of Daniel.

Adrian voiced periodic frustration with the game under his breath. Daniel also had trouble passing the same level. However, the boys refused to move from their spot. This made collaboration more difficult and infrequent among the older participants. However, the younger participants circled around, passing messages back and forth to their older brothers about discovered strategies. Gameplay strategies (e.g. "He said you gotta sacrifice the squiggly thing") that later transformed into scientific claims (e.g. "You need to sacrifice a genome to get rid of the slicer things") evolved over time.

Adrian's frustration intensified after several more minutes of gameplay. He decided to take a break and circled around the room. He looked out the window, talked with Henry, and stared briefly at the virus model before returning to the game.

The group facilitator asked Adrian about the game. What would he change?

'Everything,' was the immediate response.

'Why?'

"I dunno."

Adrian took a deep breath and thought more about the question. He believed the virus needed a weapons upgrade because the immune system was getting too strong. Even worse, the immune system already had a surprise backup weapon at its disposal: medication. This put him (the player) at a disadvantage. How was he supposed to compete with that? Adrian went on to explain why weapons were so critical by comparing *Virulent* to *Grand Theft Auto*. Virulent simply did not offer the same arsenal. To Adrian, that was a fatal mistake.

Daniel looked over from the table, confused. He explained that virus weapon upgrades could not be produced in the real world. Daniel thought Adrian was not thinking in a very scientific way and was concerned this approach would jeopardize their mission. Adrian looked unimpressed by this argument, telling Daniel that weapon upgrades were a metaphor and not to take everything so literally. The facilitator noted that any social interaction between the older participants was infrequent and brief.

Henry and William looked to the older participants for different tasks. For example, Daniel quickly became the entrusted expert on scientific terms and model-making. However, Adrian was the go-to expert for gameplay strategy. Adrian appeared to enjoy this role and actively engaged in discussion whenever the younger participants asked a question on gameplay.

Even though Adrian secretly struggled to pass some of the same levels as Henry and William, he nevertheless offered whatever strategies he could. He explained that games require players to mess around and experiment, so they needed to figure it out. Daniel compared this metaphor to scientists trying the same experiment again and again.

Day 3-4

The group's model of virus and immune system behavior expanded over the next two days. The four boys developed and reconsidered numerous recommendations on how to best stop the Raven Virus from spreading further. At one point, the group looked at whether removing the ribosome was a viable option. Daniel, who was unsure of the ribosome's function, questioned Adrian's claim that a ribosome was necessary for a virus to take over cells.

> **Daniel**: So is the ribosome essential?
> **Facilitator**: Is it?
> **Daniel**: I don't know. I don't know what they do.
> **Facilitator**: What does the ribosome do?
> **Facilitator**: You have it up there.
> **Daniel**: Oh, those —
> **Adrian**: It's a packing — it's a packing thing.
> **William**: Yeah, it makes everything in the protein.
> **Facilitator**: Right. So do you need that or do you not need that?
> **Daniel**: Pretty sure — pretty sure that would be useful.
> **Adrian**: For the virus it's useful.

In this conversation, the group questioned and evaluated Adrian's initial claim that ribosomes were necessary for the virus. From there, the function of the ribosome was redefined by Adrian and William as useful for the virus in order to synthesize protein. This helped Daniel coordinate his knowledge of virus and immune system behavior to determine that ribosomes were truly useful to the Raven Virus. Adrian went a step further to clarify that viruses would benefit from ribosomes, thereby creating a new discussion on how the immune system benefits from this function as well. Later on, he proposed a strategy for helping to stall the Raven Virus by stating, “We can have a drug that slows down the ribosomes temporarily.”

However, this solution was not the only element that Adrian considered. His curiosity about how an immune system built up resistance to a virus increased as he played more of the game. Using gameplay as a way to communicate his scientific claim, Adrian states that perhaps the Raven Virus builds up resistance over time by repeated exposure to the slicer enzymes:

> “You would have — you would have like— so, um, every time this is how you die, then like it — it’s a balance of points, like it takes points away from this and brings it to that. And if eventually you have like overwhelmingly — overwhelming death by <u>slicers</u>, then you would become slighter able to resist and be resisted to <u>slicers</u>. But you’d become less resistant to everything else.”

A final proposal that Adrian offered the group during the early days of the camp was the creation of “trigger happy executioners” specifically designed to target the Raven Virus:

> **Adrian:** If we make a drug that makes -- if we get some of the substance that make executioners trigger happy.
> **Facilitator 1:** Trigger happy? What do you mean?
> **Adrian:** Trigger happy.
> **Facilitator 1:** What do you mean by that?
> **Adrian:** Like so, one virus gets in and then it just shuts down. One of them. If we could just specifically target it to the Raven, like if it gets anywhere near the nucleus just shut down.

Participants also considered the representation of items in the game and how this information applied to real-world situations. In the following exchange, Adrian considers how the immune system could be infiltrated to more quickly the body from the Raven Virus. He makes the claim that faster genomes would help expedite the replication process based on prior observations regarding the delayed movement of genomes in the game itself. When asked why slicer enzymes are so slow, Henry responds by explaining genomes are big and heavy.

> **Adrian:** Faster genomes would can invade those pesky slices.
> **Facilitator:** Faster genomes?
> **Henry:** Yeah.

Facilitator: Why do you think they were so slow?
Adrian: Because they are not meant for moving [fast].
Henry: They're big and heavy.
Daniel: No kidding.

Later, the group discussed possible strategies for developing a video for the CDC. Daniel wanted to showcase the relationship between the virus and immune system behavior from beginning to end. William interjected, saying those watching the video would be unable to see the close-up detail of the model construction without zooming in. To resolve this, he proposed the creation of makeshift notecards that could be manually flashed across the camera during the presentation. Daniel was not happy with the recommendation but reluctantly agreed to include the cards as a safeguard.

Henry offered to be cameraman. Adrian was nervous about his brother taking on this position because Henry was a notorious fidgeter and "tornado of activity." He reminded Henry that others would be watching the film: "Don't make anyone barf, okay?"

"Uh huh." Henry wobbled the camera and waited anxious for the presentation to begin. William made a few recommendations to Henry on when to zoom in/out of the model. The two younger boys also tackled the best moments to flash cards across the screen. Figure XIII shows a picture of the group in action.

Figure XIII: Participants recording their CDC video

Adrian also volunteered to participate in the video presentation. To the facilitator's surprise, he wore the white lab coat (something he had never done before) given to participants during their first day of the camp. Adrian said the coat made him look more scientific and serious. In the video, he listed the recommendations to the CDC, and cracked a smile as he neared the end. He looked pleasantly surprised that no one vetoed his final recommendation: destroy the world using nuclear power.

Afterwards, William reviewed the video recording and decided the model was poorly constructed. He believed the model was inaccurate because it followed the game levels too closely and did not depict the virus replication process in a realistic way ("It's not how things really work with the virus and our bodies."). As a result, William wanted to take home some office supplies and construct an alternative model for review. Daniel thought the construction of a new model was unnecessary because their group already spent two days creating one. He also questioned whether William's claim was truly accurate (e.g. "Slicers attack viruses and viruses attack cells, it shows that [on the model].”). However, William insisted on creating the model, as this action would afford him an opportunity to think critically about how the virus was represented. The next day, William came back with a newly-drawn mode for everyone to see. He included the flashcard drawings and positioned the labels to represent the virus lifecycle. William explained the model was similar to what another group coined “The Circle of Life.”

Adrian was sick on the fourth day with a fever. Henry decided that Adrian was infected by the Raven Virus and that everybody in the camp was doomed. He and William ran around telling the facilitators to stay away, because the room was a makeshift quarantine zone. Daniel quickly redirected the conversation and asked them what part(s) they wanted to play during the cohort presentation. Henry and William realized that Adrian would no longer be presenting the recommendation list and decided to split the role. Henry volunteered to take on the majority of Adrian’s work, and encouraged William to showcase his new model to better “connect the dots” between the recommendation list and virus behavior.

Daniel presented their main findings at the cohort discussion. He was exact and technical, making sure to point directly at each part of the model. Henry and William appeared nervous and continued to stand in front of the model, blocking the audience from seeing it. Daniel had to redirect the younger boys away from the model and cue their lines. William decided to go last, and briefly showed his newly constructed model in conjunction with the recommendations list. Afterwards, the three boys agreed their presentation was “by far the best.”

Day 5

Adrian returned the following day to camp. On arrival, Henry “sadly” announced that Adrian was not infected by the Raven Virus. He was jokingly disappointed because the CDC could not use Adrian as a science experiment or guinea pig in the quest to stop the growing virus epidemic. Adrian told him that perhaps he *was* infected with the Raven Virus and *maybe* the doctors misdiagnosed him. He let out a maniacal laugh and chased Henry around the room for a couple seconds. Afterwards, Adrian noticed William's model in the corner and stopped to look at it. He noticed this model looked different from the one they were constructing on Day 3.

"Did you guys revise this?"

William said no. He was just messing around with the model construction at home.

Adrian gave a quiet nod of approval. "I like this one better."

The group settled down and talked about potential options for stalling the Raven Virus. Daniel and William eagerly looked through each reading option for stopping the virus. Henry read through two of the articles but decided the vaccine was the best option and stopped. Adrian started folding his articles into a diamond and agreed the vaccine was the best option because removing the mitochondria would result in immediate death.

The facilitator asked the participants whether the second option, using an RNA inhibitor, would be a good strategy for stopping the virus. Adrian thought the second option was a close runner-up because the potential for destroying the virus was high. However, Daniel disagreed with this claim: "*They don't call it the RNA Destroyer. It doesn't destroy the RNA, it only inhibits the RNA. Inhibits, keyword*." In the end, the group elected the vaccine as the best option, and presented their case to the cohort.

Scientific Argumentation Patterns

The Pink Fluffy Squids had a total of 744 scientific argument codes across the five-day period. Declarative and defense statements were among the highest coded material. In contrast, evaluation and revision of scientific arguments was less prevalent. A look at group-specific scientific argumentation discourse is found on Figure XIV.

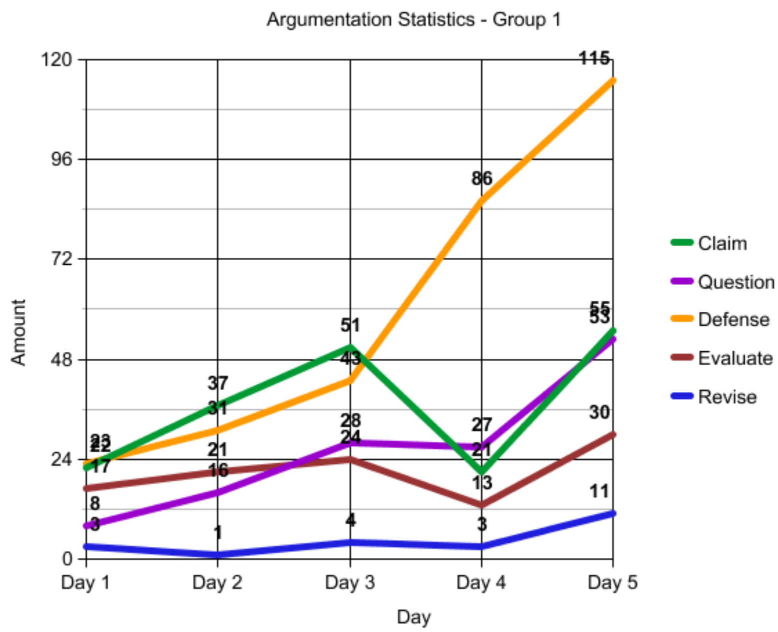

Figure XIV: Argumentation Codes for Group 1

The number of defense statements produced by the Pink Fluffy Squids continually increased across the five-day period. Adrian’s increased participation in group dialogue, combined with Henry and William’s inquiries on gameplay strategy, contributed to the number of defense statements made in later days. Similarly, participant questions surrounding scientific definitions and model construction worked in tandem with these defense statements. Finally, group dynamics were a contributing factor to the building of scientific arguments. In this group, each participant was related to another group member. It is possible this shared relationship expedited the formation of scientific arguments as participants were already familiar with communicating information with each other. Importantly, the sibling relationship also caused some friction among older and younger siblings who looked to create an alternative representation of virus behavior. While Daniel was initially reluctant to include his brother's model, he realized the added benefits of the product and ultimately agreed to share the document with those outside the immediate group. The sibling relationship could also explain the higher number of revised statements during the final day of activity.

Case Study 2: The Odd Squad

The following case study examines how a group of African American female students successfully developed and communicated complex scientific frameworks regarding virus and immune system behavior. This communication occurred through a combination of drawing, making, and role-playing. Two of the female students were identified as at risk of having a disability. None of the students knew each other prior to attending the camp. However, their shared interest in theater and science served as a catalyst for teamwork. Together, the group conquered gameplay strategy and deconstructed stereotypes of what a scientist can be.

Introduction

Four African American girls cheered loudly as they watched the youngest participant tackle what everyone in the room coined “the slicer level.” The girls swarmed the table and leaned forward with excitement as the youngest participant’s virus inched its way toward victory. Their lab coats, decorated with plastic jewels and colorful patches, caused those in the hallway to double back and watch briefly as the group negotiated the player’s next move.

‘This is impossible,’ Gail said.

‘No, you got this,’ another told her.

The screen flashed again: level complete. At once, the whole room erupted with excitement. Mia, the oldest participant in the group, let out a battle cry as the others cheered around her: “No woman left behind!”

Mia

Mia was the oldest participant in the room and held a quiet, commanding presence wherever she went. The facilitator described her as thoughtful, clever, and feeling responsible for directing group participation. Her words were quiet and reserved, but the other girls always listened without fail. Mia quickly immersed herself in the role-play activity and spoke briefly about her desire to become a veterinarian's assistant. However, she wanted the role of the scientist to be different from everything she saw in the movies or on Netflix. She wanted to see a scientist with fashion sense and sophistication. In response, she decorated her lab coat with plastic jewels, colorful beads, and makeshift patches.

Linda and Hanna

Linda and Hanna were the youngest participants in the group. The facilitator described the two participants as a "mini-team" that collaborated on everything from gameplay to model construction. Linda's quiet and careful investigation of model accuracy balanced out the loud and often excited observations Hanna made during gameplay. Hanna frequently helped Linda on spelling and grammar, as some of the words were difficult to read. These recommendations were never judgmental or directed in a way of "teaching" in the traditional sense. Rather, Linda would lean forward and casually ask Hanna to double check a word or illustration. Hanna would investigate the question on her tablet and return with an answer. From there, the two girls debated on the best way to tackle the group's model of the Raven Virus.

Leah

Leah was a math expert with a keen interest in anything scientific. She arrived a few days late to the camp because of another educational STEM-based activity she was completing out-of-state. At the other camp, Leah conducted chemistry experiments, built a circuit board, and learned more about animal wildlife. She loved the experiments and other hands-on activities. However, Leah almost never signed up to play *Virulent* because she never considered herself a "gamer." Admittedly, what attracted her to the session was the idea of learning more about biology. She was relieved when her group offered to help with gameplay strategy.

Gail

Gail was the youngest participant in the group. She was not interested in playing *Virulent* or any other game on the tablet. Gail wanted to watch online music videos and search for information on social media websites. Soon after, she received pushback from the other group members, who told her scientists needed to work together on the project. Gail agreed, and decided to give *Virulent* a try. In a recall interview, Gail reflected on her change of attitude about playing video games. Until then, she had not experienced a situation where she was gaming alongside other female players:

> *"I'd never done nothing like this 'fore now and the boys are always playing. Like, my brother plays, and my cousin plays with him, but we'd never play together. It's not something I'd ever do 'cause you know [laughter]. I'm not saying games or whatever are bad. I'm just saying it's nice to have like… us girls together."*

Group Activity

Day 1

"We're all girls."

This observation caused a mixture of excitement and confusion among the group. None of them expected to have their entire team composed of non-video gaming girls. They spoke rapidly about what this scenario meant and sought to establish their own group name based on this pleasant, though unexpected twist. The girls saw themselves as wholly different from their peers at Boys & Girls Club because none of them looked like the stereotypical scientist on television. As non-scientists, non-gamers, African American students, women, and self-described fashionistas, the participants wanted to break the boundaries of identity. The girls tossed around names like "unique," "strange," "different," and "odd" when brainstorming a group name. In the end, everyone decided on "The Odd Squad."

The participants believed working together increased the group's chance of finding a cure for the Raven Virus. For this reason, everyone agreed to sit near the round table. This arrangement allowed group members to easily compare notes, play the game, and work on the model more efficiently. Mia referred to the round table as "HQ" because it sounded like "an important thing to call it, like in the movies." When the facilitator asked what "HQ" stood for, Mia thought about this for a long moment. The facilitator could not decide whether Mia was joking or not as she smiled and said, "It means high quality, 'cause that's what we're doing here and now." The other girls, impressed by Mia's spark, nodded their heads eagerly.

The first day of the camp was largely exploratory. The participants moved through each level with minimal difficulty and became increasingly confident about stopping the Raven Virus from destroying the world. The group discovered new definitions for the in-game components and began switching out vernacular terms (e.g. blue thing) for standardized ones (B Cell). By the end of the first day, the group produced a list of recommendations on how to stop the Raven Virus. Mia wrote the letter while the other participants made verbal suggestions. Once finished, they transferred these recommendations onto a finalized document. A copy of the letter is found in Figure XV.

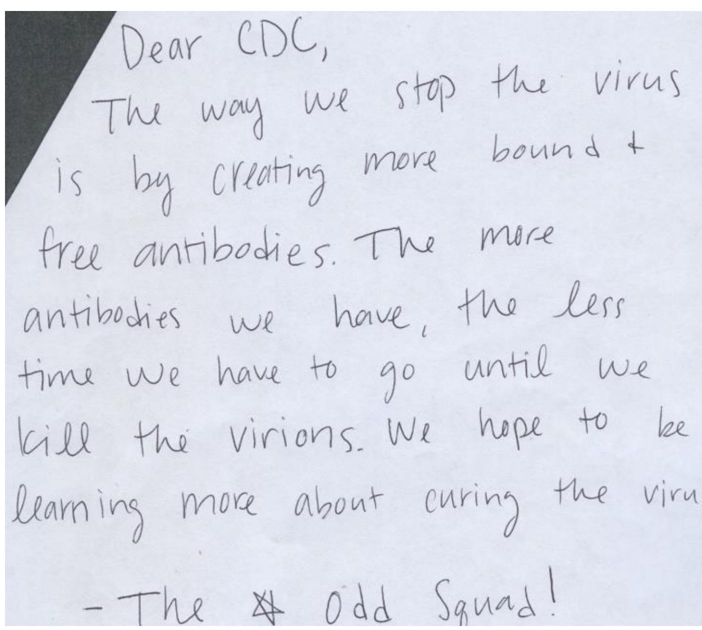
Dear CDC,
The way we stop the virus is by creating more bound + free antibodies. The more antibodies we have, the less time we have to go until we kill the virions. We hope to be learning more about curing the virus
- The Odd Squad!

Figure XV: CDC letter from the Odd Squad

Day 2-3

The participants returned the following day with decorated lab coats and clipboards. Mia said the decorations signified a shift in where science was heading but did not articulate what this meant. The girls showcased their lab coats to those passing in the hallway, and when a male participant teased them for wearing something that was “so girly,” Hanna told them “we are changin’ up this game.” While the other participants appeared unfazed by the interaction, Mia was nevertheless unhappy about the encounter. After the session was over, she told the facilitator that scientists were explorers and she was frustrated that people were so dismissive.

The introduction of model making was exciting for Linda and Hanna because it offered them an opportunity to transform their gameplay experiences into art. It also provided a needed relief from the more frustrating levels of gameplay. While the addition of model making was viewed as fun and exciting to many of the participants, Gail remained highly focused on playing the game, believing her expertise would come in handy later on. She was quick to identify inaccuracies between the game and the model, and sometimes argued with peers on whether the depiction was realistic enough for the CDC to understand.

The group’s model was described as something from a Dr. Seuss book: long, curly edges with bright colors and accentuated features splashed across the page. The girls hummed as they worked collectively on the drawing and discovered new items to illustrate from the game. A picture of their model is shown in Figure XVI.

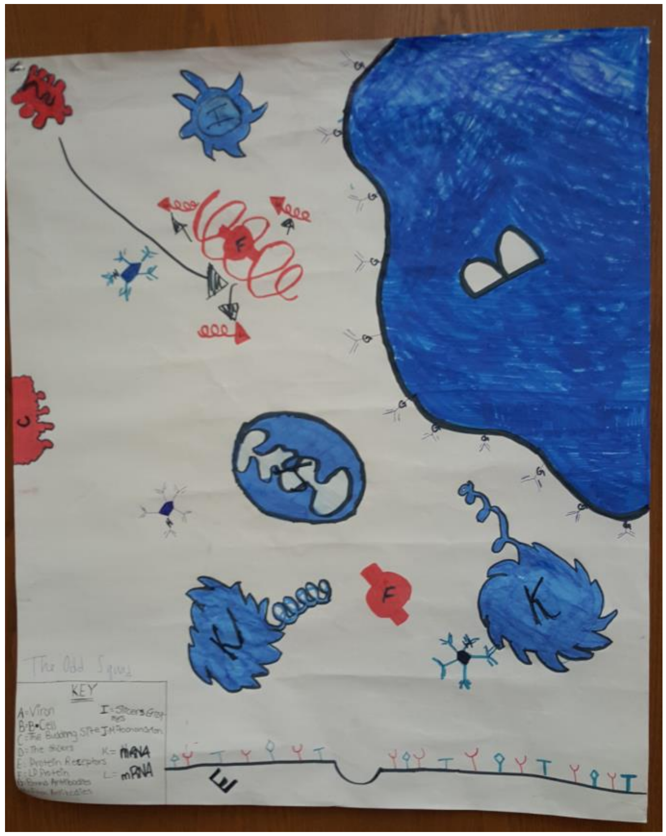

Figure XVI: Model of the Raven Virus

The minimalistic style of the model was something the group wanted to keep intact. To simplify the model, Linda and Hanna tagged all virus and immune system components with a corresponding letter of the alphabet. The alphabet was part of the model's key. The following exchange represents one of their conversations during the model-making process. As the girls coordinated the items within the key itself, the participants began using more scientific language to determine virus and immune system names. Mia starts by examining what items are currently in the model\s key while Linda describes one of the elements as a slicer enzyme. Mia questions whether the item is truly a slicer enzyme. Linda corrects her statement and Hanna verifies it. In the end, Linda closes by stating slicer enzymes are not present in their model after all:

> **Mia**: We want to see, this is A. C is the micro, I mean the, C is the budding site.
> **Facilitator**: No we aren't making microbots. We're making a model.

> **Linda**: These are slicers.
> **Mia**: Those aren't slicers are they?
> **Hanna**: Why is it your--
> **Linda**: No these aren't slicers. Those are the bound… the free antibodies.
> **Hanna**: These are free antibodies.
> **Linda**: Yes.
> **Linda**: Then where are the slicers? We need to do slicers.

The group's facilitator noted in her journal that early versions of the model did not include very detailed information on virus and immune system behavior. She was concerned by the lack of information and how this could impact later conversations with the cohort. However, the facilitator also recognized that group members identified this problem and were actively working to find alternative ways of presenting their ideas to the larger group. As a result, while the facilitator hoped group members would include more detailed information in their final product, she refrained from directly asking them to add/change certain components.

One group member who recognized the need for additional information in the model was Gail. Hanna and Linda agreed with her initial statement, but argued that additional information could only be collected through verified observations in the game (e.g. "Who else saw that?"). Interestingly, the outreach coordinator for the Boys & Girls Club was surprised to learn that Hanna and Linda were the two participants leading the model construction. She explained that Linda rarely volunteered to participate in activities that involved books or writing. As such, she was surprised by Linda's diligence in research and model accuracy as the days progressed.

The facilitator also noticed that group members were having trouble distinguishing the "good guys" from the "bad guys" during the model-making process. The facilitator attempted to resolve this issue by referring to the virus as the "red stuff" and the immune system as the "blue stuff" when discussing the matter in detail. The hope was that a change in language definition would make in-game components easier for the group members to understand. However, Mia saw a flaw in this approach: namely, that objects from the same category were not necessarily from the same family. While group members worked to resolve whether a virus was represented by the “blue stuff,” Mia argued that game labels were an inaccurate representation of what items belong in the virus or immune system family.

> **Mia**: So say you could like go one way, then you could go another way and kind of maybe work your way around it.
> **Hanna**: So like --
> **Mia**: Or risk one of your pieces dying.
> **Leah**: Okay. So which piece is the virus, though? Do we know that?
> **Linda**: Not the DNA.
> **Facilitator**: Not the DNA. Is it the red stuff or the blue stuff?
> **Group**: The blue stuff.
> **Facilitator**: The blue stuff is the virus?
> **Mia**: Yes.
> **Linda**: But weren't the bound antibodies blue?
> **Mia**: Doesn't matter. It's because they were coming at us. Okay, just because they're blue doesn't mean anything because they mean different things.
> **Facilitator**: Oh, ok.
> **Mia**: They may be in the same family, but they're different things and they do different things. Like the free antibodies kill you.

Another interaction where the facilitator attempted to adopt the group’s vernacular language by using the word ‘flake’ to describe a slicer enzyme ended with a similar result. Mia, who heard the non-scientific language being used, was quick to correct this:

> **Mia**: Wait this isn't doing anything.
> **Facilitator**: How do you know?
> **Mia**: Because it's going to slice.
> **Hanna**: There's no, there's no flake that's coming after me.
> **Mia**: Two just attacked me. One didn't kill me the other one did.
> **Mia**: Yet.
> **Facilitator**: Okay, so what are these flakes that are coming after us?
> **Mia**: These are called the slicer enzymes.
> **Facilitator**: What do they do?
> **Mia**: They slice.

On the second day of gameplay, the group also worked on determining the function of different virus and immune system components. In the following excerpt, the participants are coordinating gameplay strategy while also deciphering various roles in the immune system. This includes what role the slicer enzyme plays against the Raven Virus.

Linda: It's going down.
Mia: Wait, the purple thing can move.
Facilitator: The purple thing moves?
Hanna: The whole thing moves?
Linda: It's going down.
Linda: See look. The slicer just comes down and slices all of them.
Gail: Exactly.

On the third day, participants came back together and prepared for their video presentation. The girls were loudly, giggly, and carefree during the practice run. Many of the participants burst into laughter partway through reading the script and asked to start over. However, their on-camera performance was described by the facilitator as "something like a light switch being turned on." The participants stood confidently near the model and carefully explained each component in precise detail. Although smiling and carefree, their presentation was not filled with the same rambunctious giggles and running around as the facilitator expected.

Day 4 - 5

On the fourth day, participants argued over whether the model was complete after reflecting on their video recording from the day before. Mia and Gail both thought the model was missing information and identified flaws in the current design. The group decided that scientific vocabulary was available in the model but not expressed accurately in the presentation. In the following conversation, participants negotiated new vocabulary words in order to determine how to articulate information to others:

> **Hanna**: So it's like where you take the MRNA's and make it and put it into the rib-some and it'll become like these oval things. And then this pac three-headed paceman thing.

Mia: Yeah.
Hanna: Will come and eat him up. But I don't know if that's a good thing or a bad thing.
Facilitator: Okay. You grabbed for the marker, so you get to go last.
Linda: Okay, so I went on to that level and that three paceman thing.
Facilitator: Hold on, what the three-headed paceman? What's it actually called?
Hanna: Oh, let me go check in the almanac.
Facilitator: Yep, that's a good idea.
Linda: That's exactly what I'm going to do. Okay, well, while she's looking that up I'll take one of your RMNA - MRNA and then I'll go, it'll like leave, and it'll have this like red thing, which is your MRNA in its mouth.
Facilitator: Okay.

With the introduction of Leah, the newest member of the Odd Squad, the other participants became more attentive to using scientific vocabulary to teach and reiterate scientific concepts. Leah asked several questions about the virus model and how it compared to the game. In doing this, Linda and Hanna quickly realized the model needed arrows or other labels to showcase interactions between virus and immune system behavior. Group conversations centered on understanding and negotiating terms, similar to the exchange below:

Facilitator: What are you going to add [to the model]?

Mia: The little pac-man things.

Hanna: [consulting almanac] No, it's called a protesome.

The Odd Squad rehearsed their presentation several times before sharing their findings with the cohort. Many other groups complimented the model's design and how easily the information could be read from across the room.The next day, the group returned to decide which option (Vaccine, RNA inhibitor, or mitochondria inhibitor) would stop the Raven Virus. The group quickly decided the vaccine was most effective against the Raven Virus and collected evidence from the readings supplied to them. When asked by the facilitator whether they could identify any negative effects from choosing the vaccine, group members needed additional time to coordinate their thoughts:

Hanna: That it is bad for your health.
Facilitator: How is it bad for your health?
Mia: Yeah, how is it bad for your health?
Linda: Yeah how is it? It's helping you, actually.
Hanna: Wait the thing… the vaccine. Oh! I thought you were talking about the virus.
Mia: I don't know anything bad about it because it's giving you the flue but it's preparing your body… like it gives you the future [flu strand].
Leah: It gives you a tiny bit of it, but it didn't make it [the virus], you say it's preparing you for the flu.

The group later revised their argument as they read more about the vaccine. The following excerpt highlights a possible barrier the CDC scientists would face if they chose to proceed with the vaccine:

Mia: Pros: It will stop the virus.
Facilitator: Okay, pro: it'll stop the virus [writing it down].
Mia: Cons…
Hanna: It mutates.
Mia: Yes. It will… this guy [the virus] runs and mutates/ And iif we cannot adjust] these [vaccines] it will get worse.

This newfound information helped the group do a final "check" of their options before heading into the cohort debate. During the cohort debate, each of the participants took a turn explaining the group's decision while using the model to illustrate their argument. In the end, their proposal to stall the Raven Virus (re: vaccine) was used as evidence to secure the final vote.

Scientific Argumentation Patterns

The Odd Squad had a total of 668 scientific argumentation codes across the five-day period. Like the Pink Fluffy Squids, declarative and defense statements were among the highest coded items. Evaluation and revision statements were among the lowest scientific argumentation codes identified within the group. A look at argumentation codes for each day is found in Figure XVII.

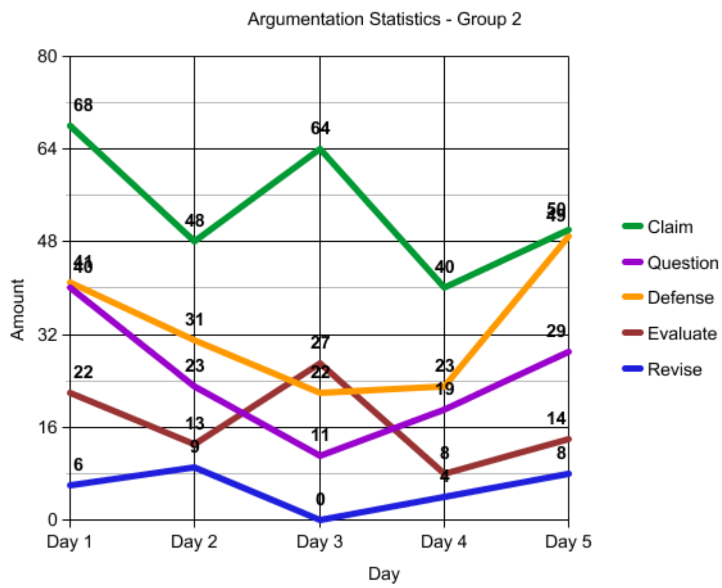

Figure XVII: Argumentation Codes for Group 2

The Odd Squad saw a decline in declarative and defense statements from Day 1-4. However, declarative statements fluctuated on Day 3 due to video production and the ongoing co-construction of group model-making. The group's defense statements also decreased from Day 1-4 as the members discovered and reworked their model. Defense statements increased significantly during the final day, likely due to group members preparing for the cohort debate.

Case Study 3: The Narwhals

This case study tracks how inclusive practice within an informal learning environment encouraged collaborative discussion and model-making. This group was composed of three best friends from the same neighborhood. One student was diagnosed with multiple disabilities that created a regular barrier to social activity. Together, these friends investigated and deciphered the behavior of the Raven Virus. The group's tenacity for problem-solving and creative spark transformed this games-based activity into a space for making, discussing, and building scientific arguments together.

Introduction

Three of the participants described themselves as best friends. The trio had known each other "since forever" (which meant kindergarten) and were excited to spend their entire spring break together. The two boys ran around the table and grabbed the nearest tablet, ready to play, while the girl sat opposite them. In minutes, the three friends were shouting suggestions back and forth as they encountered everything from B Cells to slicer enzymes. Soon, what began as a "strange game" turned into "an impossible level" followed by unexpected victory. In these moments, the group wavered between bouts of excitement and exasperation.

'We're going to lose,' a boy named Dylan told them.

'Wait,' said Ellen. She looked tentatively at the screen and grinned confidently as the level flashed again, showing the time completed. At once, they broke into a cheer.

Ellen

Ellen was described by facilitators as loud, confident, and theatrical. She hoped to someday be a veterinarian, a comedienne, or write novels about heroines on long, forgotten adventures through time. Ellen's inspiration for writing came from the *Hunger Games*, H*arry Potter*, and *Lord of the Rings*. She quoted them in passing and made a dramatic pause between lines. Her impromptu performances surfaced during intense moments of gameplay. What began as a quiet sigh would turn into a proclamation for revenge as she called the slicer "Voldy," and swearing to destroy the enemy at any cost necessary. The boys sometimes giggled at her performance before joining in.

Dylan

Dylan was the youngest participant in the group. He was shorter and much thinner compared to most sixth graders enrolled in the camp, and often adjusted his glasses because the frames were a size too large for his nose. Dylan was diagnosed asthma and life-threatening allergies at a younger age. This required him to carry an inhaler, prescription medicine, and a couple EpiPens wherever he went. The physical disabilities and underlying conditions he faced made social gatherings difficulty to arrange, let alone attend. However, Ellen and Dylan both understood ways to accommodate Dylan's medical needs and became overnight advocates on his behalf. His mother, who described the trio as "the three musketeers," was happy to see Dylan foster a longstanding friendship with the other participants. She believed these social gatherings had turned her once-shy son into the competitive and outgoing sixth grader he was at camp.

Paul

(Paul's disposition was diametrically opposite that of Ellen and Dylan's. He was quiet, calculated, and carefully tracked his every move in gameplay. He sometimes made a verbal observation to nobody in particular before returning to the screen. Paul was not a competitive player but listened carefully whenever Dylan and Ellen challenged each other to a contest (e.g. who can finish this level the quickest). Paul declined to participate in these contests. He preferred quiet reflection over the flurry of activity happening opposite him.

Day 1-2

The first day of camp began with an energetic burst through the door. The two boys heard rumor about a zombie game and wondered if the Raven Virus would cause everyone to become "zombified" within the next 48 hours. Their enthusiasm turned quickly toward the tablets sitting on the table and the prospect of finding a group name. Within seconds, the friends chose the Narwhals because it was "the absolute, most favorite, best song" they knew. When the facilitator asked them to elaborate, the trio broke into loud sing-song.

Ellen expressed excitement for this "class" and Paul agreed. Dylan asked whether any homework would be assigned, and the friends loudly cheered when the facilitator said no. The facilitator emphasized that camp activities were informal and not class-related. Ellen acknowledged this definition but nevertheless exclaimed, "This is gonna be the best class ever."

The facilitator asked for someone to read the instructions. Ellen happily volunteered and proceeded to read the script in a fake British accent. Dylan and Paul snickered, explaining that Ellen was using her "theater voice." In the excitement, the two boys soon joined her with their own version of a British accent, and everyone read the instructions together. Afterwards, the three friends went to work playing the game.

Ellen's competitive spirit surfaced early in gameplay. She and Dylan compared notes and loudly announced their achievements during the first session. For a couple minutes, Ellen sped ahead, and a few minutes later, Dylan took the lead. Paul watched them from the opposite side of the table and casually blinked as the friends argued about who was winning the game. In reality, Paul was the furthest ahead. However, he declined mentioning this to Ellen or Dylan because "it's sometimes fun watching them fight."

The participants focused heavily on gameplay strategy and less on scientific definitions throughout the course of the day. Words like "squiggly hot dog" were common and not corrected by the group members as they sought to complete as many levels as possible. However, the friends soon ran into a roadblock when trying to articulate in-game components for their letter to the CDC. In the following exchange, Dylan is trying to figure out the purpose of a protostome. Partway through, Paul intervenes when Dylan claims that proteasomes can eat antibodies (called "anybody" in this conversation) and says this statement is false. In still figuring out the different roles virus and immune system components play, Paul claims that proteasomes cannot eat genomes due to a protective shield. Dylan counters by stating the proteasomes eat the shield:

> **Facilitator**: What are those?
> **Dylan**: The prot-easome.
> **Facilitator**: Do you know what they do?
> **Dylan**: Yeah they're three chompies, they're like this.
> **Facilitator**: Yeah?
> **Dylan**: And then they eat the little guys. Anybody [pointing to game].
> **Facilitator**: The antibodies? Okay.
> **Dylan**: Anybody.
> **Paul**: Not anybody.
> **Dylan**: Anybody.
> **Paul**: They can't eat. They can't eat the antibody.
> **Paul**: They can't eat your genomes with a shield.
> **Dylan**: Well they eat the shield then.

The participants struggled to compose their initial letter to the CDC because there was a disagreement with what recommendation to propose. Ellen proposed that scientists could "reduce the space" of the infected cell. Dylan and Paul disagreed with this recommendation, saying it was scientifically impossible and would cause physical duress. Ellen was frustrated by this response and wanted to include the recommendation as an alternative to what the boys wanted to write. Paul agreed, believing more recommendations were better because they helped the scientists think outside of the box. Other recommendations made by the group included adding a protective shield to the mitochondria and developing “PRR pills.”

On the second day, Ellen and Dylan started questioning whether the rotating facilitators had the scientific credentials necessary to help them stop the Raven Virus. Were the facilitators scientists? Did they work for the university? Ellen was concerned about the number of “unqualified” facilitators who were trying to help them. She was hoping to have access to medical professionals and biology majors, and upon learning that some of the facilitators did not fit this criteria, sought out scientists beyond the room. Dylan teased Ellen, saying the “real reason” she was trying to leave was to get away from them. Ellen pretended to be grumpy at this remark and crossed her arms. However, Dylan and Paul copied her face, and she soon burst into laughter.

Ellen’s gameplay intensified soon after this exchange. She became highly excited when reaching the end of a level and yelled loudly at slicer enzymes, telling the immune system to stay away from her friend (the virus). Ellen was equally enthusiastic with model construction as this offered her a chance to showcase her artistic skills. She consulted with Dylan and Paul on the best way to tackle representing the interactions from the game.

After a couple minutes and several preliminary drafts on scrap paper, the participants chose to represent the virus taking over the immune system from multiple angles. Dylan assisted Paul in drawing a comic style panel of the virus being attacked by a bound antibody. This drawing represented a “live action” sequence of what was happening inside the body. In contrast, Ellen was tasked with drawing the side effects of someone infected by the Raven Virus. This way, people looking at the model could see the impact “inside and out.”

The group members occasionally fought with each other during model construction and gameplay. In particular, a consensus was hard to reach when it came to depicting the virus and immune system behavior. Ellen thought the comic panel looked unrealistic and needed more detail. Paul argued that her drawing of a Manga character infected by a virus was equally fictitious. In the end, the two agreed to revise their drawings based on each other's feedback.

As the two debated with each other, Dylan told the facilitator that Ellen was the Hermione Grainger of their group: she loved books, had bushy hair, was extremely smart, and annoyed them constantly. A passing facilitator who overheard the remark asked which of the boys was then Harry Potter. As though expecting this question, or having rehearsed this many times before, they immediately said Dylan, since he was the person wearing glasses.

During model construction, a discussion surrounding the role of slicer enzymes surfaced, with group members voicing differing scientific claims as to what the slicer enzymes could destroy. At first, Ellen explains that slicer enzymes slice people (or makes them sick). When asked to clarify her statement, Paul intervened by saying the slicer enzymes kill the virus. Through this, Ellen and Paul refined their statement to be more specific:

> **Ellen:** It slices people.
> **Facilittor:** But what does it do to the virus?
> **Paul:** It kind of… kills it
> **Ellen:** It destroys RNA.
> **Paul:** It destroys RNA genomes.
> **Paul and Elle:** Genomes. And MRNA
> **Paul:** [referring to the in-game text] It's what I do and it's what I'm good at, I can deal only, deal a certain amount of damage for MRNAs and one genome, before I become denatured.

Later on, Paul became anxious when the facilitator announced the group's activity for the next day: a video presentation to the CDC. He asked the facilitator a series of questions in the hope of preparing their presentation ahead of time. Who would be watching the video? How long would the recording be for? Was the facilitator *absolutely sure* no grades would be received? Ellen and Dylan did not share the same level of anxiety. At the end, they told Paul not to worry about the presentation and to just keep playing the game.

Day 3

At the beginning of the day, Dylan and Paul taped the model to the wall. This way, the participants could view the model and compare their drawing level by level. It also created the backdrop for their video presentation later that morning. On this day, Paul and Dylan took an active lead in drawing the model while Ellen provided details by referencing the almanac. Figure XVIII shows a picture of their work in action.

Figure XVIII: Group Model Construction

A deeper investigation of the model revealed some inconsistencies between drawn content and game definitions. Scientific words like “nuclear pore,” and “cell” were used as participants struggled to better understand the Golgi Apparatus:

> **Ellen**: Oh, no, no, no. The nuclear pore. The nuclear pore. So we need to remove… and it’s drawn like…
> **Facilitator**: Here, let me hold that down for you.
> **Paul**: Nuclear pore. The… a cell. This is just a cell. Then you don’t try to —
> **Ellen**: Yeah, that’s a cell.
> **Facilitator**: Yep.
> **Ellen**: There’s also like, these cells.
> **Facilitator**: Do we want to label that so we know what that is?
> **Paul**: How about a G Protein and vesicle?
> **Ellen**: Nu-nuclear pore.
> **Facilitator**: Where would you put those?
> **Paul**: We need one of those things that — what you call — like a rubber glove.
> **Ellen**: And then you have to draw a key.
> **Paul**: The Golgi - Goglis’ Apparatus.

The conversations leading up to the video presentation were loud and unscripted. This caused Paul anxiety because he believed the group needed to look more professional. Ellen said she waned to “wing it,” believing the model served as a natural guidepost. Dylan reluctantly agreed with Ellen, but admitted he was camera shy. He refused to play a role in the video presentation with the exception of highlighting the Executioner toward the end. Paul was also a little camera shy and only wanted to outline the recommendations. This left Ellen to present the majority of the virus and immune system behavior: a responsibility she was happy to take on.

After the first taping of the CDC presentation, the participants watched the video and critiqued their performance. The group realized their presentation had several mispronunciations and some information was skipped altogether. In addition, the group never introduced themselves, which they agreed was critical to any final performance. The group chose to re-record their video three separate times in order to capture the information they believed critical.

Dylan and Paul requested the video be edited by someone professional before handing over the final product to the CDC, since there was no time to complete this during the session.

Day 4-5

The participants used the video presentation from yesterday as a foundation for the cohort presentation. This included brief model revisions and thinking about more creative ways of stopping the Raven Virus. One possible solution was nanotechnology, an idea that captured the imagination of Paul and Dylan. The two boys believed advanced nanotechnology could detect and eliminate the virus. Paul began his argument by explaining how nanotechnology could be programmed to destroy specific items during an attack. Dylan agreed, but used the word "these" to describe what he believed was necessary to destroy. Paul revised his statement in order to articulate the exact items he believed the nanotechnology needed to target:

> **Paul**: The nanotechnology will be able to assist the body. It would probably be centered in the body destroy the [inaudible] because normally, it has to be like alerted before it really tries to attack it and destroy it. But with the nanotechnology, you can just like program something into it saying, like, "Destroy the certain kind of thing."
> **Facilitator**: What would you want to destroy?
> **Dylan**: It would destroy the THESE so it couldn't make anything.
> **Paul**: You'd want to destroy the budding site, virions, and the genome.

In reflecting on the group's video presentation, Paul decided that arrows and/or labels were needed to communicate the interworking relationship between virus and immune system components. Ellen and Dylan agreed, but wanted to use a labeling system because it provided a natural color scheme. Dylan thought each color could represent virus or immune system behavior. Paul disagreed with them because coloration held no symbolic meaning to anyone outside of their group. He advocated for blue and red arrows, but was outvoted. Figure XIX shows a display of the model with the arrows included.

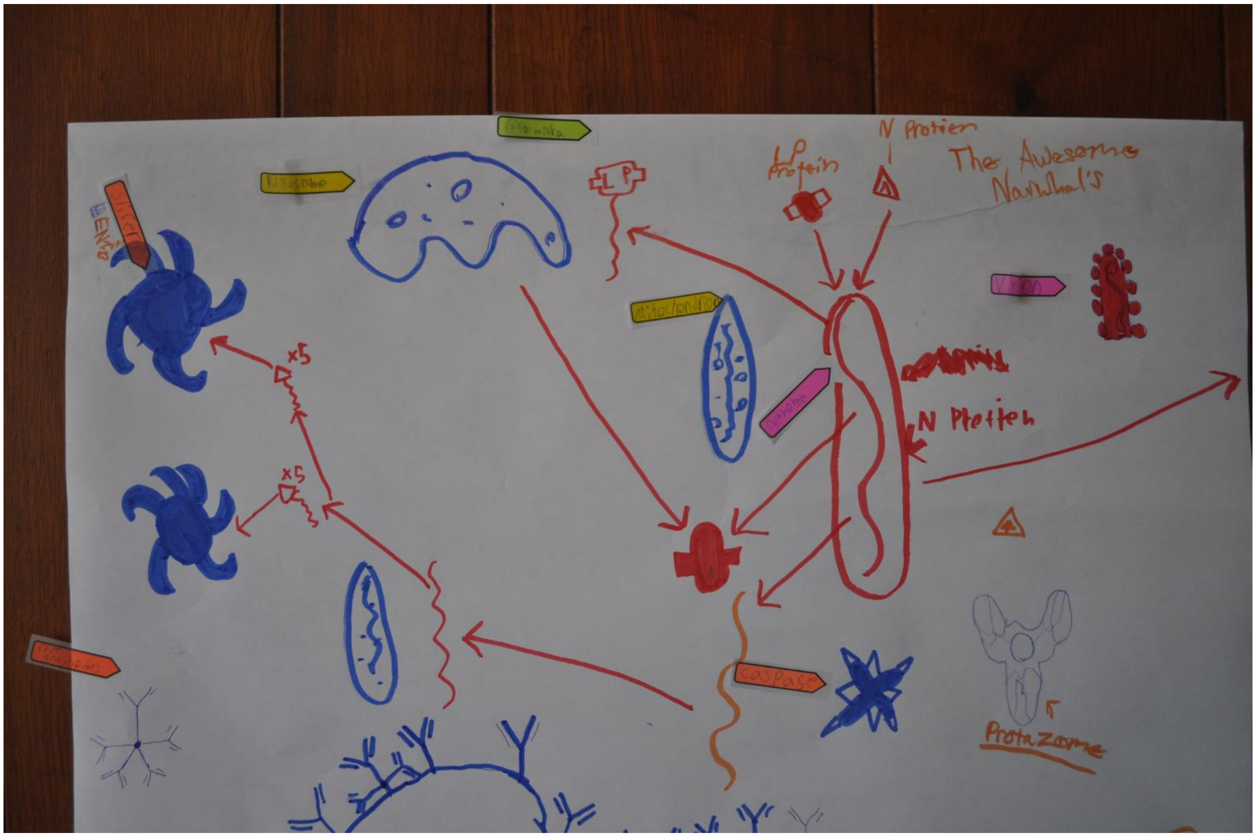

Figure XIX: Model Construction from Group 3

The cohort presentation was not as successful as the group members anticipated. Their model was hard for outside members to understand and follow. Paul and Ellen believed their project "failed" whereas Dylan thought their model reflected an ongoing investigation of what science was - something that was "messy and uncertain."

The participants returned on the fifth day to prepare for the cohort debate. The group believed the vaccine was the most viable option for stalling the Raven Virus because one of their readings discussed a journal article highlighting a successful vaccine trial on monkeys. Paul and Dylan argued that monkeys, while associated with humans, are not a fair substitute due to genetic differences in the DNA makeup. Ellen disagreed. She believed monkeys were exactly like humans with the exception of intelligence. This upset Paul, who argued that information communicated in a different way did not define intelligence, and used a butterfly to highlight his case:

> **Ellen**: Not only that, but monkeys are a little bit dumber but that doesn't really matter because we're the same dumber.
> **Paul**: That's just mean.
> **Ellen**: Well they can't talk and stuff.
> **Paul**: Yeah they can.
> **Dylan**: Yeah they can. They can communicate.
> **Ellen**: No, they can't like speak words.
> **Paul**: Words to you are different from words to a butterfly. Butterflies can talk in their own language. Just because you can't talk French doesn't mean that it isn't words.

Ellen quickly retracted her statement and believed her claim was misinterpreted by others. Paul, still frustrated with Ellen's statement, took charge of the remaining discussion as the group moved through each of the three options. At the end of the session, the group chose to create a vaccine to stall the Raven Virus because it yielded the fewest risks.

Scientific Argumentation Patterns

The Narwhals had a total of 650 scientific argument codes across the five-day period. Their highest number of scientific argumentation codes were declarative and defense statements. However, unlike the other groups, questioning was coded less frequently. Figure XX shows argumentation patterns in further detail.

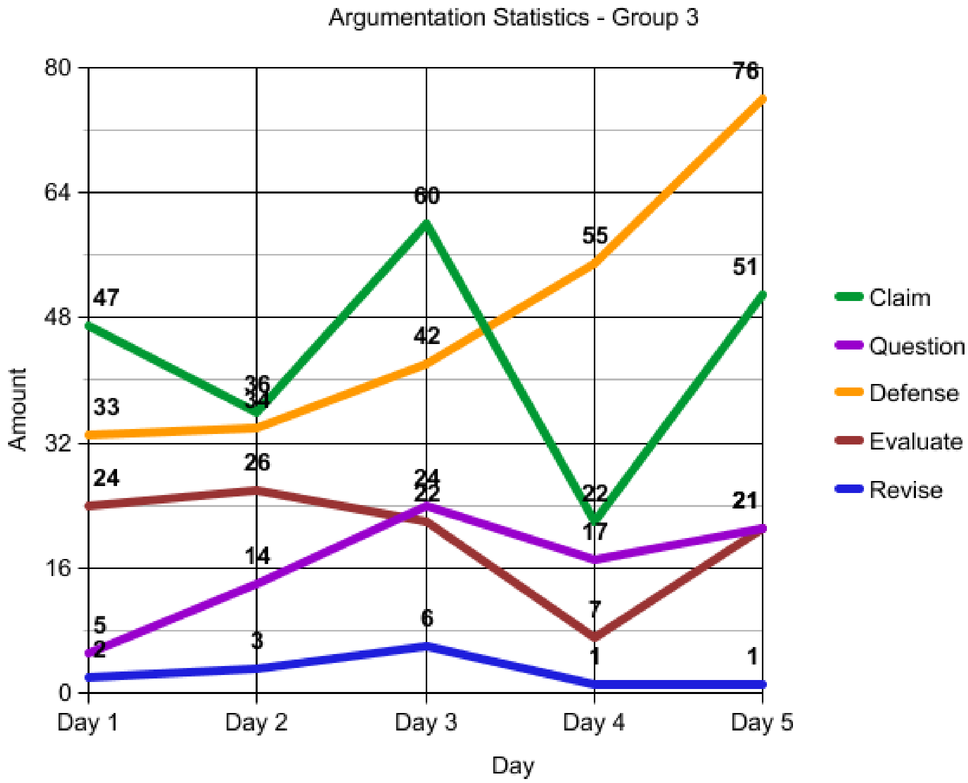

Figure XX: Argumentation Codes for Group 3

For the Narwhals, the number of defense statements increased steadily as the friends worked together to determine the best way of stalling the Raven virus. Additionally, argumentation activity increased from Day 2 to Day 3 in preparation for recording their video to the CDC. While the group had the opportunity to rehearse and recreate their video several times, argumentation patterns decreased the following day as they organized their information for the cohort presentation.

Scientific Argumentation Findings

The following chapter focuses on the scientific argumentation discourse patterns of middle school youth participating in a five-day games camp. This analysis was conducted using the theoretical framework of Berland and Reiser (2011). I chose this framework because it creates an opportunity to look at the co-construction of arguments within a community of learners, investigates different claims that emerge from diverging interpretations, and the resolutions that follow (see: Chapter 3). This chapter begins with an overview of scientific argumentation codes identified within the larger data corpus. This includes tracing shifts in sensemaking and persuasion discourse. From there, I look at how argumentation codes are identified across case studies. I close with a reflection on possible ways scientific argumentation discourse was impacted by gameplay activity and group behavior.

Argumentation Codes

I used Berland and Reiser's (2011) framework to construct the argumentation coding scheme for this dissertation. This framework was previously used to investigate scientific argumentation among middle school youth learning about invasive species in classroom communities and the interaction(s) between three separate organisms: rabbits, foxes, and grass. A simulated ecosystem was used to investigate these interactions in more detail. In this dissertation, middle school youth investigated the relationship between virus and immune system behavior. A simulated environment (e.g. game looking at the microscopic actions occurring within a simulated body) was also a tool used to examine and communicate discoveries.

The argumentation coding scheme was divided into five sections: claim, evaluating, question, defense, and revision. Each section was previously constructed by Berland and Reiser (2011) based on collaborative sensemaking (Brown & Campione, 1996; de Vries et al., 2002;

Hogan & Corey, 2001; Naylor, Keogh, & Downing, 2007). In order to identify argumentation patterns within discourse, transcripts were reviewed and identified for conversations relating to science material (e.g. talking about the Raven Virus). Discussion that involved setup, technical issues, or matters outside of the camp (e.g. asking about the lunch menu) were not included. Once identified, all relevant conversations were coded for scientific argumentation discourse.

A separate definition was attached to each section. In order to begin an argument, a *claim* (defined as a declarative fact) is spoken first. Participants who *question* a claim are asking for clarification from the speaker or group. *Evaluating* occurs whenever a participant agrees or disagrees with an idea, but provides no evidence to support this statement (e.g. "Yes," or "No."). *Defense* is providing evidence to support or negate a claim. A participant who revisits and restructures a claim based on discussion is *revising* it. Table X provides an outline of each coding definition with corresponding examples.

Utterance and Definition	**Example**
Construct a Claim - must happen first to create an argument - is stated by a participant as a declarative fact	"Slicers are bad." "A virus is alive."
Defend a Claim - can only occur after a claim is made - is stated to justify why a claim is true or false - justification is needed in order to classify this as a defense item	"Viruses are not alive. They just randomly act things. They do not have a brain."
Question a Claim - can only occur after a claim is made - must be asking a question directed at the claim	"What do you mean?" "Why?" 'How is that possible?"
Evaluate a Claim - can only occur after a claim is made - participant is confirming or denying whether a claim is true without giving justification as to why	Yes.' "No way.'

Utterance and Definition	Example
Revise a Claim - can only occur after a claim is made - when the person making the claim, or the person defending the claim, decides to revise it from its original, declarative fact	"Maybe a virus is alive."

Table X: Scientific Argumentation Coding Scheme

Under Berland & Reiser's (2011) framework, claims, questions, and revisions are separated into a "sensemaking" category. In contrast, defense and evaluation are separated into the "persuasion" category. In the middle of these two categories is the label "attending to others." Thus, both sensemaking and persuasion within a dialogue are needed for strong arguments to occur. Figure XXI provides a visual of this example.

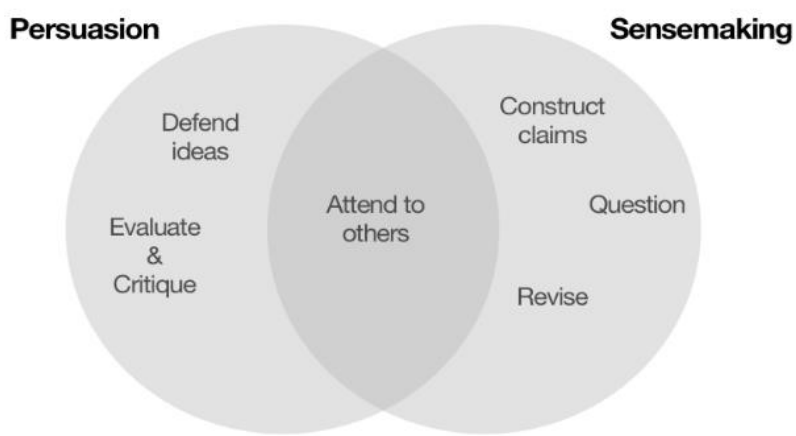

Figure XXI: Sensemaking and Persuasion Framework

Argumentation Statistics

A total of 72,046 lines were transcribed in this study. Of these, 20,0168 lines were examined by three reviewers for argumentation utterances, of which 10,721 lines were identified as containing some element of scientific argumentation discourse (e.g. a claim, a defense) during the games camp. The total number of coded argumentation utterances in the data corpus varied across days. The highest percent of argumentation utterances occurred on Day 1 (10.6%) and Day 5 (10.63%). In contrast, the lowest number of argumentation utterances occurred on Day 4 (7.66%). Participants made the highest number of declarative statements during the first day of gameplay (N=840). In contrast, defense statements were highest during the fourth (N=739) and fifth day (N=1,124) of activity. While most argumentation codes varied over time, the total number of revised statements was largely unchanged, with a range of 43-53 utterances across the five-day period (M=48). Figure XXII captures the number of argumentation codes identified in the data corpus across the five-day period. Figure XXIII provides a breakdown of argumentation codes by day.

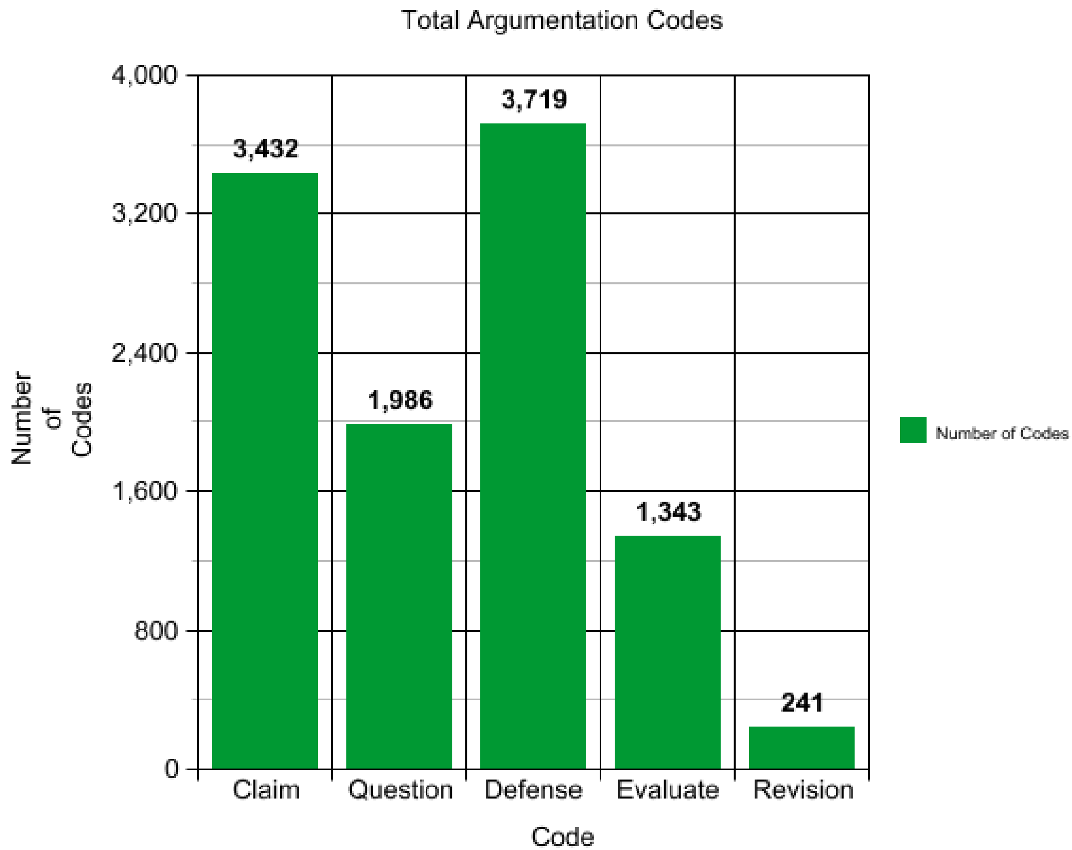

Figure XXII: Scientific Argumentation Codes Over 5 Days

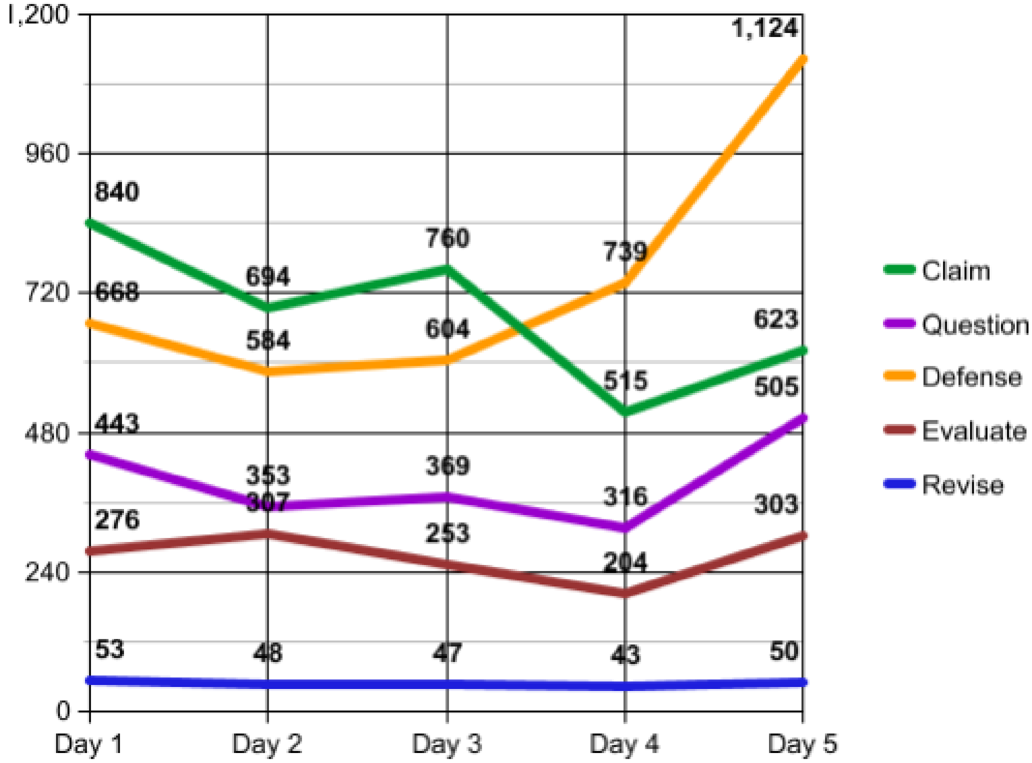

Figure XXIII: Argumentation Codes by Day

Sensemaking vs. Persuasion

A total of 5,659 lines were identified as sensemaking statements across the entire data corpus. In addition, a total of 5,062 lines were identified as persuasive statements. Figure XXIV captures these statements across the five-day period.

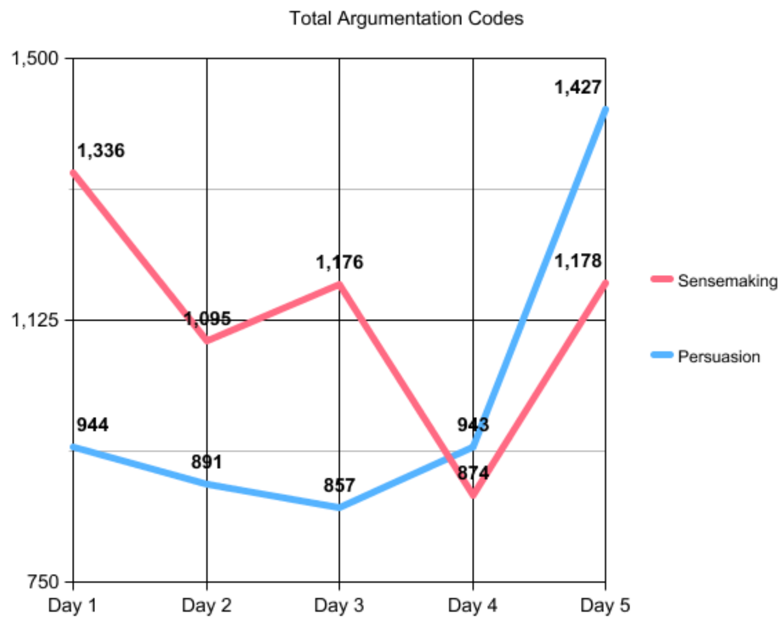

Figure XXIV: Sensemaking and Persuasion Codes by Day

The distribution of sensemaking and persuasive statements varied across the five-day session. For example, sensemaking statements were more frequent during Days 1-3. The high frequency of sensemaking statements could be attributed to youth using gameplay strategy and model construction to decipher the relationship between virus and immune system behavior. Importantly, the number of sensemaking codes drops significantly when group members prepared for their cohort presentations (Day 4). On the final day, when participants were offered new information on hypothetical solutions for stopping the Raven Virus from spreading, both sensemaking and persuasive statements sharply increased.

Discussion

The way scientific arguments and frameworks were co-constructed varied across days, with early conversations focusing on building scientific claims surrounding virus and immune system behavior. This sensemaking process, which Sikorski and Hammer (2017) identified as coherence-seeking, helps individuals seek information in order to create a “sense of unity” within the curriculum. Given space and generative questions, these researchers argued that students will naturally challenge each other's models. In this dissertation, participants were offered the same tools to investigate and build their model of virus behavior. However, the mode of expression used to convey virus and immune system behavior changed significantly as group members were asked to synthesize information learned and disseminate to others for additional review. While the construction of paper models and videos created a higher degree of sensemaking statements during the initial days of the camp, a sense of coherence was arguably reached by the time group members were asked to communicate information on Day 4 using the same resources and mode of expression as leveraged in prior days. It was not until the introduction of three hypothetical approaches to curing the Raven Virus on Day 5 that participants began to reconsider and resituate their scientific arguments to better apply this information into their existing frameworks. As a result, an increase in both sensemaking and persuasive statements occurred on the final day, particularly as participants worked to coordinate their models while simultaneously preparing to challenge other groups during the cohort debate.

These results are part of a larger discussion regarding differences between consistency and spontaneity when building science curricula (Shwartz et al., 2008), a topic further discussed in Emerging Themes (Chapter 5). The structuring of sequential activities may lead to a standardized, coherent response across classrooms, but potentially decrease the amount of ownership a child places in their own education, creating a potential barrier to mentoring opportunities. If sensemaking is viewed as a coherence-seeking activity from which participants align separate pieces of information (Sikorski and Hammer, 2017), then further considerations regarding curriculum structure should be investigated to identify how to best utilize sequential events while allowing time for personalized learning and self-discovery.

Group Specific Patterns

Scientific argumentation discourse varied significantly across groups over the five-day period. Each group differed in the number of argumentation discourse statements communicated during the five-day period. For example, participants from the Pink Fluffy Squids had more defense statements when compared to the other two groups studied. In contrast, the Odd Squad had more declarative and revised statements when compared to the other groups. Importantly, each student group reached the same conclusion on how to stall the Raven Virus, even though argumentation patterns and group composition varied significantly. In this regard, games-based learning and model construction served as valuable tools from which participants could articulate and coordinate their views in their own way.

Facilitators observed a major and unexpected shift in the use of standardized language as groups leveraged tools to communicate their ideas to those outside of their immediate learning community. However, scientific argumentation and activity within a larger data corpus represents one of many stories within this informal games-based learning environment. To better understand how middle school youth learned through gameplay and supported each other, a deeper examination of group performance across days is necessary.

Summary

The variance in scientific argumentation patterns within the context of an informal games-based learning environment for students with and without disabilities underscores how the co-construction of language is critical to situating meaning within complex frameworks. In this dissertation, student groups discussed and situated meaning in ways that made sense to other members of the group (e.g. different modes of expression). This meaning was subsequently evaluated, questioned, and revised as more information became available for review. While available resources and tools remained constant across days, the mode of expression used to communicate scientific frameworks (e.g. writing a letter to the CDC, producing a video) offered students additional opportunities to coordinate views.

Middle school youth voluntarily participated in argumentation discourse about virus and immune system behavior to build and piece together different chunks of scientific knowledge. While each group arrived at the same conclusion (vaccine) for stopping the Raven Virus, the cognitive pathway leading to this decision was nevertheless unique to each community's structure. This is important as students with disabilities must be allowed alternative pathways to demonstrate and express knowledge. Without this flexibility, valuable tools like games-based activities become a standardized assessment driven by formulaic language.

Chapter 5: Emerging Themes

This dissertation sought to answer the following research question: *How do students with and without disabilities use gameplay to construct scientific ideas*? To answer this question, I tracked and monitored scientific argumentation discourse among three middle school groups within an informal games-based learning environment. The following paragraphs investigate emerging themes that students from all groups exhibited during the camp: situating meaning through a shared language, agency, and the adoption of academic behavior.

Theme 1: Situating Meaning

The co-construction of scientific arguments within an informal learning environment allowed middle school youth with and without disabilities an opportunity to coordinate their worldviews (Cannon-Bowers & Salas, 1998; Guzzo & Salas, 1995; Hackman, 1990; Sales & Cannon-Bowers, 2000) while building and maintaining mental models surrounding virology behavior. The following paragraphs look closely at the mutual construction and negotiation of cognition (Roschelle, 1992) using shared language.

In this study, middle school youth questioned and clarified misconceptions surrounding virus behavior through the development of a shared language (Everett & Preece, 1999). This shared language, which generated scientific argumentation, was not standardized or refereed by an adult facilitator. Instead, the co-construction of scientific frameworks was situated in everyday conversation and student-driven activity. Many participants used metaphors, analogies, and slang (Brewe, 2011; Brookes, Ross, & Mestre, 2011; Manogue et al, 2014) to communicate, link, and investigate scientific concepts. These vernacular terms (e.g. “triangle things”) bolstered participant understanding (Jakobson & Wickman, 2007) during gameplay, model construction, and group discussion by giving participants a flexible channel of communication from which to situate meaning. These layers of context happened simultaneously (Cole, 1996), meaning participants constructed language and meaning together during moments of play.

As groups progressed in their activity and continued to situate meaning across days, participants refined their scientific terms, adopted more scientific vocabulary to represent virology components in model construction, and restructured past scientific arguments with newly-discovered definitions. The use of vernacular terms was arguably strategic as participants coordinated their experiences and reached a consensus on virus definitions. Popular vernacular terms from the three case studies are listed in Table XI.

Fluffy Pink Squids	**The Odd Squad**	**The Narwhals**
Triangles	Butterfly	Little squiggly thing
Bodyguards	Pac-Man	Little squiggly guy
Protein	Porpoise	Mushroom thing
Executioners	Red ones	Little triangle thing
Army	Blue ones	Big squiggly
Cannon Fodder	Three-headed Pac-Man	

Table XI: Vernacular Words by Group

Importantly, participants used more standardized language (N=6,822) to communicate scientific concepts when compared to vernacular language (N=994) throughout the five-day camp. The adoption of standardized language was higher regardless of activity type (e.g. letter to the CDC, video presentation, cohort debate). Thus, while vernacular terms created a common ground for participants to discuss and adjust scientific definitions, the standardized language embedded throughout their gameplay experience generated an alternative, and equally powerful way for groups to quickly situate meaning. For example, participants going through an unfamiliar level of Virulent may identified and resituate meaning following the experience (e.g.

“That’s a chompy” and “Chompies are proteasomes, right?”). The coordination of scientific definitions through multiple mediums (e.g. model construction, video production, script writing, and gameplay) likely contributed to the building of standardized language as well.

The coordination of multiple mediums to identify, rehearse, and communicate scientific meaning was the highest on Day 3. During that day, not only were participants asked to modify their model, continued exploring the game, and referenced past material to identify gaps in their knowledge of the Raven Virus, but they were simultaneously asked to create a video for scientists at the CDC. In this video, participants showcased their model’s progress and used evidence gathered to propose strategies for destroying the Raven Virus. Arguably, the subtle increase in vernacular language was necessary for each participant to discuss scientific concepts, build upon existing frameworks, and form a shared standardized language. Thus, while a dip in standardized language may outwardly appear as though youth struggled to adopt scientific terms, their in-group discussion nevertheless reshaped community language to better coordinate their individual world views.

On the fourth day, student groups revised statements after reflecting on the CDC videos they created the day before. Participants also reconsidered strategies for communicating information to outside group members as they prepared to outline their findings to others. Many groups also made last-minute adjustments to their model and evaluated their use of standardized language. These changes were designed to create a more coherent storyline between the virus and immune system behavior. On the last day, the scientific language and definitions across participants were more strongly synced, leading to a much higher frequency of standardized language use when compared to vernacular language. A look at standardized vs. vernacular language across time is shown on Figure XXV.

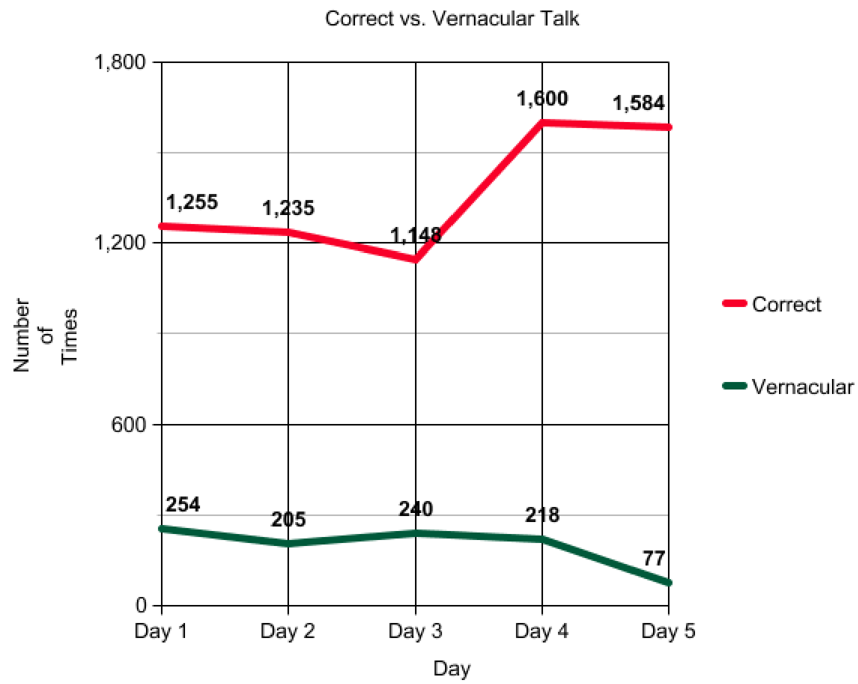

Figure XXV: Standardized vs Vernacular Talk by Day

Informal Environments and Language

The discourse patterns captured within groups demonstrates an important distinction between observations made between formal and informal learning environments. By forming and communicating new information to peers using their own language (Ash, 2004; Hutchinson & Hammer, 2010; Rosenberg et. Al, 2006), participants were co-constructing their own scientific ideas. This is wholly different from leveraging pre-established scientific terms or concepts within a classroom environment. In these instances, students are more likely to adopt scientific definitions and concepts to complete the expected outcome of the assignment (Berland et al, 2015) rather than leverage shared knowledge or tools within the environment itself. Arguably, students confined to standardized assignments have less opportunity to brainstorm or “shop around” for different ideas (Hammer & Lee, 2006) in order to better understand the phenomena in question. As a result, recommending, assembling, and verifying scientific ideas (Kapon, 2016) is harder to cultivate in formal learning environments due to teacher expectations. In short, prescribed scientific frameworks and teacher-driven conversations are frequent (Lemke, 1990) and the use of language to resolve disagreements within science education is rare (Sampson & Clark, 2008; Sandovial, 2009). Furthermore, the process of formal lesson-making is unilateral, meaning educator, school, and community are happening in concert (Cole, 1996). It's therefore important to think how context is equal or unequal, and take into account how context-creation requires multiple sides working together. The following section will briefly describe context creation in relation to communicating information from members within a group to those within the larger cohort/community.

Language and Community Sharing

In this study, the use of community language (Stevick, 1976; Dornyei, 2013) within an informal learning environment was established and built upon shared experiences and tools. However, the way youth chose to leverage those tools to make sense of complex frameworks differed from person-to-person. For example, some group members referenced visual depictions from the game to communicate virus components (e.g. ninja star) while others used textual information from the in-game almanac to express their ideas. In this regard, the games-based learning activity offered participants multiple means of expression and representation (Nelson, 2014) to personalize their journey. Just as importantly, participants recognized how ***non-group*** members may not as easily understand or decipher vernacular terms. For example, while words like "squiggly hot dog" and "triangle" were perceived as accurate within each group's inner learning community, these vernacular phrases become inaccurate when situated in a specific context (Gee, 2015). In essence, vernacular language that worked effectively in the microworld of the smaller group did not necessarily translate as easily to the macroworld (Cole, 1996) or cohort. This required participants to reconsider and reshape their language once more. As information about virus and immune system behavior became increasingly complex, participants needed to discuss and renegotiate their use of scientific terms. By the end of the week, all group members adopted the word “slicer enzyme” to replace other vernacular terms (e.g. “snowflake”) and bring additional context of what they learned to the larger community.

Summary

Through *Virulent*, middle school youth reflected upon and reconsidered how they communicated information with each other. For students with and without disabilities, gameplay offered several avenues from which to amplify their voice and produce meaningful artifacts. These shared learning experiences helped foster rich discussions surrounding science-based language and argumentation. However, just as impactful to language was student-driven motivation and persistence to better understand the complex systems within the game. In the next section, I will show how participant agency and ownership played an active role in creating a positive learning experience for all groups involved.

Theme 2: Agency

In this study, middle school youth exercised choice by leveraging tools and methodologies that strengthened their own understanding of virus behavior. Equally important, participants took ownership of their own education by investigating and constructing scientific frameworks through a peer-driven community structure. The following paragraphs briefly describe participant agency and its impact on group performance as members worked together to stop the Raven Virus from reaching global pandemic.

In their mission to stall the Raven Virus, participants created and refined multimodal data channels (e.g. paper models, gameplay) to inform their scientific arguments and ideas. These data channels were evaluated and leveraged by a combination of individual and group-defined parameters. For example, the Pink Fluffy Squids leveraged gameplay and model construction as their primary resources for understanding scientific material. In contrast, the Odd Squad preferred using the in-game almanac to guide their decisions on model construction. This evaluation allowed for moments of mentorship within each community of practice (Rogoff, 1990) whereby participants guided each other's views (Lave & Wenger, 1991; Nash & Shaffer, 2010) and created a constant "feedback loop" from which to continue their discussions.

This "feedback loop" was not a rubric or pre-established process defined by groups in the camp. Instead, participants demonstrated their mastery of scientific knowledge by evaluating each other's progress (Farrington et. al, 2012) and creating new arguments based on evidence-based practices. For example, one participant from the Odd Squad discovered slicer enzymes and developed a scientific claim based upon her observation in-game (e.g. "it's an enemy"). From there, other participants verified this claim through a combination of tools (e.g. game, model) and discussions to determine the slicer enzyme's relationship with the Raven Virus (e.g. "It will kill the genome"). In the end, how the slicer enzyme was depicted and communicated to outside members was based upon an underlying coordination of the group's shared experiences. Such coordination took a mixture of cooperative and collaborative exchanges.

Collaboration and Cooperation

Participants furthered their own knowledge of virus behavior through a combination of cooperative and collaborative opportunities. In the case studies outlined in this dissertation, participants cooperated with other team members to collect information on virus behavior while simultaneously collaborating on the co-construction of new scientific ideas. For example, group members worked independently to investigate and document components of the immune system during a game level. Once the level was complete, group members came together to produce a single product based upon their collaborative work and discussion. While not every person experienced the same outcome (Crowley & Jacobs, 2002), the tinkering with (Gutwill, Hido & Sindorf, 2015) and exploration (Peppler, Halverson & Kafai, 2016) of artifacts encouraged individuals to re-think dialogues. In short, learning happened not by *complete and immediate agreement*, but through building to scientific explanations together (Berland & Reiser, 2011; McNeill & Krajcik, 2008; Naylor, Keogh, & Downing, 2007; Osborne & Patterson, 2011). This finding is unlike many observations made within formal learning environments where students do not naturally collaborate with each other on projects (Azmitia, 1996; Krajcik & Shin, 2014), but instead are guided through teacher-driven activity. Yet as Andriessen and Baker (2014) argued, cultural, social, and experiential influences outside of school shape how arguments are created. Thus, it becomes likely that both cooperative and collaborative discussion leading to the co-construction of scientific arguments will differ greatly when middle school youth are presented with an opportunity to learn outside of formalized environments. Through this work, middle school participants took agency to build their own education while supporting others in the pursuit of knowledge construction.

Summary

Toppo (2015) described games-based learning as a living assessment whereby players are learning as they journey through different levels. Through this, games are constantly adjusting to player action and giving feedback based upon choice. This sophisticated system is a potentially transformative tool for encouraging independent and group learning. However, while informal learning environments are without the same standardized structure that exist in the classroom setting, researchers cannot automatically assume participants will refrain from restructuring informal spaces to mirror school-based tasks. The following section illustrates how academic behavior remains a key fixture to informal environments.

Theme 3: Academic Behavior

An identified challenge for youth learning about science within informal environments is the possible encroachment of academic-based structures within this arena (National Research Council, 2009). In this study, participants negotiated academic behaviors and redefined their role as mentor or mentee based upon newly discovered information. The following paragraphs briefly describe the benefits and drawbacks observed when participants used standardized activity to facilitate student-driven conversations within this informal games-based environment.

How a community of learners acts within an informal environment is different from an academic environment due to pre-established cultural and educational norms (Braund & Reiss, 2006). However, this does not preclude children from using academic behaviors to build and cultivate a community of learners within an informal environment, particularly during early moments of gameplay. In this study, participants initially approached gameplay activity and model construction using behaviors commonly found in formal academic environments (e.g. raising their hand, asking about grades). Similarly, many groups initially believed a single, correct approach existed to stopping the Raven Virus from reaching global pandemic. Participants sought early guidance from facilitators to determine whether their group was "correct" or "on the right track." Although facilitators reiterated that no formal, standardized framework existed to stalling the virus, many participants nevertheless sought a rubric system to measure their performance.

The academic behaviors exhibited by participants signify a potentially deeper challenge for educators looking to implement games-based activities within informal spaces. Youth were pre-conditioned to complete standardized frameworks and assessments in situations beyond the traditional classroom environment. This behavior caused participants to use methodological approaches and tools in ways that mirrored classroom activities. The academic behaviors adopted by some participants presented an initial challenge to group dynamics as not every participant was inclined to use academic behaviors to discuss complex scientific frameworks or ideas.

Leveraging Academic Behaviors

The adoption of academic behaviors was beneficial to some groups because it afforded an opportunity to structure model-making and gameplay discussion. For example, Daniel from the Pink Fluffy Squids took an early leadership role in the group and periodically asked others for feedback while taking notes on virus behavior. These actions helped the group quickly document and accelerate their model-making activity. It also created verbal milestones for player progression in the game (e.g. Had anyone found the slicer enzyme? How many people had already seen the golgi apparatus?). These questions mirror questions a teacher may ask a student.

At school, such questions would be associated with an assessment of a student's ability to accurately define or complete a task. Here, peer-driven questions piqued interest and ultimately encouraged others to seek answers. Participants like Adrian suddenly kept a close eye on early identified items (e.g. triangle) and adjusted gameplay in the hope of quickly finding other scientific components to share with peers. In another example, Mia from the Odd Squad prompted group members to participate in model-making and gameplay activity. Her actions resembled those of a teacher asking students for information on what they saw/heard. However, Mia never told her group what information was concretely wrong or right. Instead, she took on the role of a scientist and encouraged her group members to investigate scientific claims through a combination of experimentation and gameplay.

Academic Hurdles

While the adoption of academic behaviors helped jumpstart conversations on virus behavior, this type of approach did not always work to a participant's advantage. Daniel was sometimes inflexible with model construction and group feedback, which ultimately caused friction with his younger brother. For example, William chose to develop a new, alternative model that was wholly different from what Daniel (the leader) wanted to see. William's decision to create a representation of virus and immune system behavior benefited group members because it highlighted the cyclical pattern that otherwise did not exist in their model. Daniel also recognized how multiple means of representation (Nelson, 2014) supported group learning and encouraged this activity long-term.

Reworking Academic Behavior as Agency

In some respects, participants who structured their work to mirror academic methods did not perceive their behavior as school-like. Instead, participants became deeply invested in their personal education and the advancement of the community around them. It was an individual and collective drive to make something useful, valuable, and meaningful. The permission to create self-driven products beyond a pre-established rubric caught many of the participants by surprise. It was no longer about what the facilitator expected from them, but what each member expected from each other, and how each of them chose to evaluate success in terms of a group activity. Simply put, the construction, evaluation, debating, and coordination of multiple artifacts in conjunction with gameplay was not filtered by an authority figure, but checked by participants to determine accuracy. Participants learned that it was okay to argue with each other about whatever they believed was important to their group, for however long was necessary, until their production was complete. But then, how did the facilitators feel about this experience?

Facilitators as Teachers

While games-based learning environments afford educators a unique opportunity to introduce new material, many of these activities continue to occur in a formal academic setting and are driven by teacher directive (McLaughin, 2005). The teacher's perspective may serve as a valuable way to gauge knowledge gains, but it cannot always accurately detect moments of learning. In this study, the volunteer staff did not always perceive student activity or collaborative discourse as successful. Some facilitators questioned whether participants were learning *enough* and recalled how "off task" behavior was potentially detrimental to knowledge construction. These facilitators called for a revision of the curriculum because many felt some type of verbal or written assessment was needed to truly gauge participant activity. In this case, discourse connecting virus behavior with gameplay was interpreted by some as negative when compared to dialogue that looked exclusively at model construction. As one facilitator explained:

> "I don't really think the groups learned anything about the [Raven Virus]. It was a little crazy, you know? I saw them talking about the game and how to play it, and sure that tells me that everyone is having fun with the game, but that doesn't tell me how much any of them know about viruses. I just can't be sure what went on in their heads. And honestly, they aren't using the terms… I don't know."

In contrast, facilitators *without* a formal teaching degree saw this same type of behavior as exploratory and fun. The facilitator in charge of observing the Odd Squad recalled her group as "always laughing, and sometimes silly, but constantly in the mindset of solving the problem, even if they didn't fully understand what the Raven Virus was, yet." The facilitator for the Narwhals shared a similar perspective, believing her group was "active and diverted from the subject every so often, but these diversions actually looped back to what they were learning. It just happened in a roundabout way… in a way that made sense for them."

The facilitator role ultimately shifted from observer to what Mia described as "honorary group member" by the end of the camp. In the beginning, the facilitator's logistical knowledge of the curriculum structure and ability to troubleshoot technical issues created a teacher-like role. Participants approached the facilitator with questions related to virus or immune system behavior and looked for clarification when trying a new activity for the first time. However, this role shifted once participants became acclimated to the curriculum narrative, began developing gameplay strategy, and critically exploring hypothetical solutions to stalling the Raven Virus. Group members began to take on and exchange leadership roles while the facilitator continued to serve as a background support.

What is equally important is that middle school participants with and without disabilities sought clarification on academic behaviors and expectations. While group members like Adrian wanted to know whether homework was graded, participants like Mia took a leadership approach by checking on participants much like "my teacher would have done." In this regard, success was ultimately measured and defined by the participants within a group.

Implications

In this study, peer-driven conversation among middle school participants with and without disabilities generated rich conversations based on scientific frameworks. Games served as a flexible tool within the informal environment, providing participants with visual cues and hands-on engagement that could be transposed onto a real-life activity. Whereas in formal academic environments, students with disabilities or those identified as "at-risk" would likely be separated from peers in favor of personalized intervention, this study was designed to create a single place where middle school youth could leverage tools that best fit each of their needs.

Social activity was the catalyst for learning, and gameplay the shared experience from which youth could communicate their ideas. This environment was not created to accommodate the science enthusiast or hardcore gamer, but designed to allow students from multiple backgrounds an opportunity to bolster their voice in ways that best suited them. As Toppo (2015) emphasized, we do not really *know* what is happening when a child plays. Instead, we imagine what children are (or in many cases, are not) learning while taking efforts to correct this trajectory. The use of games-based learning opportunities inside and outside of school to educate children on core subjects must be rethought. Imagine how transformative schools could become if students with and without disabilities leveraged social activity within gameplay to create and understand scientific frameworks on their own terms.

Implications for Disability and Games

The implementation of mobile technologies in classroom environments has increased (Sharples & Pea, 2014), with researchers studying and encouraging the use of mobile devices to support scientific learning in formal environments (Krajcik & Shin, 2014; Norris & Soloway, 2009). However, using technology (and subsequently, games-based learning) in formalized environments to fulfill standardized assessments could restrict multiple means of expression. Often, students are trained to reproduce information based on pre-established academic activities and structures (Collins, 1989; Hutchinson & Hammer, 2010). For example, educator-driven discussions and activity reinforces standardized practices while not accounting for multiple means of representation and expression, particularly for students with disabilities.

In this study, students with and without disabilities used multiple tools to communicate frameworks and produce artifacts on virus behavior within an *informal* learning environment. These actions were completed without instruction from an educator, and through peer-driven support. In this informal space, students were not identified by a disability status or measured by academic performance. Instead, participants served as both follower and leader (Gee, 2011), making fluid shifts in their role based on expertise. The following section summarizes the effects of academic behavior on students with disabilities and how an informal games-based learning environment served as a catalyst for change.

At the beginning of this study, youth-driven inquiry was slow, with participants seeking assessment-based practices to measure success. Students with disabilities frequently voiced concern about whether their work was executed correctly. Participants also recalled past formal academic experiences (e.g. at school) to assess their own abilities at the camp (e.g. "I'm just a bad writer" or "I don't do good in reading"). The mindset that youth with disabilities encountered within formal learning environments created an unforeseen barrier within the camp: namely, that student confidence in their ability to succeed was notably low. This may explain why participants like Adrian were initially reluctant to participate in groupwork. For him and others, the social isolation associated with academic intervention was not restricted to classroom environments, but was a scenario that created additional barriers to peer interaction as a whole. However, games-based learning created an opportunity for youth with disabilities to communicate and demonstrate ideas in a personalized way.

In this study, playing *Virulent* and the discussion surrounding virus behavior created a continual feedback loop for participants to track during the co-construction of scientific ideas. For example, when a player was unable to complete a level because their virus was destroyed by a slicer enzyme, the group discussed the outcome, planned alternative strategies based on their prior experience with that level, and simultaneously co-discovered the functions of a slicer enzyme. As a result, this feedback loop supported individual choice (Toppo, 2015) and multiple means of representation (Nelson, 2014). In turn, group members came together to reciprocate similar, but differing experiences surrounding gameplay, model construction, and video production. It was the learning environment and activities surrounding gameplay that gave students, particularly those with disabilities, a space to share information without the constraint of a pre-established agenda or identity. As Squire (2006) explained, gameplay and the activities generated from this community are designed experiences. Such experiences are less easily reproduced within the context of formal learning environments due to a combination of resources, time, and curriculum approach. In school, curriculum is deconstructed into smaller chunks of information for students to learn and process. The moments surrounding learning and failure are largely avoided, creating a wholly different space from the games-based learning environments that we see today (Squire, 2004). In this way, students with disabilities are restricted in their ability to become expert problem-solvers while at school because the curriculum is structured to promote only a specific outcome as successful. However, learning through failure is prominent, discussed, and encouraged through games. Similarly, the activities surrounding gameplay behavior, such as model-making and video production, are seen as living works. In this study, participants did not walk away from models or artifacts asking "what they did wrong," but instead asked "what could we do better?" Thus, participant ownership began taking shape.

By the end of the camp, youth with and without disabilities took ownership of each other's artifacts and presentations, and openly negotiated their worldviews in preparation for the cohort debate. The interconnected processes of social relationships and individual learning through play (Nasir, 2005) highlight the formative role of social context and interaction in games-based activity. Similarly, this shift in participation was not about students with disabilities "blending in" with peers, but youth actively creating and engaging in leadership opportunities with one another. As such, this dissertation serves as a touchstone to how informal learning environments may transform the way students with and without disabilities work together to take ownership of their education in ways not possible in traditionally-structured classroom environments.

Implications for Disability and Identity

In this study, students with and without disabilities worked together to coordinate ideas within a games-based learning environment. The use of disability as a form of identity was based on the definitions brought to the camp by the participants. For students with disabilities, their identity in school is formal and codified, but is not always addressed in ways that students have found the most beneficial to learning. For example, Adrian's sentiment toward school was largely negative and his anxiety about making mistakes or being assessed based on pre-established criteria was observed during the earliest days at camp.

However, students with and without disabilities were not easily identified as falling into one category or another during the camp. There was no indication of students struggling, "falling behind," or social conflicts within the groups by facilitators. The game and corresponding environment offered a neutral space for students to freely collaborate, discuss, and create new scientific ideas.

While other forms of identity, such as race and gender, emerged during the course of this dissertation work, further study of these conversations must be considered that go beyond the scope of this study. Future work that ties disability, race, and community studies in a games-based learning environment should be pursued to better understand this intersection.

Implications for Big Data, Disability, and Games

This dissertation leveraged mixed methodologies to illustrate player behavior within the context of an informal learning environment. The harnessing of qualitative and quantitative data channels within discourse analysis created a unique opportunity to examine player sentiment in-group and compare these findings on a larger scale. Results from this study demonstrate various learning pathways that players used to create, build upon, and solidify scientific frameworks of virus behavior. Furthermore, this analysis demonstrates the coordination of ideas by pairing scientific argumentation discourse with in-room observations. By hand-coding scientific discourse between and among groups, information regarding shifts in argumentation patterns can be studied either on a micro or macro level while preserving the subtle nuances of learning.

In this study, gameplay served as one of several tools that students used to learn about virus and immune system behavior. Other activities included model creation, video production, and presenting newly discovered information to outside group members. Informal learning communities, like the groups created during this study, serve as a “middle space” (National Research Council, 2011) where conversation surrounding content is less standardized but is nevertheless contained within loosely structured activities. By giving students a learning space from which to build shared experiences and *multiple tools* with which to express their insights, each group successfully reached similar conclusions on their own terms. This demonstrates a need to use gameplay in tandem with other material and activities, as otherwise a single, standalone gameplay experience may not elicit the same collaborative exchange.

This dissertation serves as a guidepost for researchers looking to reconsider opportunities for designing and tracking games-based learning opportunities among students with disabilities on a larger scale, and harnessing discourse alongside educational data mining techniques. While studies on games-based learning for students with disabilities exist, many researchers continue to investigate the landscape on smaller scales and use self-reported data or academic records to drive their findings. Additional research that merges student discourse, gameplay behavior, and clickstream data should be conducted in the future. In particular, future research should address how major shifts in discourse surrounding community definitions occur in correspondence with gameplay activity, both among and between members of the same group.

Future Studies

Future studies should take a deeper look at how games-based learning impacts students with and without disabilities within informal environments. Possible routes to explore include knowledge gains in scientific material, the co-construction of scientific arguments, collaborative learning, mentorship, and the production of scientific models through gameplay use. Importantly, scholars must be careful not to design their study to encourage the separation of students into two separate, but equal groups (e.g. students with and without disabilities). Such a distinction risks promoting exclusion of students with disabilities from games-based opportunities.

A deeper look at facilitator behavior in supporting students with and without disabilities in games-based learning environments should be studied at length. This is important because how facilitators perceive and respond to students, even those who may not be readily identified as having a disability, could unknowingly impact learning outcomes. Facilitator observations and behaviors are also important to understanding how students interact with or respond to role-models in an informal learning environment. In addition, how educators perceive gameplay and dialogue as "on task" should be investigated to understand misconceptions of language in play. Similarly, a look at designing environments where students can learn about biology without an inflexible academic rubric must also be considered. In an era where maker-spaces are pushing the frontier of the digital age and giving children an experience to create something wholly their own, games may hold the same promise.

Future research on games-based activities within informal learning environments should consider using mixed-methods, particularly when looking at students with disabilities. Just as games serve as a flexible tool whereupon player feedback is customized by activity, each student with a disability will experience a different outcome based upon their behavior in-game. From discourse to clickstream data, understanding how students with disabilities work independently and alongside peers to construct frameworks requires the harnessing of multiple data channels.

This dissertation examined how multi-ability groups worked together, with the finding that informal environments create various forms of social interaction that diverse learners can leverage in ways that benefit their needs. Future research studies should closely examine how diverse learners collaborate with each other to produce, revise, and communicate scientific artifacts among peers, particularly when games-based learning is used as a supporting tool in the curriculum.

Finally, the use of informal games-based learning environments in order to construct scientific arguments is a compelling issue, but rarely studied. Additional research is needed to explore the building of scientific arguments on a larger scale. These future studies should investigate how participants use games as one of several tools to understand science, and how this understanding is amplified through mean-making activities. This is particularly important as this study demonstrates that, by creating an environment that houses various tools for learning, students can amplify voice and strengthen agency. Furthermore, exploring this research may prove critical as schools turn their attention to more personalized learning activities in science and beyond.

Limitations

There are several limitations to this study. First, portable audio recorders are not guaranteed to capture all conversation due to a) participant movement, b) equipment failure, and c) the noise level within the room itself. A second limitation is participant retention. There was no mandatory requirement for participants to attend each session. In addition, participants may have missed a session due to an unexpected illness, a family emergency, transportation issues, a scheduling conflict, or disinterest in the activity. A third limitation to this study is participant background knowledge. Not every person enrolled in the program was a self-identified video gamer or science enthusiast. Thus, each group was composed of participants with various levels of scientific knowledge, gameplay strategies, and untapped interests. Similarly, while groups were randomly generated, participants had an opportunity to become members of a group where past connections already exist (e.g. friend, cousin, sibling, or neighbor). These connections are tracked and monitored. However, this can impact the composition of the group, dialogue structure, and ultimate outcome.

A fourth limitation to this study is facilitator background. Each facilitator had different academic training. For example, one facilitator was a seasoned teacher with expertise in classroom management whereas another was an undergraduate student with an extensive background in engineering. To counteract this, mandatory training was required for every facilitator in order to establish expectations of the curriculum and students.

A fifth limitation is transcription cleaning and cost. Our research team could only afford to submit a portion of our recorded audio for transcription. Thus, the analysis was limited to 3 10-minute chunks of dialogue across Day 1-Day 5 per group. A sixth limitation is argumentation analysis. Data analysis was confined to a single argumentation structure as created by Berland and Reiser (2011). This argumentation structure includes the “defense” code which arguably can fit within the categories of “sensemaking” *and* “persuasion.” In addition, this argumentation coding scheme was used for the classroom setting and not meant for informal environments.

Another limitation is not knowing each participant’s reading level. The research team gathered no formal information on each participant’s academic record or performance. It remains unclear how much participants read and understood the corresponding text in the game. A final limitation to this study was the identification of individual participants in transcription. While facilitators supported research team members in the identification of speakers in the transcripts itself, audio quality and similarities in voice made complete identification hard to achieve. As such, not every participant could be fully identified in transcription and not every turn of talk was tagged with an identified speaker.

Conclusion

In this study, students with and without disabilities used gameplay strategy to co-construct scientific arguments within an informal learning environment. Participants leveraged digital tools to clarify misconceptions of virus behavior, develop a shared language, and refine scientific arguments over a five-day period. Initially, participants referred to prior assessment-based practices from a formal academic environment to define their potential success within an informal one. However, student-driven inquiry and activities surrounding gameplay afforded participants an opportunity to co-construct a community language based upon shared learning experiences within their environment. As such, the environment and curriculum activities surrounding the gameplay experience created an opportunity for students to actively engage, coordinate, and build upon their scientific ideas with each other. These activities also allowed for peer-driven exploration and debate without following a specific formula. In the end, students with and without disabilities took ownership of each other's educational outcomes through multiple means of expression and representation in gameplay. All student groups not only constructed their own version of a virus model, but every group independently arrived at the same decision on how to stop the Raven Virus using their collective experiences. In these moments of play, students with disabilities shifted between the role of leader and follower, creating an alternative space for learning, engaging, and discussing science education. Furthermore, this data capture occurred not through assessment-based practices, but through applying discourse analysis on a larger scale while preserving the subtle nuances of learning. Future research should concentrate on ways to harness qualitative and quantitative data channels within informal games-based learning environments, strategies for building inclusive digital spaces surrounding gameplay activity, and building informal spaces with structured activities that accommodate students of diverse needs.

References

Al-Yagon, M. (2007). Socioemotional and behavioral adjustment among school-age children with learning disabilities: The moderating role of maternal personal resources. *The journal of special education*, *40*(4), 205-217.

Artiles, A. J., Kozleski, E. B., Trent, S. C., Osher, D., & Ortiz, A. (2010). Justifying and explaining disproportionality, 1968–2008: A critique of underlying views of culture. *Exceptional Children*, *76*(3), 279- 299.

Babco, E. (2003). Trends in African American and Native American participation in STEM higher education. *Commission on Professionals in Science and Technology, New York, NY*.

Bal, A., Kozleski, E. B., Schrader, E. M., Rodriguez, E. M., & Pelton, S. (2014). Systemic trans formation from the ground–up using learning lab to design culturally responsive schoolwide positive behavioral supports. *Remedial and Special Education*, *35*(6), 327-339.

Bal, A., & Trainor, A. A. (2015). Culturally responsive experimental intervention studies: The development of a rubric for paradigm expansion. *Review of Educational Research*, 0034654315585004.

Bartel, C. (2012). Resolving the gamer's dilemma. *Ethics and Information Technology*, *14*(1), 11-16.

Barth, E. M., & Krabbe, E. C. (1982). *From axiom to dialogue: A philosophical study of logics and argumentation*. Walter de Gruyter.

Belland, B. R. (2010). Portraits of middle school students constructing evidence-based arguments during problem-based learning: The impact of computer-based scaffolds. *Educational technology research and Development*, *58*(3), 285-309.

Berk, L. E., & Winsler, A. (1995). *Scaffolding Children's Learning: Vygotsky and Early Childhood Education. NAEYC Research into Practice Series. Volume 7*. National Association for the Education of Young Children, 1509 16th Street, NW, Washington, DC 20036-1426 (NAEYC catalog# 146).

Berland, L. K., & Reiser, B. J. (2011). Classroom communities' adaptations of the practice of scientific argumentation. *Science Education*, *95*(2), 191-216. Chicago

Birch, J. A. C. K., & Johnstone, B.K. (1975). Mainstreaming a new public policy in Education. Presented at the Annual Convention of the America Association of School Administrators, Dallas, Texas.

Blackwell, L., Trzesniewski, K., & Dweck, C.S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. Child Development, 78, 246-263.

Boaler, J. (2013, March). Ability and mathematics: the mindset revolution that is reshaping education. In *Forum* (Vol. 55, No. 1, pp. 143-152). Symposium Journals.

Bornstein, M. H., Cote, L. R., Maital, S., Painter, K., Park, S. Y., Pascual, L., ... & Vyt, A. (2004). Cross-Linguistic analysis of vocabulary in young children: Spanish, Dutch, French, Hebrew, Italian, Korean, and American English. *Child Development*, *75*(4), 1115-1139.

Boykin, A. W., Albury, A., Tyler, K. M., Hurley, E. A., Bailey, C. T., & Miller, O. A. (2005). Culture-based perceptions of academic achievement among low-income elementary students. Cultural Diversity and Ethnic Minority Psychology, 11, 339–50.

Braaten, M., & Windschitl, M. (2011). Working toward a stronger conceptualization of scientific explanation for science education. *Science Education*, *95*(4), 639-669.

Brosnan, J., & Healy, O. (2011). A review of behavioral interventions for the treatment of aggression in individuals with developmental disabilities. *Research in developmental disabilities*, *32*(2), 437-446.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher*, *18*(1), 32-42.

Brown, M. R. (2007). Educating all students: Creating culturally responsive teachers, classrooms, and schools. *Intervention in school and clinic*, *43*(1), 57.

Bryan, T., Burstein, K., & Ergul, C. (2004). The social-emotional side of learning disabilities: A science-based presentation of the state of the art. *Learning Disability Quarterly*, *27*(1), 45-51.

Cannon-Bowers, J. A., & Salas, E. E. (1998). *Making decisions under stress: Implications for individual and team training*. American Psychological Association.

Carter, E. W., Lane, K. L., Pierson, M. R., & Glaeser, B. (2006). Self-determination skills and opportunities of transition-age youth with emotional disturbance and learning disabilities. *Exceptional Children*, *72*(3), 333-346.

Carter, E. W., Owens, L., Trainor, A. A., Sun, Y., & Swedeen, B. (2009). Self-determination skills and opportunities of adolescents with severe intellectual and developmental disabilities. *American Journal on Intellectual and Developmental Disabilities*, *114*(3), 179-192.

Carter, E. W., Lane, K. L., Cooney, M., Weir, K., Moss, C. K., & Machalicek, W. (2013). Parent assessments of self- determination importance and performance for students with autism or intellectual disability. *American Journal on Intellectual and Developmental Disabilities*, *118*(1), 16-31.

Cartledge, G., & Kourea, L. (2008). Culturally responsive classrooms for culturally diverse students with and at risk for disabilities. *Exceptional Children*, *74*(3), 351-371.

Chan, D. W. (2012). Life satisfaction, happiness, and the growth mindset of healthy and unhealthy perfectionists among Hong Kong Chinese gifted students. *Roeper Review*, *34*(4), 224-233.

Cheney, D., Flower, A., & Templeton, T. (2008). Applying response to intervention metrics in the social domain for students at risk of developing emotional or behavioral disorders. *The Journal of Special Education*.

Coffey, A., & Atkinson, P. (1996). *Making sense of qualitative data: complementary research strategies*. London: Sage Publications, Inc.

Cohen, E. G., Briggs, D., Filby, N., Chin, E., Male, M., Mata, S., & Swanson, P. (2004). Teaching demanding strategies for cooperative learning. *SUNY series, Teacher Preparation and Development*, 143.

Cole, M. (1998). *Cultural psychology: A once and future discipline*. Cambridge, MA: Harvard University Press.

Collins, J. (1989). Hegemonic practice: Literacy and standard language in public education. *The Journal of Education*, *171*(2), 9-34.

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Crowley, K., & Jacobs, M. (2002). Building islands of expertise in everyday family activity. *Learning conversations in museums*, 333-356.

Dalsen, J. (2017). Special Education Technology: Then and Now. *32*, 102-108.

Deaney, R., Chapman, A., & Hennessy, S. (2009). A case-study of one teacher's use of an interactive whiteboard system to support knowledge co-construction in the history classroom. *The Curriculum Journal*, *20*(4), 365-387.

Demanding Strategies for Cooperative Learning: A comparative study of five teacher education programs. In E. G. Cohen, C. M. Brody & M. Sapon-Shevin (Eds.), Teaching Cooperative Learning: The Challenge for Teacher Education. Albany, NY: State University of New York Press.

Dewey, J. (1928). *Progressive education and the science of education*. Progressive Education Association.

Dweck, C. S. (2000). *Self-theories: Their role in motivation, personality, and development*. Psychology Press.

Dweck, C. (2008). Mindsets and math/science achievement. Retrieved from: growthmindsetmaths.com

Dweck, C. S. (2010). Even geniuses work hard. *Educational Leadership*, *68*(1), 16-20.

Dweck, C., Walton, G. M., & Cohen, G. L. (2011). Academic tenacity: Mindsets and skills that promote long-term learning. *Gates Foundation. Seattle, WA: Bill & Melinda Gates Foundation*.

Duckworth, A. L., & Seligman, M. E. P. (2005). Self-discipline outdoes IQ in predicting academic performance of adolescents. Psychological Science, 16, 939–944.

Duschl, R., Ellenbogen, K., & Erduran, S. (1999, April). Understanding dialogic argumentation among middle school science students. In *Invited paper at the annual meeting of the*

American Educational Research Association (AERA), Montreal.

Eccles, J. S., Wigfield, A., Harold, R., & Blumenfeld, P. B. (1993). Age and gender differences in children's self- and task perceptions during elementary school. Child Development, 64, 830–847.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual review of psychology*, *53*(1), 109-132.

Egan, K. (1997). *The educated mind: How cognitive tools shape our understanding*. University of Chicago Press.

Elias, M. J., Lantieri, L., Patti, J., Walberg, H. J., & Zins, J. E. (1999). Violence is preventable. *Education Week*, *18*(36), 45-49.

Elias, M. J., Bruene-Butler, L., Blum, L., & Schuyler, T. (2000). Voices from the field: Identifying and overcoming roadblocks to carrying out programs in social and emotional learning/emotional intelligence. *Journal of Educational and Psychological Consultation*, *11*(2), 253-272.

Elias, M. J., & Tobias, S. E. (1996). *Social problem solving: Interventions in the schools*. Guilford Press.

Elksnin, L. K., & Elksnin, N. (2004). The social-emotional side of learning disabilities. *Learning Disability Quarterly*, *27*(1), 3-8.

Elliot, A. J., & Dweck, C. S. (2005). Competence and motivation. *Handbook of competence and motivation*, 3-12.

Erickson, W., Lee, C., von Schrader, S. (2016). Disability Statistics from the 2014 American Community Survey (ACS). Ithaca, NY: Cornell University Yang Tan Institute (YTI). Retrieved Nov 24, 2016 from www.disabilitystatistics.org

Ferri, B. A., & Connor, D. J. (2010). 'I was the special ed. girl': Urban working-class young women of colour. *Gender and Education*, *22*(1), 105-121.

Festoon, C. M., & Nutta, J. W. (1999). *Virtual instruction: Issues and insights from an international perspective*. ABC-CLIO.

Fields, D. A., & Kafai, Y. B. (2009). A connective ethnography of peer knowledge sharing and diffusion in a tween virtual world. *International Journal of Computer-Supported Collaborative Learning*, *4*(1), 47-68.

Fowler, C. H., Test, D. W., Cease-Cook, J., Toms, O., & Bartholomew, A. (2014). Policy implications of high school reform on college and career readiness of youth with disabilities. *Journal of Disability Policy Studies*, *25*(1), 19-29.

Frederickson, N., Simmonds, E., Evans, L., & Soulsby, C. (2007). Assessing the social and affective outcomes of inclusion. *British Journal of Special Education*, *34*(2), 105-115.

Freire, P. (1970). *Cultural action for freedom* (pp. 476-521). Harvard educational review.

Gargiulo, R. M., & Metcalf, D. (2015). *Teaching in today's inclusive classrooms: A universal design for learning approach*. Nelson Education: Boston.

Gee, J. P. (2001). Reading as situated language: A sociocognitive perspective. *Journal of adolescent & adult Literacy*, *44*(8), 714-725.

Gee, J. P., & Hayes, E. R. (2011). *Language and learning in the digital age*. Routledge.

Gee, J. P. (2013). *Good Video Games+ Good Learning: Collected Essays on Video Games, Learning and Literacy*.

Gee, J. (2015). *Social linguistics and literacies: Ideology in discourses*. Routledge.

Genetic and Rare Diseases Center (2016). https://rarediseases.info.nih.gov/diseases/pages/31/

faqs-about-rare-diseases.

Gerard, L. F., Varma, K., Corliss, S. B., & Linn, M. C. (2011). Professional development for technology-enhanced inquiry science. *Review of educational research*, *81*(3), 408-448.

Gillies, R. M. (2004). The effects of communication training on teachers, and students, verbal behaviours during cooperative learning. International Journal of Educational Research, 41(3), 257-279.

Gillies, R. M., & Boyle, M. (2008). Teachers' discourse during cooperative learning and their perceptions of this pedagogical practice. Teaching and Teacher Education, 24, 1333-1348.

Gillies, R. M., & Haynes, M. (2011). Increasing explanatory behaviour, problem- solving, and reasoning within classes using cooperative group work. Instructional Science, 39, 349-366.

Goggin, G., & Newell, C. (2003). *Digital disability: The social construction of disability in new media*. Rowman & Littlefield.

Gregg, N. (2007). Underserved and unprepared: Postsecondary learning disabilities. *Learning Disabilities Research & Practice*, *22*(4), 219-228.

Gresham, F. M., Sugai, G., & Horner, R. H. (2001). Interpreting outcomes of social skills training for students with high-incidence disabilities. *Exceptional children*, *67*(3), 331-344.

Guzzo, R. A., & Salas, E. (1995). *Team effectiveness and decision making in organizations* (Vol. 22). Pfeiffer.

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard*

Educational Review, *84*(4), 495-504.

Hays, P. A. (2001). *Addressing cultural complexities in practice: A framework for clinicians and counselors*. American Psychological Association.

Heath, S. B. (1983). *Ways with words: Language, life and work in communities and classrooms*. Cambridge University Press.

Hoff, E. (2006). How social contexts support and shape language development. *Developmental Review*, *26*(1), 55-88.

Hoff, E. (2013). *Language development*. Cengage Learning.

Horner, R. H., Sugai, G., Smolkowski, K., Eber, L., Nakasato, J., Todd, A. W., & Esperanza, J. (2009). A randomized, wait-list controlled effectiveness trial assessing school-wide positive behavior support in elementary schools. *Journal of Positive Behavior Interventions*.

Hosp, J. L., Hensley, K., Huddle, S. M., & Ford, J. W. (2014). Using curriculum-based measures with postsecondary students with intellectual and developmental disabilities. *Remedial and Special Education*, *35*(4), 247-257.

Huizinga, J. (2014). *Homo Ludens Ils 86*. Routledge.

Jahren, H. (2016). *Lab Girl*. Knopf Canada.

Johnson, T. E., Khalil, M. K., & Spector, J. M. (2008). The role of acquired shared mental models in improving the process of team-based learning. *Educational Technology*, *48*(4), 18-26.

Kennedy, M. J., Thomas, C. N., Meyer, J. P., Alves, K. D., & Lloyd, J. W. (2014). Using evidence-based multimedia to improve vocabulary performance of adolescents with LD: A UDL spproach. *Learning Disability Quarterly*, *37*(2), 71-86.

Kennedy, M. J., Wagner, D., Stegall, J., Lembke, E., Miciak, J., Alves, K. D., ... & Hirsch, S. E. (2015). Using content acquisition podcasts to improve teacher candidate knowledge of curriculum-based measurement. *Exceptional Children*, 0014402915615885.

Klingner, J. K., & Edwards, P. A. (2006). Cultural considerations with response to intervention models. *Reading Research Quarterly*, *41*(1), 108-117.

Kramarski, B., & Mevarech, Z. R. (2003). Enhancing mathematical reasoning in the classroom: The effects of cooperative learning and metacognitive training. *American Educational Research Journal*, *40*(1), 281-310. Chicago

Kuhne, M., & Wiener, J. (2000). Stability of social status of children with and without learning disabilities. *Learning Disability Quarterly*, *23*(1), 64-75.

Kuhn, D. (1993). Science as argument: Implications for teaching and learning science. Science Education, 77(3), 319-337.

Labov, W. (1972). *Language in the inner city: Studies in the Black English vernacular* (Vol. 3). University of Pennsylvania Press. *Chicago*

Lackaye, T. D., & Margalit, M. (2006). Comparisons of achievement, effort, and self-perceptions among students with learning disabilities and their peers from different achievement groups. *Journal of learning disabilities*, *39*(5), 432-446. Chicago

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press.

Lombardi, A. R., & Murray, C. (2011). Measuring university faculty attitudes toward disability: Willingness to accommodate and adopt Universal Design principles. *Journal of Vocational Rehabilitation*, *34*(1), 43-56.

Malvern, D. D., Richards, B. J., Chipere, N., & Durán, P. (2004). Lexical diversity and language development. *Houndmills, Hampshire, UK: Palgrave Macmillan*.

Margolis, H., McCabe, P. P., & Alber, S. R. (2004). Resolving struggling readers' homework difficulties: How elementary school counselors can help. *Journal of Educational and psychological consultation*, *15*(1), 79-110.

Marino, M. T., Gotch, C. M., Israel, M., Vasquez, E., Basham, J. D., & Becht, K. (2014). UDL in the middle school science classroom: Can video games and alternative text heighten engagement and learning for students with learning disabilities? *Learning Disability Quarterly*, *37*(2), 87-99.

Marsh, H. W. (1989). Age and sex effects in multiple dimensions of self-concept: Preadolescence to early adulthood. Journal of Educational Psychology, 81, 417–430.

Matson, J. L., Dempsey, T., & Fodstad, J. C. (2009). The effect of autism spectrum disorders on adaptive independent living skills in adults with severe intellectual disability. *Research in developmental disabilities*, *30*(6), 1203-1211.

McNeill, K. L., & Knight, A. M. (2013). Teachers' pedagogical content knowledge of scientific argumentation: The impact of professional development on K–12 teachers. *Science Education*, *97*(6), 936-972.

McNeill, K. L., & Krajcik, J. (2008). Scientific explanations: Characterizing and evaluating the effects of teachers' instructional practices on student learning. *Journal of research in science teaching*, *45*(1), 53-78.

McNeill, K. L., & Pimentel, D. S. (2010). Scientific discourse in three urban classrooms: The role of the teacher in engaging high school students in argumentation. *Science Education*, *94*(2), 203-229.

Mercer, N., Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: Ways of helping children to use language to learn science. British Educational Research Journal, 30(3), 359-377.

Mercier, H., & Sperber, D. (2011). Why do humans reason? Arguments for an argumentative theory. *Behavioral and brain sciences*, *34*(02), 57-74.

Milroy, J., & Milroy, L. (1985). Linguistic change, social network and speaker innovation. *Journal of linguistics*, *21*(02), 339-384.

Mueller, C. M., & Dweck, C. S. (1998). Praise for intelligence can undermine children's motivation and performance. *Journal of personality and social psychology*, *75*(1), 33.

National Center for Learning Disabilities (2014). The state of learning disabilities: Facts, trends, and emerging issues. Retrieved from: http://www.ncld.org/wp-content/uploads/2014/11/2014-State-of-LD.pdf

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Nelson, L. L., & Rose, D. H. (2014). *Design and deliver: Planning and teaching using universal design for learning*.

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education*, *21*(5), 553-576.

Nietzsche, F., & Nietzsche, F. W. (1980). *La voluntad de poder* (Vol. 129).

Norman, K., Caseau, D., & Stefanich, G. P. (1998). Teaching students with disabilities in inclusive science classrooms: Survey results. *Science Education*, *82*(2), 127-146.

Nussbaum, E., & Sinatra, G. (2003). Argument and conceptual engagement. Contemporary Educational Psychology, 28, 384-395.

Okolo, C. M., & Diedrich, J. (2014). Twenty-five years later: How is technology used in the edu cation of students with disabilities? Results of a statewide study. *Journal of Special Education Technology*, *29*(1), 1-20.

Okun, W. (2008). Pass or Fail. New York Times. Retrieved from: http://kristof.blogs.nytimes.com/2008/04/07/pass-or-fail/

Palmquist, S. D., & Crowley, K. (2007). Studying dinosaur learning on an island of expertise. *Video research in the learning sciences*, 271-286.

Perera, D., Kay, J., Koprinska, I., Yacef, K., & Zaïane, O. R. (2009). Clustering and sequential pattern mining of online collaborative learning data. IEEE Transactions on Knowledge and Data Engineering, 21(6), 759-772.

Pink, S. (2012). *Situating everyday life: Practices and places*. London: Sage Publications.

Reese, E. (2013). *Tell Me a Story: Sharing stories to enrich your child's world*. OUP USA.

Reiser, B.J., Berland, L., & Kenyon, L. (2014) Engaging students in the scientific practices of explanation and argumentation: Understanding a framework for K-12 science eduction. Published in the April / May NSTA K-12 journals. Retrieved from: http://nstahosted.org/pdfs/ngss/resources/201204_Framework-ReiserBerlandKenyon.pdf

Roeser, R., Strobel, K. R., & Quihuis, G. (2002). Anxiety, stress, and coping.

Romasz, T. E., Kantor, J. H., & Elias, M. J. (2004). Implementation and evaluation of urban school-wide social–emotional learning programs. *Evaluation and Program Planning*, *27*(1), 89-103.

Rose, M. (2005). *The mind at work: Valuing the intelligence of the American worker*. Penguin.

Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, *46*(8), 909-921.

Sampson, V., & Blanchard, M. R. (2012). Science teachers and scientific argumentation: Trends in views and practice. *Journal of Research in Science Teaching*, *49*(9), 1122-1148.

Sampson, V., & Clark, D. B. (2008). Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future directions. Science Education, 92(3), 447–472.

Schmitz, B., & Skinner, E. (1993). Perceived control, effort, and academic performance: Interindividual and multivariate time-series analyses. *Journal of Personality and Social Psychology*, *64*(6), 1010.

Shakespeare, T. (Ed.). (1998). *Disability Reader: Social Science Perspectives*. A&C Black.

Shogren, K. A., Wehmeyer, M. L., Palmer, S. B., Soukup, J. H., Little, T. D., Garner, N., & Lawrence, M. (2007). Examining individual and ecological predictors of the self-determination of students with disabilities. *Exceptional Children*, *73*(4), 488-510.

Shogren, K. A., Wehmeyer, M. L., Palmer, S. B., Rifenbark, G. G., & Little, T. D. (2013). Relationships between self-determination and postschool outcomes for youth with disabilities. *The Journal of Special Education*, 0022466913489733.

Shogren, K. A., Kennedy, W., Dowsett, C., & Little, T. D. (2014). Autonomy, psychological empowerment, and self-realization: Exploring data on self-determination from NLTS2. *Exceptional Children*, *80*(2), 221-235.

Siegel, H. (1995). Why should educators care about argumentation?. Retrieved from: http://scholarlyrepository.miami.edu/philosophy_articles/11/

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education*, *28*(2-3), 235-260.

Skinner, E., Furrer, C., Marchand, G., & Kindermann, T. (2008). Engagement and disaffection in the classroom: Part of a larger motivational dynamic?. *Journal of Educational Psychology*, *100*(4), 765.

Slavin, R. E. (1996). Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary educational psychology*, *21*(1), 43-69.

Smith, K. A., Shepley, S. B., Alexander, J. L., & Ayres, K. M. (2015). The independent use of self-instructions for the acquisition of untrained multi-step tasks for individuals with an intellectual disability: A review of the literature. *Research in developmental disabilities*, *40*, 19-30.

Squire, K. (2011). *Video Games and Learning: Teaching and Participatory Culture in the Digital Age. Technology, Education--Connections (the TEC Series)*. Teachers College Press. 1234 Amsterdam Avenue, New York, NY 10027.

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

Steinkuehler, C. A. (2008). Cognition and literacy in massively multiplayer online games. *Handbook of research on new literacies*, 611-634.

Steinkuehler, C., & Duncan, S. (2008). Scientific habits of mind in virtual worlds. *Journal of Science Education and Technology*, *17*(6), 530-543.

Sutherland, K. S., Lewis-Palmer, T., Stichter, J., & Morgan, P. L. (2008). Examining the influence of teacher behavior and classroom context on the behavioral and academic out comes for students with emotional or behavioral disorders. *The Journal of Special Education*, *41*(4), 223-233.

Summers, M. F., & III, F. A. H. (2006). Preparing minority scientists and engineers. *Institutions*, *17*, 1

Tardif, T., Gelman, S. A., & Xu, F. (1999). Putting the "noun bias" in context: A comparison of English and Mandarin. *Child Development*, *70*(3), 620-635.

Teglasi, H., & Meshbesher, N. (2004). Temperament and learning disability. *Learning Disability Quarterly*, *27*(1), 9-20. Chicago

Tippett, C. (2009). Argumentation: The language of science. *Journal of Elementary Science Education*, *21*(1), 17-25.

Toppo, G. (2015). The game believes in you: How digital play can make our kids smarter. Macmillan.

Toulmin, S. E. (2003). *The uses of argument*. Cambridge University Press.

Trainor, A. A., & Bal, A. (2014). Development and preliminary analysis of a rubric for culturally responsive research. *The Journal of Special Education*, *47*(4), 203-216.

Tulman, J. B., & Weck, D. M. (2009). Shutting Off the School-to-Prison Pipeline for Status Offenders with Education-Related Disabilities. *NYL Sch. L. Rev.*, *54*, 875.

U.S. Department of Education (2016). 38th Annual Report to Congress on the implementation of the Individuals with Disabilities Education Act. Retrieved from: http://www2.ed.gov/about/reports/annual/osep/2016/parts-b-c/38th-arc-for-idea.pdf

Vygotsky, L. (1978). Interaction between learning and development. *Readings on the development of children*, *23*(3), 34-41.

Wagner, M., Newman, L., Cameto, R., Garza, N., & Levine, P. (2005). After high school: A report from the National Longitudinal Transition Study-2 (NLTS-2). *Menlo Park, CA:*

SRI International. Retrieved February, *7*, 2007.

Waitoller, F. R., Artiles, A. J., & Cheney, D. A. (2009). The miner's canary: A review of overrepresentation research and explanations. *The Journal of Special Education*.

Walton, D. (2000). Argumentation and theory of evidence. *New Trends in Criminal Investigation and Evidence, 2*, 711-732.

Wehmeyer, M. L., Agran, M., & Hughes, C. (1998). *Teaching self-determination to students with disabilities: Basic skills for successful transition*. Paul H. Brookes Publishing Co., PO Box 10624, Baltimore, MD 21285-0624..

Wehmeyer, M. L. (2005). Self-determination and individuals with severe disabilities: Re-examining meanings and misinterpretations. *Research and Practice for Persons with Severe Disabilities*, *30*(3), 113-120.

Wehmeyer, M. L., & Shogren, K. A. (2016). Self-determination and choice. In *Handbook of Evidence-Based Practices in Intellectual and Developmental Disabilities* (pp. 561-584). Springer International Publishing.

Weiner, B., (1985). An attributional theory of achievement motivation and emotion. Psycho-logical Review, 92, 548–573.

Weiss, I. R., Pasley, J. D., Smith, P. S., Banilower, E. R., & Heck, D. J. (2003). Looking inside the classroom. *Chapel Hill, NC: Horizon Research Inc*.

Wertsch, J. V. (1998). Mind as action. Oxford University Press: Oxford, UK.

Whyte, G., Saks, A. M., & Hook, S. (1997). When success breeds failure: The role of self-efficacy in escalating commitment to a losing course of action. *Journal of Organizational Behavior*, 415-432.

Witten, I., Frank, E. & Hall, M. 2011. *Data Mining: Practical machine learning tools and* *techniques* (3rd ed.). Morgan Kaufmann Publishers Inc., San Francisco, CA, USA.

Wong, B. (Ed.). (2011). *Learning about learning disabilities*. Academic Press.

Wright, B.A. (1960). *Physical disability: A psychological approach*. New York: Harper and BON.

Yeager, D. S., & Dweck, C. S. (2012). Mindsets that promote resilience: When students believe that personal characteristics can be developed. *Educational Psychologist*, *47*(4), 302-314.

Zins, J. E. (2001). Examining opportunities and challenges for school-based prevention and promotion: Social and emotional learning as an exemplar. *The Journal of Primary Prevention*, *21*(4), 441-446.

Zins, J. E., Payton, J. W., Weissberg, R. P., & O'Brien, M. U. (2007). Social and emotional learning for successful school performance.

APPENDIX A

Day 1

Introduction (Large Group)

Welcome

Skype Call from the CDC

Assess student understanding by asking the following questions:

1. Do you know what a virus is?
2. Can you name some viruses?
3. How can one get infected by a virus?
4. How does a virus work?

Today's Goals:

1. Your research team will stop and discuss the following after each slide:
    - What path did you take when moving the virion through the body?
    - What does the virion do?
    - How does the body's immune system react to it?
2. Draw and label functions of the virus, cell parts and immune system.
3. Write a letter to the CDC with ideas on how to stall the Raven Virus.
4. Be prepared to share your research / observations with other team members.

Remember: You can help each other out if you get stuck!

Day 1

Introduction (Small Group)

Team Building Activity

- Find commonalities between each research team member
- Use commonalities to come up with a research team name
- Write your research team name down on a sheet of paper

Review Questions:

1. What is a virus?
2. What is the CDC?
3. What activities do we need to complete?

Distribute Day 1 Worksheet

- Briefly outline each section of the worksheet and its importance.

PLAYING THE GAME

Key Vocabulary: inhibit, microscope, infect, virulent, digi-scope, nanobot, (sheets comparing) cdc, antibodies, investigate, observations

Start: drag the virion to START

- Read the Green Information displayed on the screen.
- Play WE ARRIVE.
- Wait until everyone has completed WE ARRIVE and then discuss observations.

Questions to Ask:

1. "We are better as an army" - what does this mean?
2. What do you see (e.g. budding site, virion, bound antibody)?
3. What happens next?

Continue Playing - WE ALERT

- Read the Green Information displayed on the screen.
- Play WE ALERT.

Questions to Ask:

1. What do you see that’s new?
2. Is that a part of a cell, virion or immune system?
3. Explain what’s happening in this slide.
4. What does the virion have to avoid?

Continue Playing - WE EVADE

- Read the Green Information on the display screen
- Play WE EVADE

Questions to Ask:

1. What do you see that's new?
2. Is that a part of a cell, virion or immune system? How do you know?
3. Explain what's happening in this slide.
4. What does the virion have to avoid?

Write a Letter to the Center for Disease Control (CDC)

Have students write a letter to the CDC. In this letter, have students explain what they discovered and what they believe is needed to stall the Raven Virus.

Sample Questions to Ask:

- Can you tell me a little bit more about your plan?
- How do you know that? Does everyone agree?
- What counts as good evidence in this particular situation?
- When is enough evidence available to support or refute a claim?
- What conclusions can be drawn from your research?

End Activity: Share your group's letter to other research teams.

Review from Day 1 (Large Group)

Yesterday you…

1. drew and labeled cell and virion parts
2. recorded observations
3. determined possible ways to slow the Raven Virus

What recommendations did you write to the CDC?

Skype Call from the CDC

Today's Goal: Make a Model

- Create a model of the Raven Virus and how the body reacts to it. Through this process, you should be able to think of more ways to hypothetically slow the virion down.

Questions to Ask:

- Why do scientists use models?
- What is the purpose of a scientific model?
- Do all models have the same purpose?
- What is an example of a model?

Day 2: Small Group: Let's Investigate the Slides!

Key Vocabulary: mRNA, virion, microscope, virulent, digi-scope, models, CDC, antibodies

Continue Gameplay

Ask the following questions after each slide:

1. What do you see that's new? Is that a part of a cell, virion, or the immune system?
2. Are you seeing new information?
3. Explain what's happening in this slide.
4. What patterns do you see?
5. What does the virion have to avoid?
6. How did you find this out? Show me what happens in your digi-scope.
7. What does that mean for the virion?

Model Creation: Create a model of the process by which the virion interacts with the body.

Think about:

- how you want to organize your model
- what you want to include in your model
- if your model is understandable to those outside your group

Document your Research
Take a picture of the model with the iPads. This image will be 'sent to the CDC' for review.

End Day 2

Day 3

Review from Day 2 (Large Group)

Yesterday you…

1. worked on a model and sent information to the CDC

Questions to Ask:

- What were your theories?
- What seems to be working well?
- What challenges are you seeing?

Skype Call from the CDC

Lead Facilitator: The scientists at the CDC reviewed your models and they look great. However, the virus is continuing to spread. We need to continue our investigation!

Today's Goals:

1. update your model
2. continue your research and record new findings
3. continue working through the slides to determine whether your information is correct
4. record a 2-3 minute video to the CDC explaining your model

Small Group: Let's Create a Video!

Key Vocabulary: mutations

Continue Gameplay:
Update your model by continuing to investigate the Raven Virus.

Questions to Ask (after each slide):

1. Are you seeing new information?
2. How did you find this out?
3. Show me what happens in your digi-scope or on your model.
4. What does that mean for the virion?
5. Are there revisions that need to be made? How do you know that?
6. Can you explain what would have happened if we didn't include ______?

Make a Video: Directions for the Facilitator

a. The video should be 2-3 minutes in length.
b. Encourage every research team member to participate.
c. Tell everyone their videos will be sent over to the CDC for review.
d. Have participants walk through their model and provide suggestions on ways to stop the Raven Virus.

End Day 3

Day 4

Review from Day 3 (Large Group)

Yesterday you…

1. **updated your model**
2. **made a video for the CDC**

Skype call from the CDC

Questions to Ask:

- **What is a mutation?**

Define Mutation:

- **a change that causes variation from the original DNA**
- **mutations can cause viruses to become more contagious / resilient**

Today's Goals:

1. **Make sure your model is as complete and detailed as you can make it.**
2. **Prepare your model and your research to share with another team.**
3. **Help each other better understand how the virion continues to survive.**

Small Group: Investigate the Raven Virus and Complete Your Model

Key Vocabulary: mutations

Facilitator Introduction: Yesterday, you worked on updating your virion model and created a video to explain the virion process. What were your suggestions?

"Your team has found ways to slow the virion. However, the CDC said mutations, (a change that causes variation from the original), have been discovered in some virion. This has caused the Raven Virus to become more contagious. We need to have a more detailed model to share with others. Your research team will be paired with another research to discuss this further."

Questions to Ask:

1. What does collaboration mean?
2. Why is collaboration important?
3. How will you present your model to another group?

Groups should continue working on their model and investigate further slides.

Presentations

Directions for the Facilitator: Two research teams will be paired together. Each team will present their model and research findings. Individuals will have the opportunity to provide feedback following each presentation. A presentation worksheet should be distributed to each person to help encourage this dialogue. Have individuals complete each section.

Left Section: questions you may have regarding the other team's model
Middle Section: recording ideas, thoughts, and examples you found useful
Right Section: items that you found less useful / important

After the Presentations (in small groups again):

1. discuss notes with each other
2. decide what changes would make the model better
3. look at the digi-scopes and almanac for additional information

Meet again in a large group.

Skype Call from the CDC (Part 2)

End Day 4

Day 5

Review from Day 4 (Large Group)

Yesterday you…

1. presented information to each other's teams
2. gave feedback to each other
3. continued to investigate the Raven Virus

Lead Facilitator: "Today, we discover the CDC has fallen into chaos! The CDC is depending on your team to provide them with a solution to stop the virus. Decisions have to be made. Each group will receive 3 outside sources sent by the White House. You need to review these sources and incorporate the information into your final report to the CDC."

Today's Goals:

1. read 3 outside sources
2. compare outside sources to your model
3. decide which option is the best to slow the Raven Virus
4. explain why this option is the best when compared to others

Small Group: Preparing for the Virus Summit

Key Vocabulary: credible and non-credible sources, cite

Today's Activities:

1. Decide which solution is the best for stopping the Raven Virus. You can only choose one option, so pick wisely!
2. Be prepared to justify your position to others at the Virus Summit. There, as a large research team, you will decide which option is the best and why.
3. You will write down the pros and cons of each option. This is a group decision and only one worksheet is necessary. Make sure your decision is clear!

Sources: Give each research team member a copy of the three sources to read. Individuals can read together as a group or by themselves. Discuss the options afterwards.

The Options:

1. Create a vaccine
2. Use an RNA Inhibitor
3. Develop a drug that inhibits mitochondria

Discussion Questions: They do not have to be in order. . .

- What are you finding that you already know?
- How can these articles help you?
- Can you find similar information in the articles that are related to the game?
- How do you know this research is valid?

- How did you arrive at that?
- Does this make sense?
- What are you thinking?
- What is your final decision and how are you going to justify your choice?

Move to the Virus Summit
1. Each group should explain what option they chose and why.
2. Other groups can provide questions or input during the discussion.
3. After this, each individual votes for what option they believe is best.
4. After voting, individuals can persuade others to reconsider their choice.
5. The Virus Summit can vote again, if necessary.

End Day 5

APPENDIX B

ALMANAC	
Virus	
Term	**Definition or Almanac Description**
Budding Site	We create Budding Sites as our point of escape from cells that we have infected. We gather our Proteins and Genomes at our Budding Sites to form new Virions. Our Budding Sites are our doorway to the outside world and to spreading out infection.
Virion	We combine our Genome, our Proteins, and a piece of stolen host Cell Membrane to create our Virions. Our Virions allow us to survive outside of a host and spread. Our proteins on the outside of our Virions allow us to dock with Protein Receptors to infect new cell hosts.
Genome	Our RNA Genomes are the center of our replication inside of a cell host. We can attach our LP Proteins to our Genomes to enable transcription, the first step in our replication, of multiple types of mRNA and Antigenomes.
LP Proteins	We can attach our LP Proteins to our Genomes to start the replication process, transcription of mRNA and Genomes. Our LP proteins are the combination of two of our proteins, L and P Proteins, which are otherwise ineffective when separate.
mRNA	Our messenger RNA (mRNA) can serve multiple purposes inside of a cell host, including being the instructions for Proteins, We can distract and destroy Slicers with mRNA to project our Genomes or have them translated into Proteins at the Ribosome.
N Protein	Our N Proteins add a protective coat to our Genomes to make them invincible to Slicers. Proteasomes can kill our N Proteins, but Proteasomes can also capture our N Proteins and use them to alert dangerous T-Cells to our infection.
M Protein	Our M Proteins allow us to manipulate and disrupt the cell. Use our M Proteins to show the translation of mRNA at Ribosomes and clog Nuclear Pores. Proteasomes can kill our M Proteins and PRRs will try to drag them back to the DNA.

Antigenome	Our Antigenomes are the backup production force to our Genomes and our way to speed our infection. Once we attach our LP Proteins to our Antigenomes we can use them to make more Genomes, which can then make more mRNA AND Antigenomes.
G Protein	
Vesicle	Our Vesicles allow us to complete our Budding Sites by carrying our G Proteins to the cell membrane. Once the Vesicle reaches the Budding Site, our G Proteins are then expressed on the outside of the cell. Our Vesicles cannot stop the cell's defenses or vice versa.
Cell/Immune System	
Antibodies	
Bound Antibodies	I grab on to passing Virions and pull them into my parent B-Cell. When I grab a Virion, I signal to my parent B-Cell to start making Free Antibodies. B-Cells combine give of me to make Free Antibodies.
Free Antibodies	I attach to Virions to slow down the rate of infection. I cover up the Proteins on the outside of Virions so they can't easily dock with cell Protein Receptors. When I team up with other Free Antibodies we can disable Virions completely.
B Cells	I watch for infections by expressing Bound Antibodies on my cell membrane that can grab onto Virions. If my Bound Antibodies detect any Virions I will start making Free Antibodies to help destroy the invaders.
Slicer Enzyme	I like to destroy RNA Genomes and mRNA. It's what I do and it's what I'm good at. I can only deal a certain amount of damage (4x mRNA or 1x Genome) before I become denatured, but I have no problem sacrificing myself to save my parent cell.
PRR	Are you a viral protein? If so, come with me so I can introduce you to the Nucleus so that it knows you are here. Tattletale you say? No, no, no. I am not a tattletale, I am just a responsible cell defense trying to do my job.
Proteasome	I'm hungry for proteins. I don't really care what kind of proteins to you are, if you are one than I am going to eat you.
Caspase	
DNA	

Other Objects	
Cell	I am just an average cell doing my job to keep the host alive and functioning. If I express Protein Receptors I can pull in food, but also open up to the possibility of being infected by a Virion.
Endoplasmic Reticulum	If it weren't for me my parent cell wouldn't be able to do much. Along with the Cytoskeleton, I provide much of the transportation structure to the cell and many of my parent cell's Ribosomes reside on my surface.
Mitochondrion	I provide energy to my parent cell. My parent cell would be a useless mass of carbon if it weren't for me and my Mitochondria brethren. I don't pay attention to how my energy is being used, I just pump it out non-stop so everyone else can keep their work up.
Ribosome	Hablas Ribosoma? I am one of the many Ribosomes capable of translation, or the process to convert Protein instructions, mRNA, into useful items for my parent cell. Without me, mRNA would never get translated into Proteins.
Nucleus	I am the last barrier of defence for the cell's DNA. I might be defenseless but if it weren't for me, any Virus or Bacteria would be able to walk right over and start messing with the DNA. I'm not having it, not on my watch anyway.
Cytoskeleton Site	I don't know what the Endoplasmic Reticulum has been telling you, but I am the one that holds this place together. I provide structure to the cell and give space to the cell resources to function. If an Executioner takes me out, I take nearby resources with me.
Nuclear Pore	
Golgi Apparatus	
Protein Receptors	
Invagination	