Learning Through Work and Play:

Using Virtual Design Discovery to Facilitate Virtual Environments as a Medium for Active Learning Through Design

A Thesis

Presented in Partial Fulfillment of the Requirements for the

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by

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Authorization to Submit Thesis

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Abstract

There is a divide between how virtual environments are designed and utilized between different academia and industries. This divide is most prevalent when looking at the comparisons between data visualization and video games. Virtual design discovery could become a means to bridge this gap and gives us an opportunity to explore something new. VDD could help us create a new social design process and environment, update outdated teaching mediums, minimize the misuse of new technologies, and prevent misrepresentation of datasets. This paper will look at how simplification and access to developing virtual environments could give way to many opportunities and improvements for current design practices. Virtual design discovery can be used as a medium to facilitate better social design practices and broaden learning opportunities as well. These opportunities stem from the inclusion of access to larger social groups, online communities, incorporation of active learning, and virtual environmental design.

Keywords: Virtual Design Discovery, Learning opportunities, Technology, Virtual environments, Data simulation, video games.

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The support and challenge each of you gave me throughout my time at the University of Idaho has given passion to my research of integrating science, art and video games. I have been incorporating what I've learned in many different aspects of my life. I hope to continue my path of exploration in this area for year into the future.

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Introduction:

Interest and Intent

Virtual design discovery (VDD) is the act of learning or understanding through the process of designing or developing virtual environments. The first part of this paper will define virtual design discovery as well as describe its potential opportunities as a medium for active learning. It will also help to establish a correlation between VDD and the scientific method. Discuss the possible uses of VDD in different academic and nonacademic environments, and compare the users of Virtual environments and users of VDD. Though my personal experience working with virtual environments I will discuss metrics that will allow users of measure the effectiveness of virtual environments in both subjective and objective ways. These metrics lay the groundwork for merging the two cornerstone virtual environments, virtual narratives and data visualization. I will discuss how my experiences with the projects and studies I've worked on relate to VDD and how those metrics apply to each project, further discussing their successes and shortcomings. Beyond that, this paper will conclude with possible means of integrating VDD with interdisciplinary teams and community building. This paper will explore options and possible uses of VDD for the development of video games, simulations, and using virtual environments related to designing and sharing in a social environment.

There is a division between how virtual environments are being utilized by designers and researchers. Researchers and scientists are developing simulated environments that can be highly detailed and informative; their datasets can be hard to understand or comprehend without proper context or narrative to explain the connections to outside users. In contrast, game developers are moving away from narrative and storytelling and moving towards microtransactions and clicker games meant to kill time. In this process designers are overlooking the necessity of context and fidelity of/to their narratives, leading to unrealistic and uninteresting environments. A growing trend with scientists is to use game engines to build simulations without a basic understanding of game development or design principles. This form of simulation leads to unengaging "games" and further buries the data it is trying to represent. People see the promise of entertainment and storytelling, but when the narrative doesn't deliver and the gameplay isn't engaging, users find themselves uninterested in the context and the simulations are rendered ineffective. This is one of the reasons virtual environments in the form of simulations, specifically video games, are being overlooked as a medium for academic and commercial use. The possible interactions that VDD offers as a medium

would benefit game designers and scientists alike. The need for open world narration and constant clicking has changed the way stories are told, information is disseminated and core concepts are shared. The marriage of scientific data and virtual interaction has the potential to improve understanding of a subject as well as explore new interconnections between designers and artist.

What is VDD?

I define virtual design discovery (VDD) as the act of learning or understanding through the process of designing, developing, or modifying virtual environments. VDD is made up of active learning styles, iterative design processes, and world building philosophies. At its simplest the users learn by building and experimentation inside virtual environment. This type of development methodology draws from the scientific method as well as the design process. VDD allows the use of virtual tools and design principles to test hypotheses in rapid succession with few limitations of procedures. The combination of hypothesis testing and iterative design build a foundation for self-explorative research and understanding. The complexity can range from simple data manipulation to building virtual assets or complete virtual worlds. The importance of this freedom is the main benefit of VDD versus a traditional lab environment. While the benefits of freedom are paramount, there is also an access to building using more artistic or out of the box design approaches to facilitate each user. VDD allows the designer to dictate the overall approach within the boundaries of Virtual environment.

VDD lends itself to the design process as well as the scientific method when it comes to building virtual environments. The incorporation of virtual design grants an ease of access and infinite iteration potential. This has benefits to both designers for its ease of iteration but also to researchers in need of designing complex simulations. The core principle behind VDD is that the users are building skills, knowledge and understanding of the material through exploration of the medium. This goes beyond simply conveying information in a digital medium (virtual environments, video games, simulations) but further into allowing information to be learned through building and modification of these environments. VDD can be used to bridge the gap between the qualitative interactions and experiences with the quantitative analysis that scientists and educations require from simulations. It can do this by giving scientists and educators a means to utilize virtual environments as a means for displaying data and data analytics in a way that can be easily ingested and comprehended. VDD could bring scientists, educators and game companies together to build

comprehensive environments that not only useful for learning opportunities, but express high levels of data through narrative and storytelling.

Video game and scientific models do not need to be looked at as separate mediums. They both use fundamental components of learning to explain a narrative. The merging of these two sentiments, though the use of VDD have the potential to become an outstanding medium for updating current teaching and design practices. This medium could become the foundation for students, artists, and scientists to develop their own content, though the act of exploration and play in virtual spaces. VDD fulfills the engagement factor for learning as each student is learning in a way meaningful to the individual because they themselves dictate interaction with the given content. Artists and scientists can share and communicate ideas more easily while working within a VDD environment. While VDD is a stepping stone for bridging the gap between science and art there is still a component of interdisciplinary work that is missing from this field. How can video game and scientific models be developed together for uses as a medium for updating outdated design practices? This paper will help bring this gap to light for future understanding of VDD and learning through work and play.

Section 1: Personal Work

My exploration of VDD started in a classroom setting that was posing the question of "does science make video games better?" It really was the launching pad for most of my research and investigation. I've been working on visualization and video games for a few years prior (and it just clicked that this is how VDD should work. The combination of science, art and play, this is where I was headed and where I've been going ever since. I've worked on projects for EPSCoR, the University of Idaho, as well as a few personal projects. What I've learned from each of them, as well as about the design process overall, will influence how I live, work, and design in the future.

Over the last few years (2013-2016) I have been working on a multitude of projects that could benefit from the principles of virtual design discovery. As I worked through these projects I began to see the pro/cons of each type of development and where things could have been improved or developed differently to facilitate virtual design discovery. While this wasn't always their main objective VDD was natively available in each situation if not totally utilized. I will discuss each project, the main purpose of the project, and how it relates to virtual design discovery. Each project was different and fostered a different outcome. These projects included *Salmon Sim (*simulation made for Alaska EPSCoR ACE, VTL 2016), *WC-Wave* (virtual watershed platform and simulation, 2015), *Project Wraith* (evolution based video game, unpublished), *Darwin's Demons* (video game, 2016) and the development of *Polymorphic Games* (game studio). Each of projects have a basis in data driven environments or dataset analysis. They begin to differ in implementation and variation of "gameplay" and narrative. This is a good setup for comparison when dealing with the contrast of simulation vs. video games.

1.1 Introduction to personal work

The first project that I worked on was for EPSCoR. Working with a team comprised of Virtual Technology and Design undergraduates, Natural Resource Scientists, and fishery experts. The process involved many iterations of client based building of assets and function into unity environments. This process would be the basis for continuing development of smart assets. Developing an understanding of the content is more important for the designer than the user. As the first iterations of the project were developed I was asked to design local vegetation in the Pacific Northwest. I began my process by researching local and invasive species and building list of possible assets and information on plant and animal life cross referenced by prominence and location. After the base

assets were chosen I began to look into photo references and textbooks to build this vegetation. I didn't realized the differences in variations of trees could and DO exist. This became very apparent with my first working checkpoint. My clients (which consisted of mainly dendrologists) while they could tell that I'd developed a very diverse forest, were unable to determine what kind of tree I'd developed.

"The profile is wrong for this to be a Western hemlock"

"There's not twirl patterning happening with the branches"

Image 1.1: Dry Creek Video Capture from – VTL WCWave Video (2015) - unpublished

I was highly discouraged by responses like these. I was thinking to myself, I can't model a tree? It wasn't a problem with my modeling ability; it was a problem with my research. I had started developing assets like an artist. I stood back and made sense of the world through visual assertion. A layman would see that is was a shape that made sense to anyone that has driven the many mountainous roads in Northern Idaho. It was not until I began researching these trees like my clients had that I understood what was missing from the assets. The process became so focused on accuracy and developing real world analogs that the artistic and creative process was driven out from it. This could explain why, I think, many video games are developed without external influence. Allowing the world to be completely driven by a development team's focus on visual replication can lead to unique and memorable visual experiences, but when a connective story is missing within the created

environment, a real world connection is lost. We need to consider our creative objectives further. In a virtual environment when does a tree need to be a tree and when does it need to be a character in a story? Developing a smart, visual asset as simple as a tree can be a daunting task but there has to be a point where the concept (our tree) becomes a node of information that can be used in a multitude of situations and add context to a much larger audience. Towards the end of the development, the project was show to the target audience and they were less interested in accuracy of visual components and more interested in the number and geological accuracy. This then became compounded by the need to show massive amounts of spatial data in tandem with virtualized environment.

Over the course of building these different types of assets, I began to see a pattern in the way I learned and developed the environments. Developing smart assets forced me to do my own research and actively pursue more information that was needed to develop the visual assets in a way that was meaningful to the end user as well as the designer. The accuracy of the static assets such as trees and period specific environment was highly susceptible to the expert knowledge and research I was expecting. The distinguishing factor for accuracy in development was relative to the user as well as the expert/developer. The more I tried to create something, the more information I needed to know about it. This pushed me further and further down the path of VDD as a teaching medium. If not for these introductory successes and failures during my undergrad, my expectations of virtual environments might not be the same. I took this idea of learning through play with me as I continued developing virtual environments and video games through my graduate studies.

Image 1.2: Leaf UVW and Normal Map from VTL Tree Catalog (2025) These are examples of assets built from on sight photography used to create smart assets in Unity 3d.

1.2 Alaska EPSCoR ACE: SalmonSim

Salmon Sim (data visualization, VTL 2016) started as an interactive data visualization of salmon migration patterns in the Kenai Peninsula, Alaska. The project was adapted and built initially by Seth Haynes and John Anderson and later expanded and developed by members of the Virtual Technology Lab and the University of Idaho. *Salmon Sim's* datasets included, stream flow, temperature, oxygen content, migration statistics and geographic data. It dealt with many new challenges including converting geographical datasets to *Unity 3d* (Cross-platform game engine, Unity Technologies 2005), creating usable fish animation rigs, developing environments based on real world locations etc. The project went through many iterations and design cycles before its completion with the VTL. Its use and application as a learning tool has had many variation and possibilities to exhibit new types of VDD in an academic or commercial setting.

Image 1.3: *Salmon Sim* Video Capture a - Video link >> *Salmon Sim* Overview https://www.youtube.com/watch?v=vhAP9f4GgMs

As a video game, I would declare *Salmon Sim* a failure; as a data visualization, I would conclude it a success. So how does it hold up as a VDD project? When looking at the objective side of *Salmon Sim,* it very well stays true to its dataset. Focusing on water oxygen levels and migration numbers, it's accurate to its dataset. We spent a lot of time and effort allowing the user to make minor changes and experimentation and they work quite well as data visualization. Looking at it from a subjective viewpoint, it's value begins to falls apart. While it can be fun to explore the environment and the addition of multiple playable characters is novel, they fall flat on necessity. The flavor to the game has no significance when compared to the datasets or the interactions. As a video game, it was never designed to have gameplay. This is a very common issue with data visualization. So, we find ourselves with another accurate simulation missing out on some important VDD opportunities.

Image 1.4: Salmon Sim Video Capture b – showing salmon migration

The opportunities for VDD development hit me hard while I was working on the *Salmon Sim project*. *Salmon Sim* has the benefits of an amazing amount of data to represent, highly capable people working on the project and the freedom to develop inside a broad design outline. Objectively it completed its goal of creating a virtualized environment to visually represent the migration of salmon. We followed the guidelines and successfully implemented all the points needed for the delivery, but I feel I got much more out of it because of VDD than the end user ever will. This was another example where we were each stuck in our own little worlds. We each had a task or challenge to deal with and didn't work though our problems as a team. While the users can control an avatar of their choice of salmon they are unable to directly affect the dataset. While there is access to a very small number of variables that allow for a simulation for some active learning opportunities, I feel that I, as a designer, got much more out of the experience than the end user.

Image 1.5: Salmon Sim Video Capture c – Character select

Salmon Sim as a VDD project would have been amazing. The project itself suffered from too much data and not enough planning. We went into it thinking about it like a videogame but never really set down the rules or mechanics for the objectives of playing. We learned a great deal about the fish trying to make them swim correctly and getting accurate skin patterns. We talked with experts about fishing habits and climate that never had a chance to be put into the end simulation. In the end, we could put together something wonderful and useful but with only a fraction of our original intent. Any one of those projects set aside and carefully developed and designed, I believe, would have been a successful project for VDD. Now that the base development has been completed and assets and scripts exist to disseminate the datasets, anyone with interest in this field of study (salmon migration, water 02 level, etc.) could use this project to build and define their own game. Here is another opportunity for VDD, *Salmon Sim* is now available to be used by students and researchers who have access to it. Students can build upon the datasets

we already have implemented and create their own version, develop a fully customizable system for learning about new datasets or go in a completely different direction.

In our case, we were able to use our final builds and designs to build movies showing off the life cycle and migration of the salmon. This is a prime example of VDD and where *Salmon Sim* was an amazing success. Because we had all the medium built, we captured and produced videos within the engine. While video capture of video games (machinima) is not a new concept, using something we studied and built for one purpose for another is a prime example of the social structure of VDD. The brainchild that Seth and John started passed through multiple hands added and subtracted features such as sonication and combat simulations, and ended up as a finished project with no virtual interaction whatsoever. Looking at it from the perspective of those developing *Salmon Sim* and not as a finished "video game", *Salmon Sim* is a success project for learning and exploration of the data.

1.3 WC Wave: Creating a story with data:

WC-WAVE:

> "*WC-WAVE* will enable integration of creative observation and analytical strategies using advanced modeling approaches and CI in a virtual watershed platform. The research and CI are critical to understanding and predicting complex responses to climate and hydrologic change and cannot be accomplished by the Consortium members individually. In particular, the VW platform will allow researchers to integrate experimental and observed data, models, and visualization capabilities that can simulate watershed drivers and dynamics and lead to new discoveries. The *WC-WAVE* Workforce Development and Education program will prepare graduate students to work in collaborative, interdisciplinary teams to effectively address complex scientific issues, promote faculty professional development, and prepare diverse undergraduate students for future STEM education and employment."
>
> - *WC Wave* Project Description, 2008

Building the Dry Creek watershed as a virtual environment helped me understand the water potential and usage of a place I grew up. One of the key components for the *WC-Wave* Virtual Watershed development was to create a virtual environment for stakeholders and students to better understand the data being collected about their local waters. Growing up in the Treasure Valley, Idaho I knew about the snow melt from the Dry Creek area but never fully understood how big a role it played. Scientists have been using the ISNOBAL model to calculate variables such as air temperature, average snow cover, snow density, thermal radiation and precipitation mass. To most these words mean something but bringing all of these variables together to explain how water is

being stored in our mountains is asking a bit much. The problem becomes more complex when you begin to model them using traditional methods (image 1.6). The immensity of these datasets are needed to be able to adequate deal with complex systems on this size and scale. This level of complexity and data management is too much for an untrained user.

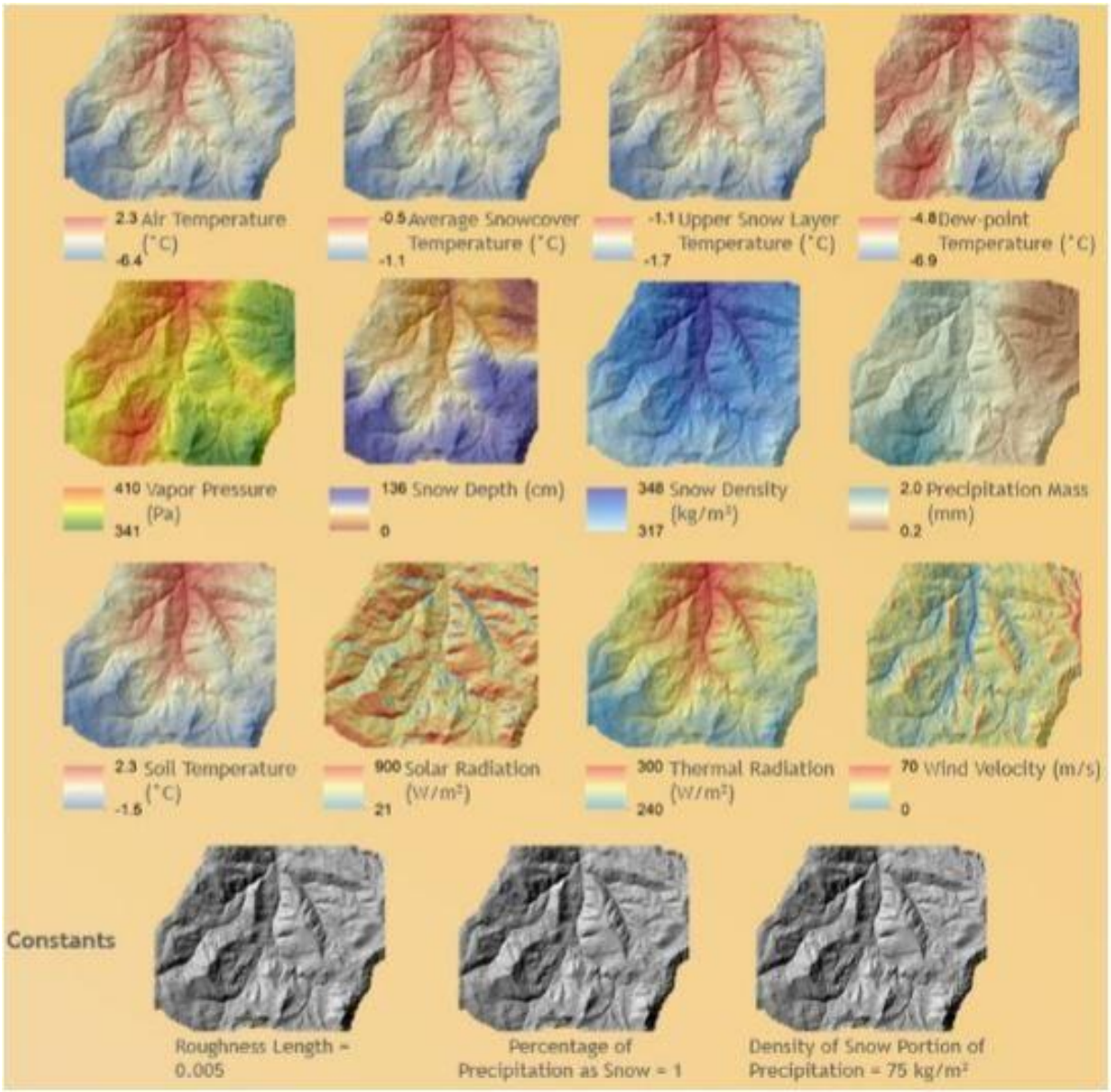

Image 1.6: Dry Creek Temperature data – taken from Design of a Virtual Watershed Client for the WC-WAVE project (2015)

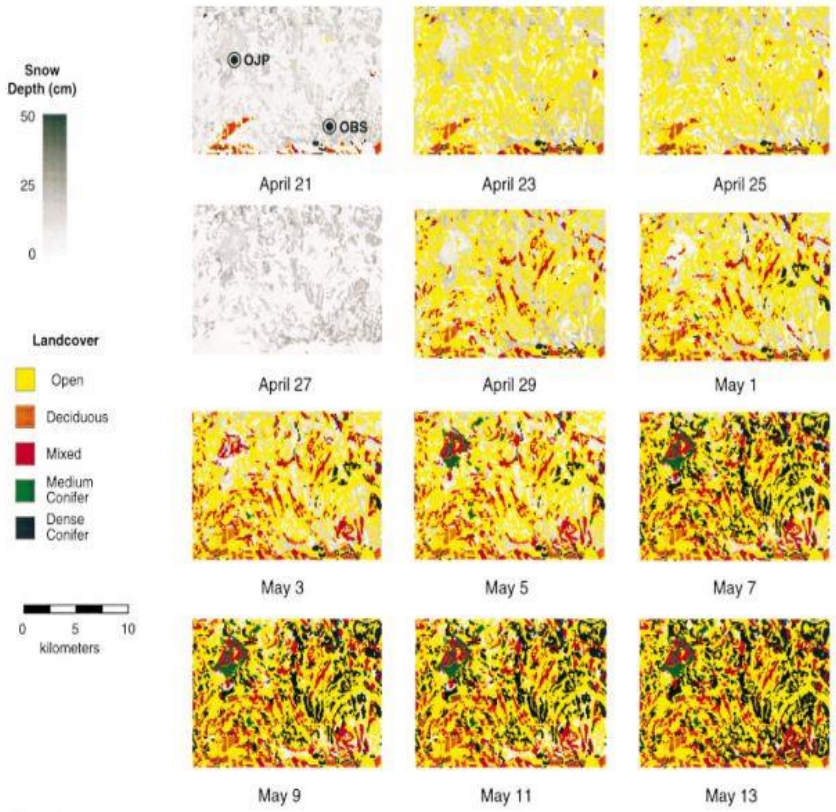

Plate 2. Distributed snowcover simulation results at the NSA modelling sub-area, 1995. Snow depths are indicated by the grayscale. When no snow is present, the canopy species class is indicated by the colour scale

HYDROLOGICAL PROCESSES, VOL. 13, (1999)

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Image 1.7: Dry Creek Snow Landcover – taken from Design of a Virtual Watershed Client for the WC-WAVE project (2015)

Virtual environments are an excellent medium for exploring complex systems because users can passively interact with complex systems in our own environment. Instead of seeing datasets and images they move through, interact and generally ignore the complex systems around them. By placing a user into a virtual environment based on these complex systems we are circumventing the need to separate each variable and instead show them the whole picture all at once. This is where Virtual design discovery can happen. The virtual environment should be looked at as a playground for new users. They can explore and interact with the environment much as they would if they were to visit the location in person (Dry Creek in this instance). At the base level, this is the ability to teach the user through a narrative much in the way an informational video would. Because we have embedded the data and variables into the environment they have the potential to learn and explore

by themselves. The narrative can become their own experiences. These experiences can be guided by questions or achievements, a narrator or even their own personal curiosity. It becomes our responsibility as designers to develop these personal narratives in a way that captivates and rewards discovery.

The *WC-Wave Virtual watershed project* is still in the beginning phases for virtual design discovery. While we've laid out the tools to access the datasets, as well as embedding them. The sheer amount of data and its complexity leave the scope of narratives to large. The virtual watershed was built to connect high end datasets with new users. Once the tools are built it's not a large step for users to dive in and begin exploration. The scope of attaching the virtual watersheds from a nationwide sever is an amazing feat. The large scope involved in such a project gives itself to almost limitless narratives. John Anderson once told me, "When data is re-represented virtually and we interact with that data experientially we learn and can more easily discover new knowledge." These new discoveries and narratives will drive exploration of the environments and as the users set up datasets, discover new and interesting uses for tools and virtual assets learning happens. Not in a way that was given to them, but though discover and play.

It also became a prime example of building a community for transdisciplinary development. We started out thinking about WC-Wave as a singular project where we were required to build the GUI and skin. In the end it became something much more complicated and involved. Not just for us but for designers, researchers and scientists from all over the country. In talking with these people about their portions of the projects and having to learn about how our assets and graphics would be interacting with different datasets and dataset types we learned a lot about the watershed it self. In the end we build a portion of a world building engine which could allow future scientist and students unlimited access to their own VDD projects. For use the process of building this world was only the first part in our understanding of the project. We spent time alone developing our own ideas and trying to integrate them later. This is where the active learning could take place, problem solving and reaching out to communities that we had no real knowledge of in hopes of building something bigger than we were capable alone.

1.4 Project Hydra: Building a new Monster

Project Hydra was the brainchild of a small group of grad students and professors over the fall semester of 2015 at the University of Idaho. The group planned a *Unity 3d* based twin stick shooter as the platform to experiment with a generational model of evolution. The project lasted 1 semester and a single prototype was developed and used as a promotional example of evolution in video games. We set out with very defined goals and a very short timeframe.

The first stage of development will be defining what our goal for the game is. Defining where the conflict is and what interactions will be necessary to achieve that goal. Stage Two will include developing a genome/neural network to house these complex interactions. Stage Three will be developing a Creature/Enemy/Hub/Object that will be able to hold and translate the genome into a virtual object for interactivity. Stage Four consists of developing an environment that balances the need for gameplay as well as offering experimental setup and staging. Retaining the core ideas layer out in stage one will be paramount for the development of the project.

Stage One Goals:

- *MUST show Evolution*
- *MUST be fun*
- *MUST use generational model of evolution*
- *Allow for higher mutation rate*
- *MUST be repayable to show different evolutionary paths*
- *MUST contain enough variation in creatures to allow evolution to be visually dynamic within the Population*
- *MUST contain multitudes of evolutionary pressures*
    - *This can be in the form of:*
        - *Direct competition*
        - *Food (limited availability to food)*
        - *Indirect competition (positive/negative mutations)*
        - *Evolutionary Drift*
        - *Sex and reproduction*
        - **Selective pressures driven by user playstyles*
        - ***Aggression (fight or flight psychology)*

- *Environmental interactions*
- *Population predation*

**The user MUST NOT be able to adjust genetic values during runtime*

***The user MUST be in direct competition with the evolving creatures.*

*To allow for evolution to take place without the direct interactions of the user (creationist and morphological models, God game, life simulation game, real-time strategy, *i.e. Spore. Electronic Arts 2008.Video game*) the user must be limited to selective pressures and competition/predation.

**Any directed changes should only be applicable to the player (user's avatar/mode of interaction) in the form of upgrades or statistics changes. These changes should only affect the evolving population by means of player/population interaction.

Conflict/competition is a driving force for gaming. That competition can come into play as direct competition with another player PVP (player vs. player). Environment vs environment is the model most simulations take to build complex systems. Player vs. environments is placing the competition between the player and the computer, this model is the most simplistic for virtual interactions and video game development. Now building a complex system that can combine the research potential of a simulation and the interactivity of video game is going to require a blending of the three.

The second stage started with a large amount of discussion about how the code should be organized and built. This is one of the most important and complex parts of the development for me. Not being well versed in C#, a scripting language used for *Unity 3d*, I relied heavily on my classmates and coworkers to develop the code that drives this section. My infinite thanks to Roger Lew, David Street, and Chris Mirabzadeh for their hard work developing the codes and scripts to allow us to work on *Project Hydra*. Development of the genome started with discussions and decision making regarding what the creatures need to be able to do. We decided that a rudimentary instincts that already exists in nature as the basis for our creatures actions and interactions with the player. This is a prime example of the need for experts and research to improve the oversight of game designers. We brainstormed about wanting the creatures to have the ability to defend themselves as well as react to different types of stimulus. For this purpose, to talked with biologists as well as computer programmers to determine the next step of genome creation.

Building the creatures included many iterations of fire types, morphology, and creature movement. There variables are all waited by a fitness function to progress evolution of their genome. A large component of the creatures was our decision to develop them with modular nodes for each body part. While most of their decisions and reactions were directly controlled or guided by the genomes the visuals, designs, and movements were all created preproduction. Both the creatures and the player characters were built around modular skeletons and rigs. Each created component; legs, arms, claws, tank wheels, was designed to be swapped out and augmented without coding or destructively rebuilding the model. This left the game open for not only variable editing but custom building individual pieces of the game without changing the algorithm. This type of plug and play adaptation was built with VDD in mind or at least my current understanding of it at the time. Our original design thoughts were that users would learn more though playing with the variables and assets than just completing a set storyline. We focused on the customization and variation of both genome and visuals. This setup the ability for rapid testing and experimentation inside the Unity 3d editor.

While most games development can be driven by answering “Is this fun?” working to combine the modes of play and the need for experimentation will bring more productive possibilities. These challenges will bring themselves to light in build issues and game balancing. An end goal for this project was to allow users to integrate their own character adaptations into the game, developing their own maps, weapons, and creature types. While we build this game with active learning in mind what we had not realized at the time is the potential for VDD. Not only was this an amazing example of a small team learning and designing in a VDD environment we were building a playground for future users to learn and develop as well. The time constraints for *Project Hydra* was limited and unable to be deployable in the original prototype. The combination of the evolutionary algorithm and modular based creatures and players set up the users to be able to easily mod, test and iterate. While this game was developed with gameplay and objective based play in mind the dataset was very buried in the aesthetics. We lost site of the datasets for more than just the background creature control. While it was highly successful at a game it suffered as an accurate tool for study.

1.5 Darwin's Demons: Arcade Style Space Shooter

Darwin's Sandbox (video game, 2016) and *Evolve TD* (video game, 2016) were the predecessors to *Darwin's Demons* (video game, Polymorphic Games Studio, 2017). *Darwin's Demons* was designed as a standalone video game using a complex genome to improve the difficulty of the creatures the player interacts with. It very simply allows students to interact with it on a surface level (as a purely entertaining game) but still allow for in depth learning and customization for experimentation. *Darwin's Demons* allows for students with minimal coding and artistic backing the ability to learn about evolution on a variety of levels and difficulties.

The great advantage of this kind of arcade style game is the simplicity of the play style.There are not a lot of complex numbers to get in the way of understanding what is going on. One shot from the player kills a creature and one shot from a creature kills the player. This 1 to 1 ratio allows for the game itself to not get in the way of other variables to be changed. Virtual design discovery can happen fairly quickly by allowing certain variables to be accessible to the players:

Image 1.8: Darwin's Demons Experimental Mode Screenshot from Darwin's Demons (2017)

- Number of creatures in a population.
- Number of creatures on screen at one time.
- Creature type distribution.
- Numbers of lives for the player.
- Creatures starting variables
- Fire speed
- Aggression
- Mutation rate
- Size of the creatures
- Player Starting variables
- Fire speed
- Controls

- Size of the ship

These variables can be augmented and changed without disturbing the way the game is played or how the fitness is calculated for the creatures. Changing these variables will however change the data that is exported. A student could easily try these different variables based on their own assumptions to achieve an outcome. Students can be offered questions about evolution without being giving direct instructions of how to achieve an answer. This could lead to many unique solutions to the question, from adjusting how the creatures shoot, or how the player reacted to the creatures. While the need for students to understand how to collect and properly portray the data using *Darwin's Demons* is a prime example of using video games in design discovery. Each student would come away with a slightly different video game and a slightly different solution. Each having learned the same thing but in way that made sense to the individual.

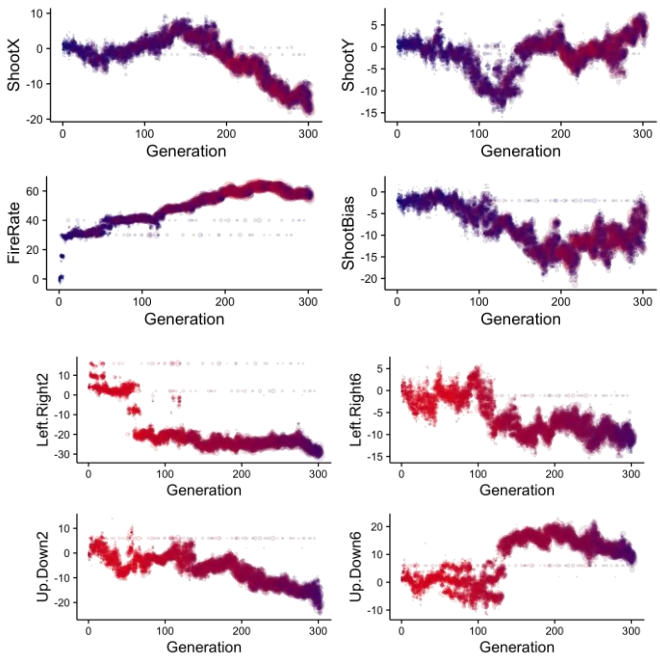

Image 1.9: Darwin's Demons Generation Tracking – Polymorphic Games (2016)

Image 1.10: Darwin's Demons in Game Screenshot from Darwin's Demons (2017)

Darwin's Demons ended up being a prime example for VDD from two different perspectives. First, it works well as a VDD project for users playing the finished gamed. Secondly how it was developed is an amazing example of VDD from a studio stand point. The game being set up and developed with these changeable variables in mind allow the game to represent the data very accurately. In this case the evolutionary algorithms are accessible and testable every time the game is played. Students and researchers can experiment with variables or simply experiment on their own

and compare their experiments with other users with little to no programming or creativity. These models should how each variable interacts within an evolutionary algorithm regardless of their input. This is a great example of active learning inside of a VDD environment. It's not as complex as developing the environment yourself but though modification of a pre-existing environment you're able to play and explore in a way that wouldn't be possible otherwise.

At a rudimentary level *Darwin's Demons* is a successful VDD environment. Inside of the "experimental mode" each variable is adjustable allowing for numerous experimentation. There are still many limitations because of its standalone nature but the development and "studio" style learning environment backs up concept of social input. Games like *Darwin's Demons* with a very simple starting point (arcade shooters) and a singular question (does evolution make games harder?) allows for untold exploration and play. This is the closest I've come to a true VDD project. We develop something within a short amount of time that I believe will be the starting point for developing new VDD based interdisciplinary projects and studios in the future.

1.6 Conclusion of Work related to VDD

I have had the Great privilege of working with people at the University of Idaho who are passionate about changing the way we learn and work. I have worked on several projects of varying degree of success related to VDD. Each project brought my understanding of what would be needed to use VDD as a medium closer to fruition. While each project had its elements of success and failure the people were instrumental to making VDD a possibility. The more I develop the idea the more it becomes aware to me how important the community is. Whether it's classmates, peers, coworkers having a sounding board to keep the balance between the objective views and the subjective views in any project has become a grounding force for me. As VDD development continues I believe that keeping the balance between the two and building a community will drive its use and development in the future.

Community based studios are the perfect breeding ground for VDD to be developed and prosper in. Studios like *Polymorphic Games* and how they work inside of the academic community at the University of Idaho is a great example. They are branching out on YouTube and on the web, as well as blogs and papers on campus as well as online. (*Argonaut Online*, Polymorphic Games - A Game Studio at UI (2017)). These types of spaces could really become the birthplaces for new types of learning, VDD included. Moving forward I hope to see more video game companies and scientists

reaching out to these highly cross disciplinary spaces. The more experts and developers there are working in the spaces the more access there will be for students who need to find their peers and audiences.

Section 2: VDD: Benefits and Challenges.

The dissonance surrounding VDD is caused by a misrepresentation or misinterpretation of authority where productive learning is involved. Many people throughout my life have written off video games be a waste of time or unimportant. Culturally, they are seen as something generated by the entertainment industry to occupy youth. But this simplistic view is short-sighted; it misses the potential opportunity and impacts that virtual environments can offer academic environments. Virtual spaces can be mediums for understanding the real-world in a more focused way instead of just being a mode for escapism. Video games use a collection of artistic principles as well as psychology, developmental learning, etcetera inside of virtual environments as an infrastructure for storytelling. Video games are subjective, and can lack the objectivity of scientific knowledge and methods. Scientific knowledge (rigorous, repeatable, rational) is the result of multi scaled structured studies, crossing numerous time spans and cultures. A limitation of the objective approach is that it is communicated in ways that are not accessible with a large audience. They primarily strive to communicate to their peers with little regard to whether the public understand their work. Showing data for the sake of furthering academic exploration gets lost when delivered to end users outside of the field of study. VDD does not strive to match objectivity of science. Science identifies empirical data and strives to build models and theories with predictive validity of the real world. Science is reductive; it breaks phenomena into its constituent components and explain things mechanistically. Whereas VDD is holistic, where the underlying findings of science can be assembled to explore the different aspects of the information. Both contain the use of direct observation and testing of hypothesis. The dissonance around VDD is not one of people not willing to use the virtual environments but misunderstanding the similarities between its parts. VDD can articulate science in a way that can be more accessible to a larger audience and hopefully open the perspective of uninformed viewers.

2.1 Science vs. Design

VDD is a marriage of science, art and design. When scientific knowledge is encapsulated into virtual worlds through VDD there are limitations to what can be explained by science. Any given simulation of scientific study is limited by the number of interactions being studied, access to current data and the current understanding of the laws that govern it. There are still many unknowns that have not been thoroughly explored and explained by scientists. VDD relies on the artistic and the

designer aspect of interactive environments to make reasonable assumptions and explore how holistically fundamental concepts are related. This is not unlike how many projects and studies are handled in the real world. The scientific method still applies to the simulations, and are limited by current understanding and available data. With VDD the rules of our world become variable and controllable. We have control over the virtual environments, and can methodically change variable in ways that are unattainable in real world situations.

We use science through direct observation and understanding of the natural world to set forth laws and principles that can be directly applied to virtual environments. An example of this is the physics simulation engine found in most video game development software. Based on our understanding of the physical properties of the universe we're able to have objects in virtual space interact with each other in specifically designed environments. This has been used to model or simulate a wide range of environments from solar systems to atomic particles. A physics engine is a science based simulation or simulator. It is ubiquitous across many platforms and development software because it it's a fundamental understanding of our universe. This step of applying real world observable interactions to virtual environments was a huge leap forward for immersion. The inclusion of a physics engine gave designers and artists a reference point that has spawned countless environments: *Kerbal space program* (Video game: Squad, 2015), World of Goo:(Video game, 2008), *Angry Birds*(Video game: Ravio entertainment, 2009), *FIFA 2014*(Video game: EA 2014). These games all work around a physics based engine. They all use real world variables defined and used by physicists in practical application. It is then the job of the designer to decide which of those variables are accessible to the user and for what purpose. Simulations are representative of the datasets they are built for, or at least they should be to be effective. Design at its core is the development of a process or plan created to achieve a desired effect or outcome. For VDD the development of the process is where the learning happens. VDD expresses artistic challenges in a way that represents the student's goals. Allowing the students to define problems and possible solutions that push them into self-guided research in the topic of their choice. The design process is very similar to the scientific method in that they both follow the same set of guides. The main difference in the design process for VDD is the speed at which iteration can happen. Because we're working on a virtual world, we can adjust the time scale as well as the sample size. While this does lose some of its objectivity they allow us to assume and make educated guesses based on current information. Students can take what we

know of how and where salmon spawn and simulate the collected datasets into the future. They are to change and adapt their strategy very quickly based on the outcome. In this way, we get rapid turn around and constant iteration. Mixing this with collaboration with their peer's experiments and design the classroom become filled with numerous ideas and perspective outcomes. Each student and conducted their own researched and defined their strategy based on their own interests or perspective keeping them engaged and exposing them to many different possible outcomes.

Science is good at breaking phenomena into understandable pieces but is not very good at telling us how to assemble those pieces into meaningful representations. While engineers can solve specific problems in a prescribed manner with well-defined constraints (e.g. designing a bridge with a known span for known loads). There is no prescribed method to simplify or elaborate the equations to the general public. The datasets surrounding the project are written and formatted to meet with peer review not public understanding. With design there are infinite possibilities, but without access to the information creativity gets lost along the way. The design process allows us to sort through some of the possibilities. The design aspect of VDD would allow students to define their own constraints and solutions. In this way, VDD is able to connect the good from both scientific methodology and design principles in an active classroom environment.

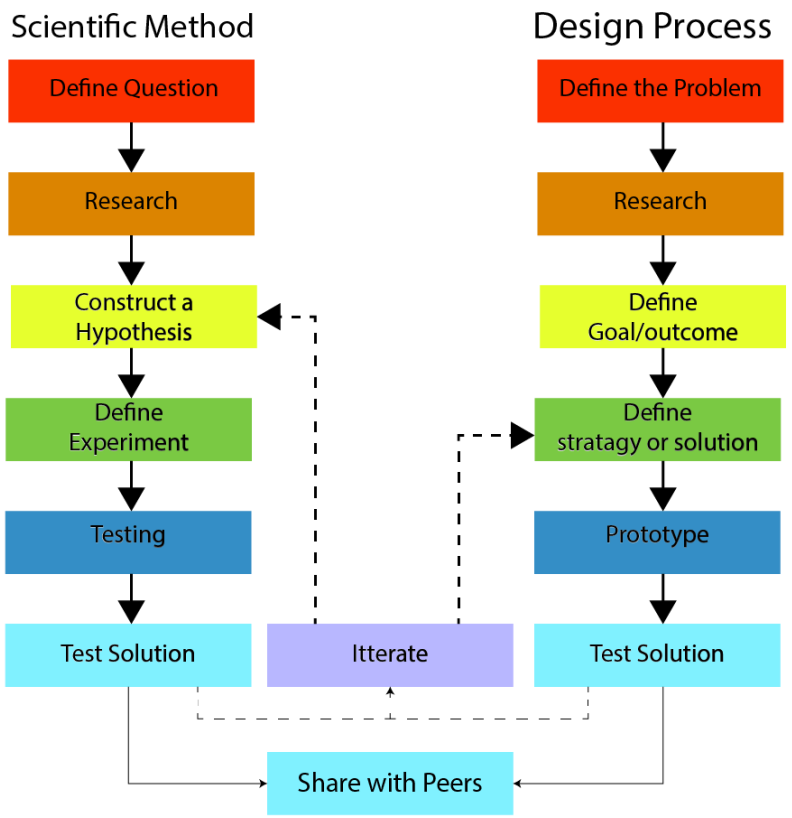

Image 2.1: Scientific Method Vs. Design Process

2.2 VDD for Education

Using video game development in the form of VDD can be utilized at any age or skill level. The complexity of the design can be changed and augmented by the instructor, but at its simplest general computer knowledge, is all that is required for implementation. A small study done by Laura A. Whitlock (2012) showed improvement in cognitive task analysis over a short time with groups age 60-77. Whitlock goes on to say "The results of this study add to the body of evidence suggesting the efficacy of certain types of video games as cognitive interventions for older adults. *World of Warcraft*, a game selected because of its demanding attentional characteristics, was found to improve the cognitive ability of older adults." These kinds of study could help people become more comfortable with the idea learning using games and virtual interactivity is very achievable for most users. Small games and applications directed at memory development and upkeep like *Memrise* (Application, 2010) have been growing in popularity in recent years. As we advance in technology usage and access, so must our teaching and learning practices. Starting with traditional teaching practices, we can use VDD and a medium to target students of all ages.

Image 2.2: Thumbnail from Sw1Ftx16 (YouTube 2012) Minecraft: How To Build A 4-Bit Computer - Part 1 - Explanation and Design [Tutorial]

If students can write virtual books or develop their own science experiments based around their learning objectives instead of just being read to or regurgitating the ideas already presented, then students will be able to absorb the information in a way that is most useful to the individual. In Malcolm Gladwell's *The Tipping Point* (2000), speaking of the James Earl Jones Effect, Gladwell expresses that "An adult considers constant repetition boring, because it requires reliving the same experience over and again. But to preschooler's repetition isn't boring, because each time they watch something they are experiencing it in a completely different way." Replay ability or Iterative development is the key to VDD and is a key principle for both video games and learning. The components that make games enjoyable are different to each user. Interactive dioramas can be developed cheaply and quickly using prepackaged virtual tools and assets. This will

allow for the students to participate in the narrative on multiple levels and in their own unique way. The immense difference in opinions and individual ideas of enjoyment creating an objective list of requirements is a difficult one. These differences can also bring about different points of view as well as expose students to different problem-solving methods. Games like *LittleBigPlanet (2008 video game, Media Molecule)* express themselves in 2 ways: one by telling a story and letting players explore their virtual world, two by giving building power to the players in a sandbox environment and then share these worlds on the *PlayStation* network. This is a prime example of openly shared social interaction. With everyone using the same original base tools and packages the community can develop very complex and unique interactions in world. People have even gone as far as to make rudimentary computers and musical instruments with these worlds. Prime examples of these worlds are games like *MineCraft (2009 video game, Mojang) and Super Mario Maker (Nintendo video game, 2015).*

2.3 How to Make VDD Successful

A key component of developing virtual environments as an educational medium will be defining the desired outcome. This can be broken down into many different categories including: simulations, dioramas, linear narratives, games, reports, etc. These differentiations will be helpful for communicating the transition away from current leaning practice.

A simple example of this is transitioning from a simulation based virtual environment into a gamified environment. The data set can be the same as well as the environmental expression. The key differences are how the data is accessed and sent to the users. Gamification will focus more on user interaction and allow the data to support the actions and narrative. While simulations are data driving and will produce the data with little user interaction. Working in tandem, the data analysis of a simulation combined with the user interactivity of gamification has the potential for higher level engagement and concept building than either of the two processes before. The developmental side of this kind of build has allowed professionals to cross pollinate their ideas and skills in an interdisciplinary fashion not only with peers but the users as well. Visual designers and Computer scientists learning about biology gain higher level understanding of how their virtual assets should behave. [*Polymorphic Games*]. (Jun 24, 2016). This understanding is then reflected in the work and new generations of game simulations are born.

We use science as a means of understanding the individual pieces of a puzzle. The challenge then is to use it in a way that in engaging and interesting to wider audiences. Barrie Robison is doing this now with *Darwin's Demons.* The next generation of virtual designers will come from both artists and scientists alike. These creative individuals have taken it upon themselves to start building and sharing these skill sets with the game community. Posting "how to" videos online as well as experimenting with pushing the bounds of their current limitation. This open community of shared ideas and ways of sharing ideas opens the classroom to more mediums. This form of free information is key to VDD development. This type of open information is how learning and development needs to happen in the classroom. Teaching principles need to be robust enough for the students to build upon core lessons and expand their knowledge through creativity and social interaction. At the same time, they can build a repository of assets and lesson plans built by the community. This process can

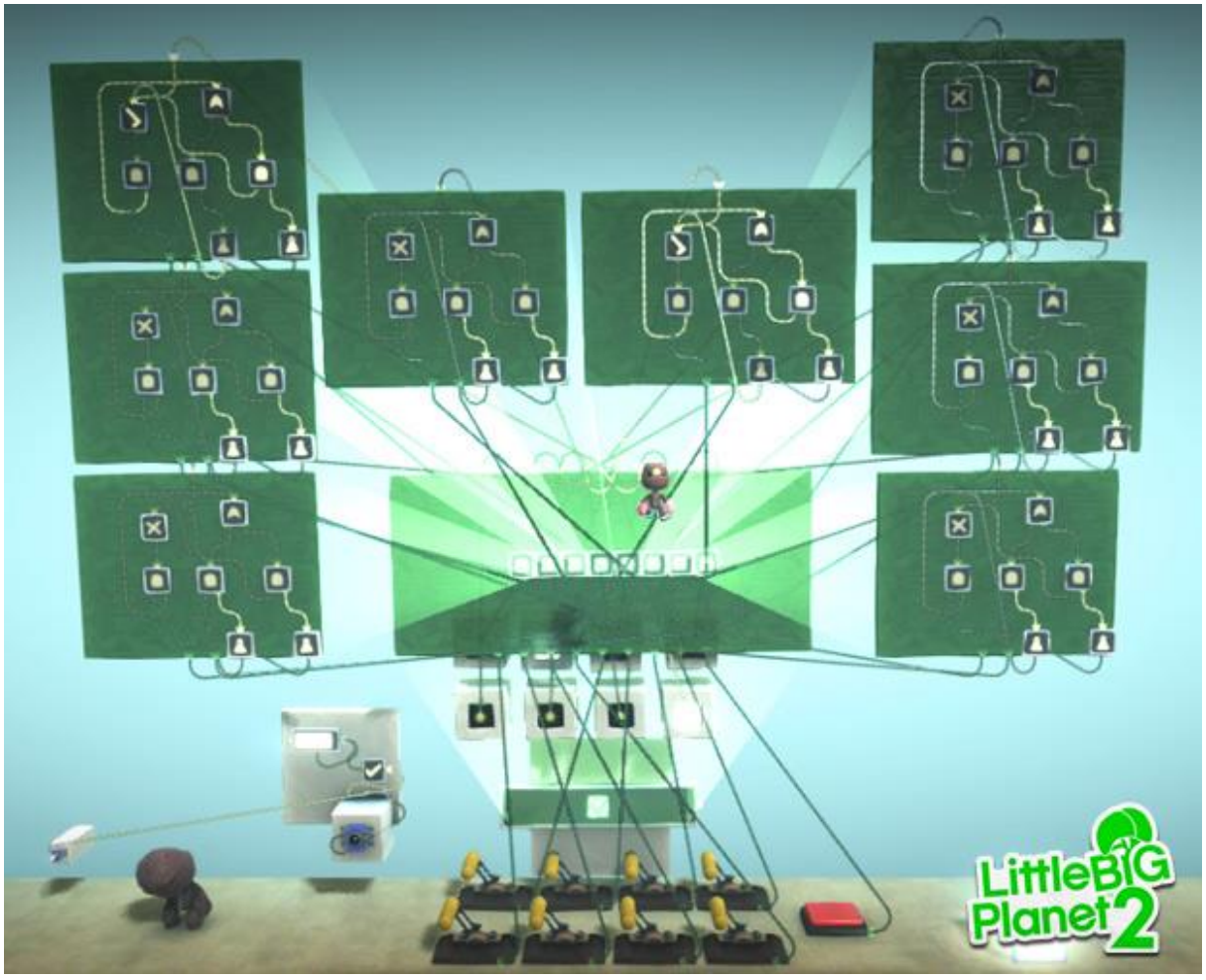

Image 2.3: A Fully-Functional Computer processor and display built in engine LBP 2 by Chris C. of Media Molecule

only begin once a guideline and curriculum is set in place that can make these social interactions possible. Then, though these interactions, data can be displayed in a way that is both successful as a game as well as a simulation. This balance between building an entertaining narrative, exploration of data, and concepts through community sharing is unique to this new type of design.

This type of shared space and community driven design is a great environment to develop VDD practices. While many companies and institutions are developing community spaces to story virtual environments it is currently very inclusive and proprietary. Spaces like Nintendo's *Miiverse* community, and Sony's *Play Station* Network allow users to share saved files of user built content. The Steam store allows users to build assets and skins for integration with a variety of games and simulations. On the academic side the Northwest consortium is building the Virtual Watershed (see 1.3 WC Wave) allowing researchers to share and edit watershed data across the country. Each of these are well on their way to becoming the norm for community based virtual environment development. Further allowing VDD users a space to edit, share and discuss their ideas and developments. VDD is all about the process and their ability to share that process in open environment. Finding a unified shared space, and building a system to access it is key to developing VDD for academic purposes.

VDD has the potential to be used as a highly successful medium for educators, researchers, artists and video game developers. VDD can deal with many different age groups, but it can be tailored to the individual's skill level and desired complexity. Many video games and simulations, both hold pieces of VDD but very rarely achieve a balance of both effectiveness and Accuracy. Students of all ages are capable with interacting with virtual environments at a superficial level. While many others can get a high level of understanding and competency of the material by expanding into a VDD level of active learning and social groups that fit to their interests. The access that VDD brings to the classroom allows students to uniquely adapt the lesson plan to their own unique hypothesis and skill level. For designers and scientists working on virtual environments with VDD design principles in mind could greatly improve their user base and foster cross disciplinary interactions.

Section 3: Defining the Subjective and Objective Methods for Video Games, Simulations, and VDD.

My time at the University of Idaho has brought about many conversations about what makes a “good game”, and questions about if there are metrics for comparing subjective and objective ways to quantify it. At the same time, we can look at science being based on materialism and less about the subjective views and opinions of end users. So where do these two come together and meet? And what opportunities could come about from this type of comparison?

3.1 Defining the Separation

While discussing the separation of simulations and gaming, the lack of metrics for defining effectiveness for each respective genre only widens the gap between the two. Looking at games and simulations as learning tools, the effectiveness can be broken down into 2 parts. The subjective side, (entertaining/artistic) and the objective methods (informational/data). Further breaking down these ideas, the audience's engagement and the author's intent. Data driven interactive/non-interactive environments can lead to miss information or poorly represented data when taken out of context without some form of perspective. This leads us to the need for narration, storytelling and context. Understanding the use of context and perspective is essential for utilizing VDD to its maximum potential. VDD gives designers the opportunity to merge the accuracy of its data as well as the engagement and clarity of its context. This combination of subjective and objective is obtainable through different degrees of complexity and effectiveness. Using a premade virtual environment as the product relies heavily on the developers to establish both sides in a way that can be understood by the user. Context is driven by the user and can lead to a deeper understanding of context and connections between variable assets. Within both the metrics of successfulness needs to be driven by their end goals. If the goal is purely informational then there is no need for complex narrative and interaction. On a similar note, with pure entertainment there is a drop-in need for realism because there is no interest in real world relatability. For VDD to be successful both pieces into account and develop with both entertainment and accuracy in mind.

3.2 Defining Subjective and Objective Storytelling

Looking at storytelling as a means of conveying infromation, the author or designer of an environment must tell the story in a way that is consistent. The audience is only asked to understand

that the universe and characters exists in the confines of the story. The realism of our world is set aside and replaced with the truth of the author's universe. In the case of oral narratives or through written word, the audience is guided in the generation of the universe and its inhabitants. Even though the author sets down the rules and guidelines for the universe the audience creates the substance (voice, color, scale, etc.) This suspension of disbelief is what allows us to enjoy and interact with anthropomorphic creatures, characters that have been dead for thousands of years, or characters that have never existed at all. As the mediums for narrative become more realistic the gap between author and audience becomes smaller and smaller. Finding the balance between objective realism and subjective artistry becomes more important in terms of augmented reality, virtual environments, and data visualization. Objective principles include: factual accuracy, scientific accuracy, and believability. While subjective artistry includes: creative lens, artistic lens, creativity, and the abstract.a

Data visualization is useful tool in compiling and visually representing a data set. The narration is achieved when the dataset through time or space. The author is guiding the audience thought gathered data about our world, using correlated data points for example via experimentation. The author still controls what is shown and retains the use or the artistic lens as a storyteller. In the case of data visualization, the aspect of the storyteller can be minimal and sometimes left out completely. The data is the most important part and the visualization must be told this way. The data is being shown as fact, as the truth of the universe for this narrative. This form of direct narrative leaves a very small margin for the audience to interpret or invent the substance. This is understood because the data is being shared with other authors for use in their own narratives. In this way data visualization help define a universe without regards for the voice of its inhabitants. Data visualization is excellent at displaying the finer details of a much larger world.

On the other end of the spectrum, static art forms: photography, paintings, and illustrations. These single frame narratives are a wildly subjective narrative with little or no references or anchor points for the view to understand the author's intentions. Single frame narratives give the audience a selected amount of data. The emphasis of these narrative being on the interpretation and creativity of the audience. The author uses an artistic eye and selective content to deliver the substance of the narrative. What is missing from this method is the context. With some much emphasis being on the artistic effect the reality of the situation is lost. The audience is allowed to take the non-contextualized information and create their own narrative. This is a powerful form of narrative and

for all its beauty it has also been used despicably. The danger lies in the context, in the framing, and in the lens. Because the audience can delve into their own meaning from the images, the context can be distorted and misrepresented by the lack of data. Therefore, balance is important in narrative.

Simulations and video games fall somewhere in the middle using single frame narratives, interactions data visualization and storytelling. The division between the two lies somewhere in how much importance the author gives to each individual piece. A video game can be very interactive and use stunning visuals, but forget about the importance of their data and context. While scientific posters will represent their data clearly and simply but with little to no impact. Finding the balancing point for VDD is a big step in the process to merging simulations and video games. The first step will be to define subjective and objective methods in relation to the design process of VDD. Define their importance to both simulations and video games individually and when compared to each other. And finally discuss their meeting and merging to work successfully with VDD in a way that is useful and meaningful to the authors and users. VDD can be a successful medium the balance between simulations and games is in equilibrium.

Image 3.1: Importance of Context, comparing use of perspective in single frame narratives. Original photograph taken anonymously and submitted to Fox New (2012)

3.3 Defining Subjective and Objective in Video Games vs Simulations:

The first step towards the merging of visualization and game is to define importance and metrics for success. Both simulations and video games can be graded, reviewed, and discussed on their overall success compared to their like. Where this breaks down is when you start comparing the two to each other. Simulations and games have different agendas and goals but are still related enough to compare. While both can be objectively viewed for their content, the content itself usually have different levels of importance. On the other end, the Subjective views of engagement and entertainment value are weighted inversely. After many classes and brainstorming sessions with a group of designers and scientists of varying disciplines. The following means of comparing

simulations and games was developed. Each axis as a point of relation that should be shared in both simulation and video games to different degrees. On the X-axis we can compare entertaining fun(fantastical) and informational function(realism). On the Y-axis we can compare factual or fictitious. This breaks down gaming and simulations into 4 quadrants. Fun and factually accurate (historical based fictions) fun and fictions (fantasy). Informational and accurate (documentary) and informational and fictitious (science fiction).

X-axis: Entertainment – is the lesson plan fun or not. Is there a way to build the narrative that it will be engaging and entertaining enough to keep the attention of the audience? Will there be any replay value or is this just a quick piece of information to be absorbed and stored? The comparison here would be the difference between teaching values vs. immediacy. Both have their place. One is an immediate reminder that touching the electrical wire could kill you and the other is an understanding of electricity and realizing that high power is a dangerous thing. Both have their place and their necessity.

Y-axis: Fiction vs. nonfiction – Hyperbole can be a very useful tool in storytelling but many times when dealing with scientific data or principals (mathematics, grammar, physical constructs of the world) there is no wiggle room. Logical thought processes are set in place and must be used. This comparison is the bridge between the storytellers and the historians. From a videogame standpoint moving at normal human walking speed and average human jump height is slow because of how we as humans interpret data. If you say he walked the football field in our minds, it happened. In less than a second we've built the event and played it out. So, for accuracy sake do we say to ourselves, "he took a step taking .6 of a second followed by another step until he reaches the other side of the field in the amount of time we had recorded?" There is a balance that is missing between simulations and stories. The amount and quality of the data available can make a huge difference in the execution of the virtual. When the artist is allowed to decide everything, we belittle the world we live in and remove ourselves from truly understanding the world. But when our stories are built entirely out of highly detailed information the audience loses perspective of our own creativity and the larger picture is lost. Finding the balance between game and simulations can be broken down by quadrants. The quadrant system was developed during conversations with Biologists, computer scientists and video game designers. The attached images were placed as a proof of concept developed during one of the classes.

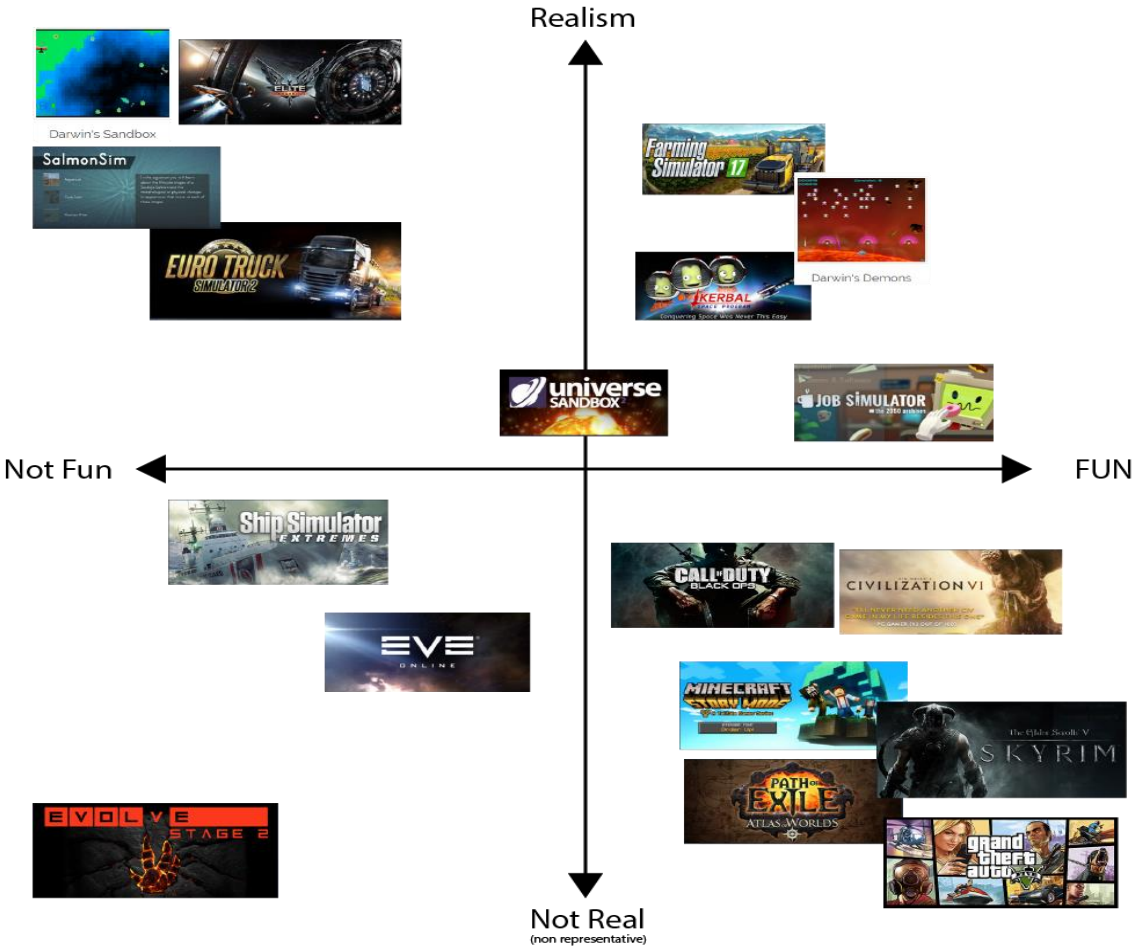

Image 3.2: Metrics graph used as an example of comparing metrics for virtual environments.

With the metrics set in place, the next steps would be to create an individual survey comprised of questions designed to add Subjective AND qualitative metrics to these axis. The qualitative nature comes from the volume of users and surveys conducted. While the subjective side of the questions allows people to respond honestly about how they interacted with the simulation or game. This type of questions based metric was tested with *Evolve* (video game Turtle Rock Studios, 2015) during our time in the class with limited results based on sample size.

How is the successfulness of a project measured? The simplest way to understand success would be by comparison to like projects. This can be seen most commonly on sites that allow users to rate and critique movies and video games like rottontomatoes.com. Movies and TV shows can be

compared and their success can be distilled down to a number in this case of fresh or rotten tomatoes. The problem with this type of system is it doesn't consider the level of complexity and medium being used. Do we compare all video games, all shows, and all book to each other? How can we compare action comedies to horror films? We can do this by looking at the medium itself and build up simple metrics to base them from without digging into the context or narrative of the movie itself. The small pieces and the techniques. This is how we can rate our simulations and games. For the successfulness of VDD as a medium the information does not need to be looked at directly, but its application does. VDD is process focused, while there can be a definite product at the end of the design cycle the benefits of this style of design happen during the development. VDD is worried less about the specifics of how the questions was answered and more with how the information is presented. The successfulness of a VDD projects will be very specialized to each designer or student because it was built in a way that made sense to them. If it remains accurate in its information and keeps them engaged. Each designer becomes more of an expert in their area of development and that knowledge is shared among the community.

3.4 Teaching with Subjective and Objective Principles

Studies done by Nicholas Omale (2009), and another by Barney Dalgarno and Mark J. W. Lee (2010), both support the use of 3-D environments as learning mediums. Both studies found that using virtual environments offered greater opportunities for experiential learning and growing community. As consumers of information we are no longer forced to go to libraries for information. Students are no longer limited by distance and time for field trips. These interactions that 20 years ago were limited by physical distance and space are not unbound thanks to our dependency on technology. We can virtually be anywhere in the world at the click of a button. This ability of teleportation is only limited by current knowledge and datasets. It can be edited ad adapted to any situation or lesson plan and custom fit to different learning styles.

Everything we do and interact with online is being cataloged and turned into a dataset. This type of Information acquisition is not taught to be turned into useful information the students can easily be lost in the overload. In a paper by Ochola, J. Evans (2015) the authors discuss the importance of this distinction; it’s not only the amount of information but teaching students how to access it and use it meaning ways to facilitate learning. They used the example of navigating *Wikipedia* (website, www.wikipedia.com) which is an amazing social environment for the acquisition

and distribution of both information and expert knowledge. But knowing when and how to trust and disseminate data in such an environment is just as important online as it would be in a video game.

Time between interactions in a video game are instantaneous with each keystroke and mouse click. While classroom learning happens at the pace where the teachers are unable to accommodate this level of personal interaction. Higher feedback and rewards encourage students to continue learning and develop higher levels of confidence and motivation. This is a great example of active participatory style of learning. Studies done by E. Seymour and N. Hewitt (1997) are showing that the lecture based class is becoming an outdated means of teaching. While it still has some practical use the underutilization of interaction between the information and the students is leaving many fields wanting. Video games have been shown to be a great force for combating this loss of interest in STEM based fields, Merrilea J. May (2009). The way students interact with technology and information is different than it was 20 years ago. This lends itself to the need for change in the way we teach. When the classroom becomes infinite the necessity of attention and participation become paramount.

How can the interview of expert knowledge be added into the virtual environment? This could be a very interesting question VDD could answer. VDD can be used to see if and how teaching and learning are adapting to its digital and social environments. Experts are no longer limited to single teachers in class rooms or speaker that give guest lectures once. We can reach out at interact with experts and communities without much delay. Building communities of students and teachers of varying levels of expertise and share experiences and information almost instantly. Expanding this type of community driven learning environment people are using outlets like YouTube (see sec 3.3) to build these community and catalog their experiments. These are amazing outlets for subjective and objective mediums. While these are still considered 1 directional lectures, they are driven by community interaction and discussion.

Lectures and interviews are the simplest means to share expert knowledge. Interaction through conversation or one on one interaction can lead to deeper understandings and building knowledge because it's delivered in a way that can be tailored to an individual. When this information is delivered in a way that is one sided – for example: the expert talking to a large group of people or through a video-- access to comprehension becomes inhibited by access to interactions. If you have a conversation with someone you're able to ask questions and ask for clarification. As well as build onto the experience by means of challenging the core concepts. In the lecture setting

access to this type of interactions is limited from 1:1 to 1:100's this limitation has been brought over to the virtual environment with no real improvements. Applications like *Second Life (*video game, Linden Labs 2003*)* and *Blackboard (virtual learning environment, 1997)* try to bring learning into the virtual world with limited success. The problem stems from the delivery method not the location. A prime example I've experienced is with learning environments in Second Life. Our instructor would regularly have classes inside of an online world allowing people to create and build. But when the class was required to show up for a virtual lecture all hell would break loose. The novelty of the 3d environment mixed with the ability to create overshadowed the lecture completely. Retaining the lecture mentality while allowing for students to interact in a virtual space is more of destruction or means to remotely avoid the interaction all together. The virtual environment requires a new way of thinking about interaction and the dissemination of information.

Case studies done by John Yaps (2011) for the Computer Centre, National University of Singapore (SINGAPORE) testing how users interacted with a narrative inside of a multi user narrative using a "Cyber Crime" simulation in Second Life. While this type of learning is still one directional it is a good example of community learning. Each user/student is asked to complete a set of goals but they are able to work together, communicate and decide how best to achieve these goals. One of the obstacles Yaps talked about with his case studies is the emotional detachment from the process. Once again, we have a given assignment and directed form of completion. The students are set with a singular objective to complete the task in a given a time frame. Objectively they are exposed to all the coarse material and processes involved in the simulation but without the personal interaction and ownership of the experience people take away the community and avatar interactions more so than the information.

Expanding upon John Yaps case study with MUVE, students learning by personal experience and then comparing experiments can be more powerful than single directional narratives. But not always in the way that was intend. The key takeaways from current models of using 3d environments in the classroom or as a classroom are increase engagement and with problem solving using social interaction. There will always be some drawback to lecture based classrooms and integrating expert knowledge regardless of the medium. The amount of freedom and ease of customization for virtual spaces greatly improves on these drawbacks. The result of a VDD infused classroom should not be a total remove of current teaching methods but an update of current methods and practices that are already in use today.

3.5 Conclusion

It is easy to get lost in the idea that "This is my idea! I am the only person that should be able to use or talk about it." This is a bad way of thinking for narrative and social interactions. When ideas are shared in a social environment everyone is able to build upon commonality and embrace dissonance. Building a strong vocabulary of the task will happen naturally if people are communicating together. It is natural to want ownership or credit for work, which is still acceptable in the case of VDD but the willingness to share your successes and failures is important in an objective learning environment. Peer review and continuous questioning is key for VDD to succeed. When we as designer, scientists, and artists start hiding ideas squirrelling away unique views, communication breaks down and so does learning.

Understanding the need and use of narrative and perspective lenses can increase the effectiveness of most data driven environments. When information is rendered as a single data set without context, overall impact is lost. Therefore, graphs and charts can be utilized to begin to define scope and comparison of the data. But at what point does each of those points of data become something more than one point. Each point can be expanded upon and unpacked into further datasets and narratives. This is the basis for social ecological systems and complex interactions. Each data set must be gathered knowing it is part of a larger system, building the understanding of its components and each of its interconnections. Breaking down of the components into these more complex systems is what allows us to really understand where our data is coming from. Finding a means of data sharing and social development would be a huge step forward for designers and students alike.

Defining the subjective and objective portions of VDD as a learning style helps us understand what is needed from VDD as a medium. Finding commonality is datasets and storytelling is an early step in understanding how it can be used to design better games and simulations. While there are still issues that are set in how perception of the whole should act and learn. Understanding the narrative and context of each dataset and project can help define the context of each project. VDD gives us the opportunity to teach people how to learn, not just what to learn and do it in a way that engages not just the end users but the designers as well. These social learning practices are important because it allows for checking of the objective datasets and broadening the subjective input inside of each project. Without both working in tandem VDD falls back into the current issues of complacency and inaccuracy.

Section 4: Current Practices of VDD, Virtual Environments, and Video Games.

4.1 Introduction

Using VDD as a social medium for cooperation and design has branched off a variety of disciplines and expertise. This stems from the breadth that virtual environments can bring to the table. Cognitive psychology, storytelling and worldbuilding have shaped the way we build and use virtual worlds. With the introduction of the digital form we have had to discover, explore and reinvent the way we think and work. VDD is a collaboration across these schools bringing many people together working towards improving the way we interact with virtual environments. Biologists, computer scientists, evolutionary computational scientists, writers, artists, etc., all play a part in building these narratives and keeping the process true to its form. There are many projects and producers currently working towards the VDD process, even if they are not directly meaning to do so.

4.2 Pioneers in VDD

There is already a growing force of academics using virtual environments in the classroom and laboratory settings. These people are instrumental in the push for developing VDD and understanding out it can be used in these types of environments. People like Barrie Robison, Terry Soule and John Anderson are pushing the forefront of how video games and simulations are being designed. Challenging traditional learning environments and experimenting with the what is and is not a successful simulation or video game.

Barrie Robison, Ph.D.: Biologist and Professor at the University of Idaho, co-founded the *Polymorphic Games Studio* in 2016. Barrie has been a driving force for finding new ways to integrate science and art in an academic environment. While is work has not been focused on VDD it has offered many opportunities for community based active learning. His work with Terry Soule, Ph.D. and *Polymorphic Games* has created an environment to support transdisciplinary cooperation that has been overlooked in both academic circles as well as the video game industry. See *Darwin's Demons* (video game, 2017) evolutionary based video game.

Terry Soule, Ph.D.: Evolutionary computational theorist and Professor at the University of Idaho, co-founded Polymorphic Games Studio in 2016. Terry has been working on integrating evolution into

simulations and video games for many years. He has been instrumental in incorporating biology into a coded language for integration with world building engines. Both he and Barrie Robison bring expert knowledge from their fields as well as teaching and mentorship to their students.

John Anderson: Program Head for Virtual Technology and design and Founder of the Virtual Technology Laboratory at the University of Idaho. John has been working with scientists and indigenous people around the world with the thought that virtual environments can help bridge the gap between science and indigenous knowledge. Working with local communities and researchers all over the world John has helped create social connections and opportunities for communities and students. His work with Alaska EPSCoR and the National Science Foundation has brought to life many new virtual environments as well as unique ways to use them. See *Salmon Sim* (virtual environment, 2016).

Other influential names include: J.P. Gee, MA; Ph. D., Daphne Bavelier, Ph. D., Kurt Squire, Ph. D. These people as well as those listed above have helped build infrastructure, develop and prototype learning environments and each contributed individual components to VDD. On the side while they all make contributions to developing video games and simulations as a learning tool many components are still missing to make VDD a complete and usable medium for teaching. The key components that I see have still not been discussed and displayed are: content management, technology allocation to students, teacher understanding, and content filtering. These are less setbacks and more challenges that will need to be addressed before VDD will be a usable medium on a large scale. On a smaller scale, these issues can be managed on a local level such as a classroom or campus. The University of Idaho is able to dedicate space though their own networks as well as set up inter office VPNs. Other uses for data sharing and version control of virtual environments are handled over cloud services and *GitHub*.

Beyond the classroom there are many individuals (like those listed earlier in 4.2) that are pioneering the sharing of technology and creating new mediums for understanding. These individuals and organizations are incorporating interdisciplinary fields of study and multimedia to create repositories for assets, tutorials, and ease of understanding online. For this section, I'm talking about makers, YouTuber, and hackers.

4.3 The YouTube Connection and the Maker Movement

The makers movement has been growing since 2005 giving “inventors, designers and tinkerers” the community they needed to build and share their ideas. While the movement is focused more around building and pushing the bounds of physics, machine and design, its core beliefs match very closely to VDD. Where in this case the virtual is set in meat space. The components I love about the maker movement and the spread of it to and across YouTube. Is the sharing of knowledge? This concept of not only saying, “Hey this is how you build…” but the challenge of “build one for yourself and experiment”, that's is the aspect I would love to bring to VDD. The expert makers come from many different fields; artisans, blue collar workers, physicists, engineers. And all come together in the spirit of discovery. Coming together and building spaces for people to learn and explore. Some notable examples of this are:

Destin Sandlin: Host of *SmarterEveryDay* (YouTtube series): hosted by Destin Sandlin, an American engineer focused on education video and challenging people to build and experiment. While still focusing on closer to home ideas and concepts the series reaches out asking questions and finding unique ways to answer them.

Adam Savage: Co-host and executive producer of the Discovery channel's, *Mythbusters* (TV Series). Adam Savage is an avid maker whose focus is more on creativity and entertainment, is creating such YouTube series as *Tested* (web series) where they champion science and technologies. He received an honorary doctorate from the University of Twente for his role in popularization of science and technology in 2011.

Matt Parker: Host of *Standupmath* (YouTube series), author of *Things to Make and Do in the Fourth Dimension (2015).* Matt challenges people to use math in unique and interesting ways, while entertaining and sometimes silly the show actively engages with people to try the purposeful applications of math and learn through doing and experimentation.

4.4 Significance To VDD

Each of these people bring something new to the VDD process. From finding and challenging the way datasets are used and how to test theories, to how the world looks at and shares ideas. VDD

needs people in universities and classrooms challenging how things are done. VDD needs experts in the field to be accessible to larger audiences for their successes and their failure to be helpful. When research papers and textbooks are hidden behind high-priced pay walls, that knowledge is lost for most of the audience. Building communities of like-minded inventors and tinkers opens the world of learning to untold hours of information. VDD will only work when people building virtual environments or diving into a dataset could try and fail and ask then ask for help or critique. VDD starts with teachers willing to give freedom to explore and express new means and modes of learning to their students. People like John Anderson who go out of their way to make connections with people that have wonderful science and stories and bring them together with people who can share and grow those ideas. Challenging traditional ways of thinking and development processes from data management and presentation to video game design. Knowing that information and technology are powerhouses that lets students find new ways to learn. These people make this possible. In my experience working with Polymorphic Games sometimes all it takes is a time set aside to spitball ideas off people who may or may not be interested. That act of play and failure works for the learning process, and more over for VDD. Having the backing of academics as well as experts, relative to learning as well as individual subjects of study, is foundational for the development of VDD as a medium.

4.5 Conclusion

The work currently being done by these and other individuals is insurmountable in the efforts of redefining how teaching and learning should be done. While these individuals are building new methods and techniques within the academic sectors there are also those who choose to build this idea of shared learning and VDD outside of traditional learning environments. Both angles need to be available for students learning through discovery. Academic structure and curriculum can set a pace and guide students to important milestones and career goals. But with VDD building a social community for study and development there will need to be outside influences and teachers willing to mediate, test, and host these new methods and platforms. The combination of academic influence, personal interest, and self-exploration will the defining factor for VDD. As we have seen each of these areas are already using principles of VDD but have yet to bring the whole together as one.

Section 5: Building a Better Video Game (Methods)

5.1 Building the Framework for Virtual Design Discovery

In the summer of 2016, I took part in the Video Game Design Lab which later became *Polymorphic Game Studios*. We brought together a widely diverse group of college students from many different disciplines from arts, sciences, and musician. The goal was originally to produce an evolved version of Space Invaders (video game, 1978) in a hope to make the game more challenging by adding working genomes to the creatures. While what we produced wasn't directed at VDD at the time (see above. 3.5) the process we used to coordinate and develop the game is a good example of the framework required for VDD to succeed in a group setting.

If we looked at the *Polymorphic Games* Studios as a classroom, the main objective would be to teach students about evolution through virtual design discovery. Building upon the idea that the best way to learn is to explore and build. Finding a path or means of learning that is unique to each student and build upon their intuition and creativity. We were able to do this within our group by making sure each person, regardless of their station, understood how and why we were building the creature's/genome the way we were. It was a daily activity to have someone explain what they are doing to the whole and tell their peers their success and failures on the development.

Having a fundamental understanding of evolution started as a quick definition but then each member of the group spent the next 3 months exploring and pushing boundaries of what could be done with it. We all wanted to answer the question: "Does evolution make the video game harder?" So, we pushed each other and experimented with different methods but as a group we were able to test this question in many different ways with many different views and opinions. Because we were all working on the same question but from different angles we help each other learn and understand the question more fully.

We knew the steps we would need to take to "complete" a video game we as a group set down our goals, objectives, and timelines to finishing the project. We knew what skills were needed, and we knew what milestones we wanted to hit. We developed a design document for the final project knowing that each of us would need to bring our own side to the table for the project to be completed. We defined the bare minimum we would need to understand for us to work together as a group:

Skills:

- Variable based manipulation of the Unity3d engine.
- Applying and adjusting genetic variables in a population
- Applying and adjusting player variables.
- Game design principles (optional)
- Game balancing (optional)
- Basic math skills.
- Data analysis (creating charts or comparing graphics)

Guiding Considerations:

- What is evolution?
- What is required for evolution to take place?
- What is the difference between evolution and adaptation?
- What are generational models?
- How does fitness and competition effect evolution?
- What are evolutionary pressures and their sources?

We then discussed different means of achieving the same goals from different individuals points of view. During the building phases of *Darwin's Demons*, we had a documentarian following, keeping tabs on us for a university based documentary. What we discovered is that we collectively learn more about each other and our fundamental understanding of each individual contribution for other members because we could talk behind closed doors. Creating outlets for teammates to discuss not only their own project but discuss other teammates projects aided us a lot when it came to interdisciplinary teamwork. A great example of this is the videos of *Does Evolution Make Video Games Harder?* (YouTube 2016). It all broke down to very honest critique and iteration. For us to really be able to develop and add content to the game we had to understand the how and why of the evolution process. Because we comment honestly and iterate frequently, it was very quick for each member of the team to be able to understand our end goals and objectives. They were then able to take that back to their own portion of the game and develop and share their process.

5.2: How did VDD help?

We selected these questions as our baseline for understanding for the team and asked them on the first day of the studio and then again towards the end of the project.

1. What was your selective pressure on the creatures?
2. Did it affect the creatures? If yes how?
3. Did we see evolution happen? If yes how?
4. Did your selected pressure affect the creatures?
5. What is drift?
6. What is evolution?
7. How does evolution differ from adaptation?

Overall there was an improvement in understanding of evolution and the game launched in Feb. 2017. What I found to be more interesting was the level of understanding that was grown about each component during the game process. This is where VDD stands out, with a basic idea of "let's teach someone something about evolution using video games." We were able to expand the scope of the original parameter to fit multiple disciplines and perspectives. We let biologists, computer scientists, writers and musician all explore a single question and experience the different mean at which they all tackled it. These video are available on YouTube a prime example would be *What is Evolution?* (YouTube *Polymorphic Games Studio,* 2016).

5.3 Conclusions and Discussion

From start to finish the *Polymorphic Games Studio* itself is the closest working structure of VDD I've seen to date. Part working business, part class room, part playroom. The overarching themes are the same. Goal driven work and exploration based around virtual environments and developed by a small community. This is how VDD should be looked at for classroom implementation. VDD projects should not be used as a single project like a book report but as a medium to facilitate social interaction and growth. As a project we succeeded, but more than that we created something that can now be used to facilitate more learning than we had originally anticipated. We built a game that could be added to and developed by future students. *Darwin's Demons* is a working model that can be used experimentally and scientifically in future studies. There now exists the foundation for more VDD projects based around Darwin's Demons. With VDD in mind the next iterations are infinite.

Section 6: Conclusion

Virtual design discovery (VDD) can become an effective tool to further learning and development in our fast paced, technologically advancing world. As the way, younger students interact with the world changes so does the way teachers have to create engagement.

VDD is a highly adaptable medium making it viable for challenging different age groups and supporting various levels of exploratory complexity. Its highly adaptable nature allows teachers and developers to set forth goals and objectives easily and support individual needs for each group or student. VDD is focused around self-driven discovery and exploratory learning. Students learn and grow as they develop virtual environments and assets. These environments and assets then can be used by future students to further explore and develop their own studies. VDD is a growing, living medium that has the potential to keep up with contemporary educational needs and interactions with the digital world.

While VDD is a new medium for transdisciplinary projects, it is not wholeheartedly a new idea. VDD is a culmination of well-established methods and principles being utilized in a technological changing landscape. VDD helps bridge the gap between creative writing and the scientific method, giving more freedom of expression and understanding not directly addressed by an individual principle before. This freedom can foster connections and cross disciplinary interactions to extend the reach of audience. From students struggling to understand core principles to stakeholders seeing scientific data in a new light. Falling under many different categories of learning VDD is able to encompass multiple disciplines and become more insightful as it does. Like its predecessors, it is a cumulative method that grows and develops as people use it and tailor it to their specific needs. In this way VDD is able to help define both subjective and objective views without one belittling the other.

VDD is still in its infancy and while there are many people in academia and in a multitude of different industries using pieces there is still a long way for VDD to become a concrete medium. These people are actively working to banish the old thoughts to art and science being separate, removing the sterility from hard facts and bringing back the importance of storytelling and narrative. It’s no longer enough to say that information exists and can be left on a shelf. Science and art are living things meant to be engaged with and questioned. With the exponential amount of information at our fingertips engagement is becoming more and more important that just access. For those who live in a world where access is a given. We are never more than one Google search away from an

answer, and in such a world context becomes very important. VDD is medium that may be able to help deliver that content in a graspable way and the work done by these individuals is paramount in its development.

For my own part, working with NSF, the University of Idaho, and *Polymorphic Games* has been amazingly rewarding. Not only was I able to build and develop simulations and games to help bridge the gap and develop new ways of thinking, but I learned more about the importance of social design. Discovery, virtual or otherwise spawns from questions and play. The tools and mediums change with the times, and it seems that people are not always able to keep up with them when it comes to teaching the next generation. Learning through discovery, designing virtual environments or otherwise is a highly under exploited medium for both academic and industry environments. I've seen the potential that VDD can offer across the different disciplines. I have come to see that world design is it's less about the product and more about the process driving its purposeful creation.

VDD is a rich academic territory for video game and scientific models to be development together for use as a medium for updating outdated design practices. VDD allows us to question what we know and gives us a safe environment to push our boundaries in, while giving us the ability to share and communicate. We can develop and create worlds infinitely similar to our own or as different as our minds will allow. While there will always be constraints of money, time and, memory, we shouldn't be limited by industry and laziness. Interdisciplinary interactions and workflow need to be part of how we live and learn. The ability to share and communicate has become so ubiquitous that it is nothing but wasteful to not utilize this combination in all things, especially in design and learning. Virtual design discovery starts with an idea, and ends with a community. The reach goes far beyond simple videos games, or scientific models. VDD allows not only for more accurate games, or well-spoken models but it allows individuals to express their voices in a way that may not have been thought of or to new audiences. This combination of technology, community and individualized project design are the first steps to improving our current practices and developing a more robust design community.

Citation

A. C. Graesser, N. K. Person (1994). *Question Asking During Tutoring*. Am. Educ. Res. J. 31, 104.

Argonaut Online (2017). Polymorphic Games - A game Studio at UI [people and blogs] Retrieved from https://www.youtube.com/watch?v=Oe7KeM5SIAE

C. D. Carthen *et al*. (2015). "Design of a Virtual Watershed Client for the WC-WAVE project," *International Conference on Collaboration Technologies and Systems (CTS)*, Atlanta, GA, 2015, pp. 90-96. doi: 10.1109/CTS.2015.7210405

Dalgarno, B. and Lee, M. J. W. (2010), What are the learning affordances of 3-D virtual environments?. British Journal of Educational Technology, 41: 10–32. doi: 10.1111/j.1467-8535.2009.01038.x

E. Seymour, N. Hewett, *Talking About Leaving* (Westview, Boulder, CO, 1997).

Hans Haacke and Jeanne Siegle, (1971) An Interview with Hans Haacke, *Arts* magazine, vol. 45, No. 7 (May 1971) 18-21

Haven, K. F. (2007). *Story proof: the science behind the startling power of story*. Westport, CT: Libraries Unlimited.

J. J. Vogel *et al*., *J. Educ. Comput. Res.* 34, 229 (2006). http://journals.sagepub.com/doi/10.2190/FLHV-K4WA-WPVQ-H0YM

J.M. del Campo, V. Negro, M. Núñez (2012) TRADITIONAL EDUCATION VS MODERN EDUCATION. WHAT IS THE IMPACT OF TEACHING TECHNIQUES' EVOLUTION ON STUDENTS' LEARNING PROCESS?, *INTED2012 Proceedings*, pp. 5762-5766.

J. P. Gee (2003). *What Video Games Have to Teach Us About Learning and Literacy* (Palgrave MacMillan, New York).

J. Yap (2011). Multi user and Virtual Learning Environments : Case Studies from NUS. The Centre for Excellence in Learning and Teaching (CELT), NTU

John W. Anderson, Roger Lew, et al (2016). *Salmon Sim*, Virtual Technology Laboratory. University of Idaho, http://webpages.uidaho.edu/vtl/Projects/unity/ss/salmonsim.htm

Kevin Knudson Professor of Mathematics, University of Florida. (2017, November 12). The Common Core is today's New Math – which is actually a good thing. Retrieved November 16, 2017, From http://theconversation.com/the-common-core-is-todays-new-math-which-is-actually-a-good-thing-46585

Lakoff, G., & Johnson, M. (2011). *Metaphors we live by*. Chicago: Univ. of Chicago Press.

Laura A. Whitlock (Individual differences in response to cognitive training: Using a multi-modal, attentionally demanding game-based intervention for older adults,2012 http://www.sciencedirect.com/science/article/pii/S0747563212000143)

Laurel, B. (2014). *Computers as theatre*. Upper Saddle River, NJ: Addison-Wesley.

Lisa Palathingal, Rui Wu, Riad Belkhatir, Sergiu M. Dascalu, Frederick C. Harris (2016). "Data Processing Toolset for the Virtual Watershed", *Collaboration Technologies and Systems (CTS) 2016 International Conference on*, pp. 281-287, 2016.

Malcom Gladwell; Little, Brown.(2000) *The Tipping point: how little things can make a big difference*.

Marzano, R. J., Pickering, D. J., & Heflebower, T. (2011). *The highly engaged classroom*. Bloomington, IN: Marzano Research Laboratory.

Mayo, M. J. (2009). Video Games: A Route to Large-Scale STEM Education? *Science, 323*(5910), 79-82. doi:10.1126/science.1166900

McLuhan, M., & Fiore, Q. (1967). *The medium is the message: Marshall McLuhan, Quentin Fiore*. New York: Bantam.

Murray, J. H. (2017). *Hamlet on the holodeck: the future of narrative in cyberspace*. Cambridge, MA: The MIT Press.

OCHOLA, J. Evans et al.(2015). Wikipedia: the difference between information acquisition and learning knowledge. **First Monday**, [S.l.], dec. 2015. ISSN 13960466. Available at: <http://firstmonday.org/ojs/index.php/fm/article/view/4875/5164>. Date accessed: 14 nov. 2017. doi:http://dx.doi.org/10.5210/fm.v20i12.4875.

Omale, N., Hung, W.-C., Luetkehans, L. and Cooke-Plagwitz, J. (2009), Learning in 3-D multiuser virtual environments: Exploring the use of unique 3-D attributes for online problem-based learning. British Journal of Educational Technology, 40: 480–495. doi:10.1111/j.1467-8535.2009.00941.x

Polymorphic Games Vlog. Does Evolution Make Video Games Harder? (YouTube 2016) – https://www.youtube.com/watch?v=u6_BlNYMco0

Polymorphic Games Vlog - What is Evolution? (2016, June 03). Retrieved November 16, 2017, from https://www.youtube.com/watch?v=5PRPwQBBDSs&list=PLCdFGE6Ps4jvn_O5z2EzSVI0iWtGc_Apy

Postman, N., & Weingartner, C. (1972). *Teaching as a subversive activity*. Harmondsworth, Middlesex, Eng.: Penguin Books.

Shanken, E. A. (2015). *Systems*. Cambridge: MIT Press.

Soule T., Heck S., Haynes T.E., Wood N., Robison B.D. (2017) Darwin's Demons: Does Evolution Improve the Game? In: Squillero G., Sim K. (eds) Applications of Evolutionary Computation. EvoApplications 2017. Lecture Notes in Computer Science, vol 10199. Springer, Cham

Sw1Ftx16. (2012) Minecraft: How To Build A 4-Bit Computer - Part 1 - Explanation and Design [Tutorial]. Retrieved from https://www.youtube.com/watch?v=yY-jixFtF0w

Turtle Rock Studios (2015). *Evolve* [PC Video Game]. Lake Forest, California, United States

University of Idaho Virtual Technology Laboratory (2015). SalmonSim Overview, November 16, 2017, from https://www.youtube.com/watch?v=vhAP9f4GgMs&t=1s