THE VALUE OF DOING SCIENCE:

A COMPARISON OF TRADITIONAL VERSUS VIRTUAL LABORATORY ACTIVITIES IN THE HIGH SCHOOL SCIENCE CLASSROOM

by

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(Under the Direction of David Jackson)

ABSTRACT

This study examines student perceptions of the value of virtual labs in the high school chemistry classroom. Since the 1990s, there has been a tremendous increase in the use of computer technology, especially Internet-based instruction, in both secondary and post-secondary science classrooms. Scientists and science teachers have always been very insistent of the important role that laboratory activities play in science instruction. With the introduction of virtual technology, there has been controversy among science teachers regarding the pedagogical soundness of virtual labs.

Four chemistry labs, one in each of the areas of calorimetry, thermochemistry, solutions and acid-bases, were studied because they represent four major areas in chemistry and there were virtual labs available where a corresponding traditional lab could be performed with practically the same instructions. The order in which virtual labs and traditional labs were experienced by students was alternated to achieve a balanced design.

12 students, six males and six females, were interviewed, before the labs were conducted, to determine their prior experiences with video games and in science classes, especially with laboratory/hands-on experiences in those classes. After performing both versions of the four labs, they were interviewed again to assess their knowledge of each topic, in terms both of calculations and of lab procedures, and to solicit their perceptions of the virtual labs, the traditional labs, and any perceived synergies of the use of both formats.

Major findings include that most students: were familiar with virtual technology from playing video games and with using computer equipment in their personal lives and in education; reported that their experiences with science labs were very minimal in elementary school, with some minor improvement in middle school; perceived their science experiences in high school classes to be of much higher quality and much more conducive to learning because of the much larger lab component.

While most students perceived the traditional labs to be superior because of the hands-on component, they viewed virtual labs as valuable, especially in circumstances where the traditional lab was not an option. In addition, they saw value in performing both the traditional and virtual versions of the same lab, especially if the virtual lab was performed first in order to fine tune their skills before tackling the potentially more dangerous, costly and time consuming traditional lab.

INDEX WORDS: VIRTUAL LAB, HIGH SCHOOL SCIENCE, SIMULATION, VIDEO GAMES, CHEMISTRY, SYNERGY.

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DEDICATION

I would like to dedicate this work to my family. To my parents who always encouraged me to pursue all the education I could and who were willing to sacrifice much leaving everything behind to move to this country in search of a better future for me. To my wife, for seeing me through all this long, and many times tedious, process always willing to be by my side, to read, and critique my work. To my children for believing in me and understanding when my time had to be shared with my school work.

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CHAPTER 1

INTRODUCTION

It is generally believed among science educators that the inclusion of laboratory activities in science courses is not only advisable but essential. Laboratory activities in the context of high school science class are also commonly referred to as "labs," "laboratories," "experiments," and "investigations." In this study the shortest and most commonly used term "labs" will be adopted. Wellington (2000) devotes a whole chapter in his book to the use of investigations in the teaching of science. Some of the benefits of investigations include motivating students who may otherwise not be motivated by science content, to develop understanding of science procedures, to encourage teamwork in science learning and to introduce students to the nature of science, even though classroom investigations may not exactly reflect the true nature of science.

Wallace, Louden, Mcguiness, Roth & Gilmer (2004) discuss the problems associated with the use of labs in teaching science; one such problem being that classroom laboratory experiments do not lead to true discovery of scientific facts that took scientists hundreds of years to discover. However, they recognize the need to include the laboratory experiences in teaching science and offer suggestions for improving the practice. The focus of the section is not to question the inclusion of laboratory activities in the practice of teaching science but to discuss the necessity for improving such practices.

Traditional Labs versus Virtual Labs

Currently, there is a debate among the science education community over the use of virtual labs as replacement for traditional labs. Depending on the algorithm used to program the virtual lab, they could be also used in inquiry activities. According to the National Science Education Standards "Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results." (2000, p. 23) If the virtual lab is capable of responding to multiple student imputs, the students are able to explore beyond pre-established procedures and inquiry is possible. On one side of the debate are those science educators and scientists who believe that students are not properly prepared to do work in science unless they have been trained using traditional hands-on lab work. "Prompted by skeptical university professors, the College Board, one of the most powerful organizations in American education, is questioning whether Internet-based laboratories are an acceptable substitute for the hands-on culturing of gels and peering through microscopes that have long been essential ingredients of American laboratory science" (Dillon, 2006, p.1).

Some scientists and science educatiors believe that students need to experience what a scientist experiences when doing science. They claim that virtual labs are preset and do not allow for the variety of results that are possible in a "real" hands-on lab. They also believe that virtual labs are void of the challenges that are often present in

conducting hands-on science such as equipment handling, breakage and malfunction, safety concerns, or time commitment, just to mention a few. In an article that appeared in *The New York Times*, Jackson (2000) says that "What is lost [in the virtual lab] is the tactile experience, the learning that comes from teamwork as well as the missteps that refine technique."

On the other side of the debate are those science educators who knowing that not all science students are going to be scientists and that virtual labs are just as effective in teaching and reinforcing science concepts as traditional labs. "The past two decades of research indicate that computer simulations show great promise in supporting student learning science." (Smetana & Bell, 2006, p. 267).

Furthermore, this camp argues that the current generation of students has grown up in a world where simulation games and other computer and video games are commonplace. These students may be more likely to be motivated by virtual labs than traditional hands-on labs. Video games use virtual technology in much the same way as virtual labs, creating a virtual environment where the student or game player operates. While the technology used in video games is generally more advanced and more exciting than that used in educational virtual software, the student nevertheless is asked to operate in a virtual reality in which risks can be taken with minor or no consequences. Another benefit of virtual labs is that they can provide access to science experiments which may otherwise not be possible to do due to other factors such as high equipment costs and safety concerns. High school labs are not equipped to conduct many lab experiences that would be possible with the use of virtual technology.

The above mentioned debate is all in relation to the traditionally delivered science course. However, a different set of challenges exists when the course is delivered over the Internet. In looking at college science courses taught over the Internet, most are strictly lecture courses. Students desiring the lab component take a corresponding traditional face-to-face lab course alongside the lecture course.

From personal experience with Gwinnett County Public Schools, Georgia Online Campus, this is not the case for high school science courses, which are taught as a unit where a lab grade is not separate from the lecture grade. This creates further complications. There are high school science courses that are taught strictly over the Internet and either they do not include a lab component or they include all virtual labs. Other such courses require students to attend a certain number of face-to-face lab sessions, which defeats some of the advantages of online courses, such as providing convenience, flexibility and availability to students in large geographical areas or without transportation.

Rationale of Study

Not much has been researched or written in this area mainly due to the fact that Internet instruction as well as virtual technology are both fairly new phenomena. Proliferation of Internet-based instruction only began in the very late twentieth century. Examining current practices and exploring what options may have not been tapped within the modern technology can lead science educators into a wider range of choices and opportunities for increasing student learning.

Interest in this resulted from involvement with teaching Chemistry courses online. Laboratory experiences are a critical component of science courses. In the arena of Internet-based instruction, a problem exists in this area since laboratory experiences have traditionally been done in a face-to-face environment. Many scientists doubt the validity of virtual labs in satisfying the laboratory experiences in science classes. Also, along with improvements in technology have come much more realistic virtual labs, which are very similar to the traditional labs even to the point of using very similar instructions. Use of this virtual technology in the face-to-face classroom could prove very beneficial to the students in several areas, such as practice and reinforcement of lab procedures.

Significance of study

The results of this study could have an impact in the future of science instruction, both in the Internet setting as well as in the traditional setting. If the virtual labs prove to be received by the students as well or better than the traditional hand-on labs, this study could lead to more research in the area. It could, eventually, lead to the inclusion of virtual labs in Internet-based science courses as replacement for the current traditional labs required for many Internet-based courses, making these course available to more students. Even more so, it could lead to the inclusion of more virtual labs in the traditional classroom to supplement the current lab instruction, especially in areas where cost or safety concerns prohibit the use of traditional labs.

If this project finds that there is some perceived synergy in using both traditional and virtual labs together, it could radically change science instruction. High school teachers could use virtual labs to either introduce a traditional lab to familiarize students with what

they are going to do so they can be more efficient in its execution, or use them after a traditional lab is completed to reinforce the concepts taught. Furthermore, the findings about the students' attitudes towards the virtual labs could influence instruction by offering teachers another tool to motivate students and improve student involvement, which would eventually lead to increased student learning. Throughout this paper, thoughts, feelings, and perceptions are also used to describe students' attitudes.

Research Questions to be Addressed in this Study

This topic raises many questions as it explores the possibilities that virtual labs may open up in science education. While recognizing that video games are slickly-produced and have great entertainment value in contrast to the technology used in virtual labs, both essentially place the student in a virtual reality situation. The scope of this study will seek to answer the following research questions:

A. RQ #1 What are the students' prior experiences with computer and video games?

Video games are slickly-produced, high-entertainment-value, obsession-inducing in contrast the typical computer lab simulation and they attempt to recreate "microworlds" that are fairly complex and realistic virtual realities versus science lab simulations (or virtual labs) that are more abstract and less realistic. In spite of the differences, there may be similarities in connecting the virtual and the real world.

B. RQ #2 - What are the students' prior experiences with science labs?

There is very little standardization of science instruction especially in elementary and middle school. There may be a wide variation in the experiences that the participants

may have had in science classes over the years. It is important to understand what the students prior experiences have been especially as they may affect their views of virtual labs, or even labs in general.

C. RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?

The advantages and disadvantages may include but are not limited to motivation, enjoyment, ease or difficulty to perform activity, perceived value in learning content and/or laboratory skills.

D. RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?

If any perceived synergies are found, do the students feel the labs should be performed in any specific order, which the virtual or the traditional should be first and why?

To avoid investigator bias from preconceptions of these students' achievement levels or other characteristics based on prior experience with them, another person will either perform or attend many or all of these interviews or else serve as a second analyst/interpreter of the data. A stratified sample, as indicated by their previous test scores, was achieved as twelve students representing different ability levels (low, medium and high within the classes involved) volunteered to participate in the study.

In order to document actual student learning an oral exam on chemistry content and laboratory skills will be conducted during the interviews. These questions will be used as a springboard to further invesigate the perceived source of their learning. Following is a list of questions that can be used to determine the students' learning:

1. *Freezing Point Depression*

a. Explain the steps required to determine the molecular weight (molar mass) of an ionic solute such as NaCl in water using the freezing point depression method .

b. How is the freezing point depression calculated? Explain the mathematical equation used.

2. *Heat of Reaction*

a. Explain the steps required to determine the heat of reaction of an acid-base reaction.

b. How is the heat of reaction in kJ per mole of NaOH. Calculated. Explain the mathematical equation used.

c. Why is it important to check the initial temperature of both the acid and the base? Explain the chemical reaction between hydrochloric acid and potassium hydroxide.

d. What is the reason for the insulated cup? Is the reaction of acid and base endothermic or exothermic?

3. *Calorimetry*

a. Explain the steps required to determine the specific heat of a metal.

b. How is the specific heat of a metal calculated? Explain the mathematical equation used?

c. Why is it important to transfer the metal to the water quickly? What is the purpose of the water in the calorimetry experiment? What happens to the temperature of the water in the experiment? What happens to the temperature of the metal in the experiment? Where does the heat absorbed by the water come from?

4. Acid-Base Titration

a. Explain the steps required to determine the concentration of an unknown acid with a base of known concentration.

b. How is the molarity of the unknown acid or base calculated. Explain the mathematical equation used.

c. In a titration, what does the equivalence point mean? How can it be recognized

CHAPTER 2

LITERATURE REVIEW

This chapter will review the literature related to the use of virtual technology and simulations for instruction in the traditional classroom as well as in distance learning. The second part will consist of a review of the research that looks at the exposure of children to computer and virtual technology through video and computer games.

Virtual technology in education

Multimedia technologies include audio and video, as well as simulations both interactive and non interactive. We will concentrate particularly on the use of virtual technology and its associated benefits and challenges because it is most pertinent to this study.

One of the concerns with using simulations in the science curriculum is the idea that simulations cannot adequately portray the nature of science to the students. Supporters of this way of thinking argue that simulations have a tendency to be easier than “real” science. They believe that some simulations are programmed to always work and do not show all the issues involved when experiments do not turn out right the first time and have to be repeated. However, more recent simulations do allow for mistakes

being made while conducting an experiment, such as Virtual Chem Lab, developed by Woodfield and Asplund of Brigham Young University.

According to Wellington (1999), there are problems associated with using multimedia in learning environments, especially in science. Some of his concerns focus on how realistic the simulations are compared to the science being portrayed, as well as whether the simulations give the right impression of the nature of science and how scientists work. He also believes that simulations may convey misconceptions related to the number of times a science experiment can be performed without regard to equipment wear and tear, and costs. And, he is concerned with the lack of hands-on experiences for the learner.

On the other hand, there are some scientists who see virtual labs as an excellent resource to use with some students. For a multitude of reasons, there are students who are hesitant to become involved in lab experiences. Srinivasan and Crooks (2005) say that a benefit of using multimedia in science is that students with a phobia to performing science experiments may be able to conduct virtual labs without the fear that their experiments may fail. Additionally, they have the ability to conduct many trials until they feel confident. These students may find these simulations more acceptable than traditional lab experiments since they minimize or eliminate their fears. There are very conscientious students who are genuinely afraid of laboratory work. Some students have safety concerns, others have a fear of breaking the equipment and yet others do not like the smell or the mess involved in many lab experiments, especially in Biology and Chemistry. Doing virtual labs will usually alleviate these concerns for the students. In these cases, the alternative labs may prove very useful.

The students with an aversion to the lab environments are not the only ones who might enjoy the virtual labs. Lawless (2001) reports that students involved in a study reported very favorable attitudes towards multimedia science activities. These students found the activities interesting, enjoyable, helpful and very valuable in understanding the subject matter better. The study did not involve only students with negative feelings toward lab experiences but a general population of students.

Not only can virtual labs serve as tools to reach students but they can also make difficult concepts more clear. There are some concepts in science, which are very abstract and very difficult to demonstrate in the typical classroom environment due mostly to budget and safety constraints. Virtual technology is a very useful tool in these cases. Science educators have been trying over the years to find better ways of teaching science and many of these involve the use of technology.

We find that even at this early stage in the development of virtual technology, people are starting to discover the necessity for different technologies in the instruction of science. Carmona (1996) argued, “From full, hands-on MBLs to virtual experiments on CD, CD-i or videodisc to Java-based simulations on the Web, technology has a lot to offer in the teaching of science.” Carmona talks about virtual fields trips. A virtual field trip is useful in teaching students about ecology and other science disciplines by taking students to all corners of the earth and even to space, which is not possible in the classroom. As I mentioned before, multimedia technology is not restricted to the use of virtual labs and simulations but includes other technologies. In addition, virtual

technology is not limited to virtual labs but offers other applications such as virtual field trips, virtual patients for medical training, and many other uses.

Discussing educational reforms in teaching math and science in liberal arts colleges Priscilla W. Laws (1999) says, “Students studying genetics can breed fruit flies and observe the inheritance of characteristics such as eye color. They can then augment their laboratory experience with software that simulates the breeding of thousands of virtual fruit flies, leading the student to discover the laws of genetics.” Here we see virtual technology used in conjunction with traditional hands-on lab experiences to augment them. Virtual and traditional technologies are not mutually exclusive. It is possible, and even desirable, whenever possible to combine the two approaches to enhance the instruction. Sometimes, the limitations of one approach can be minimized by the use of the two approaches in combination. They can be good supplements for each other.

In discussing the advantages of using the Internet to teach students with different learning styles, Ross and Schulz (1999, p. 123) say “An excellent way to involve them is to provide online virtual labs where students can conduct experiments or look more closely at curricular problems.” This can also hold true in a traditional classroom. Another instance where virtual technology can be effectively used to teach genetics in the traditional classroom involves the breeding of mice. “Conducting breeding experiments with live organisms, though valuable, is often prohibitive in terms of the money, care, and time commitment required, not to mention the issues surrounding the ethical treatment of animals used for laboratory experiments.” (Bell, Bell & Yam, 2003)

Briggs (2002) says that “Virtual reality may be one of the most important technologies in our future, producing a great leap forward in many fields. While most people now focus on VR's use in entertainment areas, its real impacts will be in the arts, business, communication, design, education, engineering, medicine, and many other fields.” He defines virtual reality as “a three-dimensional, computer-generated simulation in which one can navigate around, interact with, and be immersed in another environment.” Advances in virtual reality are essential in the development of more realistic science virtual labs. He explores the numerous applications of virtual reality in many fields including education. As far as science education, he claims that, “Chemistry students will be able to conduct experiments without risking an accidental explosion in the lab. Astronomy students will be able to visit a range of virtual galaxies to study their properties.” The uses for virtual reality are limitless. It can be used to train pilots and astronauts, doctors, and firefighters. The possibilities are endless.

Not only are educators in traditional settings discovering many uses to virtual technologies, but also educators in the fast growing distance learning settings depend on them. According to Halal and Liebowitz (1994), over the ten years prior to that time, enrollment in distance learning through Public Broadcasting System increased from 55,000 to 350,000 and that was twelve years ago. Definitely there is a continuing increase in distance learning at both the high school and college level, which includes enrollment in science courses. The use of virtual labs and simulations can be a very useful tool in teaching science in the online environment and the demand continues to grow for more offerings.

The use of virtual technologies extends beyond traditional student learning into the training of adults. Today's military personnel are required to be knowledgeable in a number of areas. Training is necessary for the acquisition of factual information and complex performance skills. Gaming has been used in training military personnel to determine if the gaming facilitated knowledge acquisition and retention. “Traditional classroom approaches for teaching knowledge are not always enthusiastically received by young service members who have grown up in a era of computers and computer gaming. Gaming can be considered a potentially powerful instrument for training. Applications are numerous and costs are potentially low. That is, relatively basic computing technologies are needed and instructor time is minimal-at least for fact-based gaming applications.” (Ricci, Salas & Cannon-Bowers, 1996)

Virtual technology has the potential for revolutionizing education in the future. As advances occur in computer technology, the quality and availability of hardware and software will continue to improve. Along with these advances in computer technology will come more realistic simulations and virtual labs. The more realistic these simulations become, the more likely they will be used in the classroom, both virtual and traditional. It is important to know the impact of these technologies in student learning in order to maximize their use to improve learning, rather than just to change instruction for the sake of making it different.

Children’s Use of Computers

National survey data gathered in spring 2000 indicate that children, ages 2 to 17, spent about 34 minutes per day, on average, using computers at home, with use

increasing with age. Preschoolers ages 2 to 5 averaged 27 minutes per day, school-age children ages 6 to 11 averaged 49 minutes per day, and teenagers, ages 12 to 17 averaged 63 minutes per day." It also indicates, "That when children between the ages of 2 and 17 have access to computers and video games as well as television, they spend, on average, about 5 hours a day in front of some type of screen, over an hour more than children without such access." (Shields & Behrman, 2000, p. 4). This study shows that children today are involved in activities using computer and virtual technology to a great extent, making this technology very commonplace for them. "In 1999, American children between the ages of 2 and 17 were spending approximately one hour and 37 minutes a day using a computer or playing video games -- an increase of 24 minutes over 1998." (Moll, 2003, p. 600).

In today's world children spend time with computers more than with any other type of technology. "Most American children now have access to home computers and are using them for everything from playing games to doing schoolwork to chatting with friends via e-mail to surfing the Web. In 1999, an estimated 67% of households with children had a computer game system such as Sega or Nintendo, 60% had home computers, and 37% had home access to the Internet--more than twice the percentage with access in 1996. Although children still spend more time watching television than using computers, when a nationally representative sample of children ages 8 to 18 were asked which medium they would choose to bring with them to a deserted island, more chose a computer with Internet access than any other medium, including television. Simulated worlds created by electronic games, computers, and the Internet are expanding

children's experiences from real to virtual. Through electronic games, children interact with simulated characters and creatures; through the Internet, teens assume multiple identities to interact with strangers-and even robots ("bots," computer programs that represent themselves as people) in the simulated worlds of MUDs and chat rooms. Computerized games and the Internet move users into a world where the distinction between real life and simulation may not be clear, especially for children." (Subrahmanyam, Kraut, Greenfield & Gross, 2000, p. 123). The simulations that students encounter in their play are no different from the virtual technology they will encounter in education. The goals may be different, entertainment versus instruction, but the technology is the same. This means that students are familiar and comfortable with it.

Technology as an Educational Tool

Din & Calao (2006) studied kindergarten students' reading and spelling performance. Students who played Lightspan, an educational video game from Sony PlayStation, showed improvement over those who did not play the game. The same study also found that the same students reported no gains in math performance. The researchers speculated the lack of improved mathematics performance due to lack of maturity to perform the mathematics tasks. They go on to say that video games can improve performance but only in students who are developmentally ready to perform the task in question. They also state that the results were inconclusive and that a study with a much larger sample size was needed.

River City is a leading educational MUVE created at Harvard University by a group of professors from various universities and used by about 60 teachers and 4,000 students in the US and Australia. A MUVE is a multi-user virtual environment. In the simulation, students work in groups of three and are allowed to interact with residents of the virtual town of River City. They can look at documents and can gather data with virtual instruments. Teachers can allow students to interact electronically with each other but not with students from other schools. The study was conducted with 1000 students and 11 teachers in the Boston and Milwaukee areas in 2004-2005. The results of this study show overwhelming evidence for the benefits of using virtual games in education, "after using River City for 20 class periods, students showed a 32 to 35 percent improvement in their knowledge of biology." Analyzing the letters the students wrote to the mayor of River City, the researchers found that "students demonstrated an understanding of the process of inquiry," and that "both low-and high-performing students demonstrated a clear causal relationship between the problem and the reason(s) for the problem." The report also notes two other significant outcomes. In one classroom, where attendance had been a major problem before River City was introduced, the teacher saw a 35 percent decrease in absenteeism from the first to the last week of the project. In the post-program evaluations, teachers and students both asked to use the program again." (Blaisdell, 2006)

"Video games seem to appeal to the biological reality of human beings. That is, whatever we are, we seem to enjoy playing certain games, and having our skills challenged by certain kinds of play or games. Human beings have evolved to have certain

brain and perceptual/motor abilities which respond well to stimuli that challenge people and often help people learn to perform even better," (Darwin, 1872; Eisenman, 2003; Buss, 1999). The effects are no doubt due to a large variety of reasons, but one thing we know: motion has powerful physiological effects on people, and holds attention to the image (Simons, Detenber, Roedema, & Reiss, 1999)," (Eisenman, 2004). This article discusses game playing in relation to the effect of video games on violent behavior. However, we see that it is natural for human beings to play games, which translates into playing video games in our technological age, further supporting the fact that most children today play video games.

Also relevant to children playing video games are gender issues. "Since the introduction of the simple but hypnotic 'Pong' nearly 25 years ago, consistent gender differences have been found in children's time commitment to electronic game playing (Dominick, 1984; Funk, Germann, & Buchman, in press; Greenfield, 1984; Griffiths, 1991; Provenzo, 1991). Males are found to spend significantly more time playing than females, across locations (home and arcade) and across age groups. In our 1990s surveys of 900 fourth through eighth graders, proportionate gender differences persisted across the grade levels examined (see Buchman and Funk, 1995, and Funk, 1993, for descriptions of survey techniques)." (Dominick, 1984; Funk, Germann, (Funk & Buchman, 1996). Gender differences are significant if we consider the possibility that playing video games are beneficial to academic performance. Since girls generally spend much less time playing video games than their male counterparts, they may place themselves at an educational disadvantage.

After looking at the literature, we can conclude that children in our society will play video games, some to a larger extent than others. We can also conclude that these video games, just like any other game or activity children engage in, will have an impact on them. Video games will likely have an impact on the students' attitudes towards virtual technology and will also likely have an impact on their academic performance. Video games are currently being used for both entertainment and educational purposes.

Additional Literature Findings after Data Collection

Over the last few years, there has been a large proliferation of technology in education along with science course taught over the Internet. Between 1997, when online learning was in its infancy, and 2004, there was an increase in the number of colleges and universities offering some type of online learning environment from 22% to a large majority, especially in the public sector, where it has been reported that as many as 90% were offering fully online courses in 2004, serving over 2 million students. They also report that "that 52.6 percent viewed online learning as critical to their institutions' overall long-term strategy." (Picciano, 2006, p. 75) While not everyone agrees on the value and the pedagogical soundness of online education, it cannot be disputed that online education has become a major force in education, including science education. Online education offers educational opportunities to a much larger audience in many different circumstances; therefore it is expected to continue to grow. As online education grows, as well as the science education segment, the need for more tools such as virtual labs will also increase. With improving technologies to deliver pedagogically sound

virtual tools to the online environment, these tools will also become available to the face-to-face segment of education at all levels from elementary to post-secondary.

According to Tiala (2006, p. 9), “Today's students are technologically savvy. They use computers to play video games, post web pages, publish weblogs, and chat online.” Tiala also mentions in the same study that “Virtual-reality technologies tap students' motivation to use computers while delivering standards-based curriculum.” Students feel very comfortable with the input devices such as mice, flash-drives and other types of input devices used in virtual reality educational tools.

In addition to other technologies, virtual labs can be effectively used by teachers in face-to-face science classes. “A science teacher at Trigg County High School (KY), Parker often juggles lesson plans spanning physics, geology, astronomy, and chemistry. With help from Unitedstreaming and Science Connection, she can easily create multimedia presentations. ‘I'm addicted to the virtual labs because I am able to show my students a complicated, time-consuming process without pulling out all of my lab equipment to do a demonstration’" (Matranga, 2007, p. 40).

One example of the use of virtual technology in traditional face-to face classes is found in a study conducted in the use of VPLab, a set of virtual Physics labs. “VPLab's target users include on-campus learners as well as distance education students. For the latter, virtual labs will often be the sole or principal means by which they learn through experimentation. By contrast, in a school or campus-based context, virtual experiments are used mainly as a complement to regular laboratory work or as surrogates for specific

experiments difficult to carry out in actual laboratory settings. (Francis & Couture, 2003, p. 439)

"As technology advances, so does the potential it holds for education. Special education is making use of these new developments in a variety of ways." (Smedley & Higgins, 2005, p. 114). Virtual technology has also been reported to have been used in special education classes. Virtual technologies are being incorporated in special education in order to immerse the students in new environments; some examples include virtual field trips, simulations and demonstrations. These technologies make available to students that would otherwise not be possible because of safety or cost restrictions. Additionally, virtual technologies allow the students to repeat experiences as many times as needed and use different modalities to address different learning styles. The same reasons for using virtual technologies in special education classes are also relevant to regular education students.

With respect to virtual reality technology used in virtual labs, Jonassen says that it "a new type of computer tool that adds vast power to scientific visualization." (2004) Jonassen also says, in the same publication, that "with virtual reality, sound and touch, as well as visual appearance, may be used effectively to represent data. Perceptualization involving the sense of touch may include both tactile feedback (passive touch, feeling surfaces and textures) and haptic feedback (active touch, where there is a sense of force feedback, pressure, or resistance)."

Virtual labs are very useful when used in conjunction with other teaching tools. By using different approaches, the teacher is better able to reach students with different

learning styles. “Technology is not the answer for every teaching issue and that old ideas are often worth revisiting, especially when they are seen in the context of new concepts in education. In this case, neurological data indicates that learning through several different modalities both reinforces learning and speaks to students with different learning styles.” (Flannery, 2007, p. 170)

Smetana & Bell offer several comments regarding the use of virtual technology in traditional face-to-face classrooms. They point out that computer simulations are not intended to be stand –alone or to completely replace traditional hands-on activities but to supplement. They also mention that computer simulations offer alternate representations or explanations of scientific concepts which help them bring to life abstract, complex concepts. They additionally warn that the focus should remain on the students and not on the simulation and teachers should consider the difficulty of the simulation and whether or not this will detract from its value in reinforcing the content. “When used appropriately, computer simulations can help students gain a conceptual understanding of complex concepts, then internalize, and finally, transfer these understandings to new situations. Following the guidelines presented here, teachers can take advantage of the opportunity computer simulations allow for students to visualize, contemplate, and explain something as abstract as cellular mitosis or the bunching up of sound waves undergoing the Doppler Effect. In doing so, students are engaging in and further developing the scientific habits of mind encouraged in the recent science education reform documents. Not only can computer simulations transform the way we teach and learn, their cost and time efficiency benefits offer a solution to challenges presented by

tight budgets, limited resources, and restrictive school schedules." (Smetana & Bell, 2006, p. 267)

Several students in this study expressed that video games and virtual labs, while they used similar technologies, were not the same. Many of these students also said that games with a story line were more interesting. This finding is similar to a finding in an earlier study by Horn which found that "You might be thinking that simulations and games are the same thing, but they are not. Several decades ago, researchers at the Xerox Palo Alto Research Center (PARC) became intrigued by the intrinsically motivating aspect of video games. …To answer the question of what draws people to games and holds their attention for so long, the researchers designed a series of games with different attributes. As it turns out, successful games include a goal or challenge, offer adequate user control, present unknown or unforeseen events, and are built around a mystery or fantasy--in short, a story." (Horn, 2007, p. 73)

CHAPTER 3

METHODOLOGY AND DATA ANALYSIS

Methodology

My background in science generally leads me towards a post-positivist theoretical perspective. This means that there is a truth to be discovered. Instead of an absolute truth, as a strict positivist would claim, there is an approximate truth to be discovered. A certain level of objectivity exists based on probability rather than absolute objectivity.

The research questions were guided by an interpretivist theoretical perspective. An interpretive theoretical perspective "looks for culturally derived and historically situated interpretations of the social-life-world." (Crotty, 1998, p. 67). I interviewed students and tried to understand their backgrounds in computer and video games and their experiences with science labs. I examined the students' responses in trying to discover meaning. I, also, tried to discover what the students' perceived advantages or disadvantages of virtual and traditional labs were, as well as perceived advantages or disadvantages in performing both. If advantages were discovered, I examined their responses in order to discover their preference for the type of lab that should be performed first, if indeed the order appeared to be a factor.

The study was strictly qualitative. However, there is value in conducting the study following a quasi-experimental design as explained by Sadish, Cook and Campbell

(2002). According to Cook and Campbell (1979), internal validity means that the variation in two variables indicates that a causal relationship exists between the given variables. In order to show that internal validity exists, we must be able to show that one variable precedes the other and their co-variation cannot be explained through any other relationships but a causal relationship between them. According to Krathwohl (2004), internal validity means that there is a set of evidence that explains when a causal relationship exists. He also refers to internal validity as linking power (LP) meaning that a study links the variables into a causal relationship.

External validity according to Shadish, Cook and Campbell (2002) refers the ability to generalize the results of a study to different persons, settings, treatments or outcomes, whether or not these are present in the experiments or not. External validity is all about generalizations from the findings of a study a larger population outside the study participants. Krathwohl (2004) refers to external validity as generalizing power (GP) or how widely the relationships found in a study hold beyond the study. He mentions that sometimes where two variables are both influenced by a third variable we mistakenly treat these relationships to a third variable as causality between the two variables. Krathwohl (2004, p. 131) says, “causal relationships are always inferred, never proven.” He goes on to say that they however can be tested. He also mentions that causality always involves a chain of causes from which we choose the most appropriate for a given inquiry.

Krathwohl (2004) identifies five judgments involved in internal validity. They are explanation credibility, translation fidelity, demonstrated result, rival explanation eliminated and credible result. Explanation credibility involves judgment of the

credibility of the rationale of a study or a hypothesis. Translation fidelity means an extensive description of how a study is carried out or translating the hypothesis into the aspects of the study with high fidelity. Demonstrated result means that the data must show authenticity of evidence, precedence of causes, presence of effect and congruence of explanation and evidence. Causality is best evidenced when the effect shown in the experiment follows a detailed prediction and when the causal pattern is complex, the more complex the more evidence for causality. Elimination of rival explanations means that the goal is to rule out any possible plausible rival explanation, thus leaving the causal relationship discovered in the study the best explanation. Credible results follows from all the four judgments previously mentioned.

Internal and external validity can be thought of as reduction of uncertainty that the relationship discovered in the study indeed exists and that it can be generalized beyond the scope of the study to other persons, settings, treatments or outcomes. Shadish, Cook and Campbell (2002) describe a set of threats to each the internal and external validity of a study. The list of threats to internal validity includes:

1) Ambiguous temporal precedence, which deals with confusion in regard to which variable occurred first therefore confusing which is the cause and which the effect;

2) Selection, which has to do with the fact that the subjects receiving one treatment are different from the subject receiving a different treatment;

3) History, which refers to all the events that could occur during the study and could the reason for the outcome of the study;

4) Maturation refers to naturally occurring events that happen over time during the study and could be confused with the effects from a treatment;

5) Regression can occur when subjects at some extreme of the spectrum are selected for a study; sometimes their scores on other measures do not differ much;

6) Attrition of one type of participant over another can produce effects due to the fact that a certain type of participant is either absent or less represented;

7) Changes that occur over time in a measuring instrument can cause effects due to these changes to be taken for changes that appear to have happened from the treatment;

8) The above threats may have an additive effect on each other.

There are ways to reduce or eliminate these internal threats. Some of the above threats will be applicable to my study and steps will be taken to minimize the threats. The history threat could be a problem in my study. I will address this threat by selecting participants for both types of treatments form the same classes to assure that they are all exposed to the same series of events in the classroom. Events outside the classroom are not likely to affect the outcome of the study. In order to minimize the effects due to selection, male and female students were selected to receive the treatment in a certain order and also in the reverse order. Both male and female students treated both ways were selected. The other threats are not significant enough to be considered because similar types of students taking the same classes will be used and the duration of the study was relatively short, about three months.

The threats to external validity include:

1) The participants in the study, even if members of the larger target group, may not be representative of the target group;

2) The results could be different from those of the study in a real-life situation with a larger population, which may include different students and different conditions;

3) The result of the interactions may be different if success is measured using different outcomes;

4) The effects found in the study could be different from the effects found if the settings were different, such as different schools or classes;

5) In a different context, the same results may occur but not necessarily for the same reasons.

The first threat is a very valid threat because it is difficult to exactly duplicate a population with a sample. However, in my study, I tried to minimize this threat by randomly selecting the participants. I had 118 students in five classes and most agreed to participate in the study so I could have a certain amount of randomization within the constraint that I selected males and females with different sequence of treatments. Purposive sampling along with random sampling alleviated the threats to generalization.

Half the students were treated with the virtual lab first and the other half with the traditional lab first. The group treated with the virtual lab was then treated with the traditional lab and vice versa

Methods

The study began by interviewing twelve students who, along with their parents, had given consent for participation in the interviews. It was intended that students would be randomly chosen from groups of students of different ability levels. This step was not necessary as twelve students representing different ability levels volunteered. The differences in ability levels is evidenced by their test scores and their average grades in the class. The students were high school sophomores in a suburban high school in a suburb of Atlanta. The students were enrolled in a first year Chemistry course. In all five classes combined, there were equivalent numbers of girls and boys. The ethnic background of the students was: 11% African American, 24% Asian, 3% Hispanic and 62% Caucasian. These students had average to above average intelligence and were enrolled in either Gifted or Honors level Chemistry.

Twelve students were interviewed in an attempt to reach saturation. The interviews lasted approximately 30 to 60 minutes total, depending on the individual student's responsiveness to the questions. The interviews were semi-structured and were divided into two one half-hour maximum sessions. Grounded theory methods were employed in the analysis of the interviews. The first session concentrated on discovering the students' exposure to computers and involvement with video games. It also concentrated on discovering the type of lab activities they had been exposed to in their past science instruction as well as their current attitudes towards science labs. These interviews took approximately one or two weeks to conduct.

After, or concurrently with the initial interviews, all students, in the classes performed both traditional and virtual labs. There were five classes of 20 to 28 students each involved in the research project. Approximately half of the students performed the traditional lab and the other half the virtual lab. Then, the students switched and performed the same lab using the other format.

Althought this is a qualitative study, the project followed a quasi experimental format. The groups of students receiving each treatment were gender diverse. Four labs were conducted over a period of six to twelve weeks. The depth of the virtual labs was matched as closely as possible to that of the traditional labs. The labs were conducted over several topics in Chemistry and the data analyzed as a whole, not topic specific. Participant observations were made during the lab sessions to examine the level of student involvement in each of the labs.

Each group (class) was made up of 20 to 28 students. Since there were five classes the following schedule was followed (see Table 1, below; note V = virtual, T = traditional):

Table 1. Lab Schedule

	Lab 1	Lab 1	Lab 2	Lab 2	Lab 3	Lab 3	Lab 4	Lab 4
Groups 1 and 2	V	T	T	V	V	T	T	V
Group 3	V	T	V	T	T	V	T	V
Groups 4 and 5	T	V	V	T	T	V	V	T

The second interview sessions were conducted after the students performed the series of virtual and traditional labs. It focused on the students' perceived advantages and disadvantages of both the virtual and traditional labs and their opinions, thoughts and feelings of performing both. If they perceived benefits of performing a lab in both formats, which order should they be performed in? These interviews took approximately two or three weeks to conduct.

Data Analysis

The data was analyzed from a grounded theory perspective. According to Maykut & Morehouse (1994, p. 126), "One of the defining characteristics of qualitative research is an inductive approach to data analysis." They state that an inductive approach, in contrast to the deductive approach used in quantitative scientific research, does not

follow a predetermined hypothesis. An inductive method allows the data to determine what is important. There are no preconceived categories for analysis.

Grounded theory is an applicable methodology to my study as I try to understand how students feel about the lab experiences, especially the virtual labs. I imagine that the students would probably have positive feelings towards the virtual labs, as they are novel and use technology similar to that of video games. However, I really don't know. I want the students to speak to me about their experience and to discover their feelings about it from the interview data. I don't want my preconceived ideas to influence the study. As Dey (1999, p. 251) says "There is a difference between an open mind and an empty head." I can keep an open mind in spite of my opinions.

The interviews were designed to be semi-structured in order to discover what the students' experiences had been and their opinions about each type of lab, virtual and traditional. An inductive analysis was conducted, as it is appropriate for discovery. No preset codes were used in analyzing the interview data. Line by line coding was used and the codes were derived from the transcripts; in vivo codes were used as much as possible in order to make the description as close to the words of the participants as possible. All the interviews were analyzed at the end; therefore strict constant comparison methods were not used. However, since the interviews were semi-structured, previous interviews influenced the direction of future interviews in an attempt to delve into areas discovered throughout the interview process.

The first step in the analysis was line-by-line coding. (Strauss & Corbin, 1998). Each student's interview was printed and read line by line to identify codes, either words

or phrases. Each code was underlined. Following the line-by-line coding, each code was scanned with a line scanner into a Microsoft Excel document. These codes used the students' wording. Following this process, related codes were sorted and grouped together into axial codes, still trying to retain as much of the original students' words as possible and therefore as close to grounded theory as possible. During the axial coding process, memos were written to clarify the meaning of each of the axial codes. The next step in the process consisted of further sorting and grouping the axial codes into categories or themes. Memos were then written as these themes were identified to clearly explain the meaning of the themes and connect them to the codes. The same process was followed to analyze the second set of interviews.

Following the analysis to identify and explain the themes discovered in the two sets of interviews, further analysis was conducted to identify connections between the themes within each set of interviews and across both sets of interviews. Index cards were printed for each theme for each student with the corresponding memos to facilitate the discovery of connections between the themes. The index cards were physically connected with string whenever a connection was discovered. After all the connections were made, a chart was created using Inspiration software to show the connections between the themes. This process was followed for each student and a case analysis written for each.

Additionally, a cross-case analysis was conducted. For each theme identified, index cards were printed for each student. The cards were grouped based on the students' comments of each theme and trends were identified across all twelve students as well as individual differences. At this point, similar themes from different students were given

standardized names in order to be able to compare the connections between the themes for each of the students.

For the evaluation section of the second set of interviews, a rubric was developed to assess the students' knowledge as evidenced by their responses to the interview questions related to the content each of the labs. Points were assigned for each lab and a total number of points were tallied for each student for an overall assessment of the knowledge of all four labs.

Pilot Study Findings

Two interviews were analyzed from participants in a pilot study. Following are the findings from that study. The following findings in the pilot study led to the development of the research questions. Pseudonymous initials are used to name the participants.

A. Age Issues

First of all, both participants indicated that they had been playing video games as far back as they could remember as very small children. "Uh, I've played computer and video games since I was about 5." SC said, "I probably started playing when I was about 4 and I played up until about 13 or 14." They said that they remember playing video or computer games as very small children mostly with games that were intended to be educational and to spark children's interest in learning. As children, they both enjoyed playing these games because they saw them as games, not as structured learning experiences. "I first started out with a lot of educational type video games and computer

games." (EK). Both EK and CS used the word "fun" to describe their initial experiences with video and computer games. They remember that the initial interest in the games came from them, not their parents, even though their parents were eager to provide those learning opportunities. They remember having seen the game on television or at their friends' houses and that was what got them interested, because they either looked like fun or because they had tried them and enjoyed them.

Another age-related theme that emerged from both interviews was that, as the participants got older, they went from more educational games to more recreational games. EK said "it was pretty gradual, you know, going to less educational video games" Also, as they transitioned into high school, the amount of time spent in playing video games decreased because of the demands on their time from their schoolwork. CS said that as she grew up, she "started playing less hours in a day or I'd start playing less days in a week." The age theme had one of the highest frequencies in the area of games, six times for EK and five times for CS.

A. Fun and Compelling

Another theme that emerged from these interviews related to video games is the idea that they played them because they were fun and compelling. These codes were in vivo codes; the students used these words repeatedly. These codes appeared about 17 times between EK and CS. It appears as if the subject was more important to EK since he used the more powerful word "compelling." He said about the games that they "had fun elements that actually compelled me to play them." EK was also much more enthusiastic and offered much more information about the different types of games available and the differences between them, from sports games, strategy games, role-playing games and

many more. EK said “there are a lot of different types since there are a lot of different genres and it’s a very big industry.”

Later on in the interview he went on to say about the games that, “just creative elements that make it compelling and unique, but I mean, there are role playing games that are some of the most strategic that involve like taking a character, or multiple characters, and trying [to decide] which ones to use in different situations, in fights or scrimmages, or whatever it may be. But that definitely requires different types of strategy from you know different assault-type games like war simulations and plane simulations.” Later still in the interview, he offered very detailed information about sports games. He said, “There are a lot more sports games out than any other genre.” EK has obviously been very involved in video games as evidenced by his wide knowledge of them.

B. Translatable Skills

Both of these students felt very comfortable with using the computer since they have been using it from an early age to play games. They both made some mention to the fact that they liked computer games because they can start over again if they mess up. This fact could possibly translate into a preference for virtual labs because they can start over again if they “mess up.” Wellington (1999) saw as a concern of using technology that it may give students the wrong impression that in real life labs are easily disposable and there is no cost of equipment or supplies incurred in discarding labs easily in the virtual realm. It should be stressed to the students that in real life, disposing of a lab is not as easy as clicking a button.

Another issue brought up in relation to video or computer games was the fact that you are able to experience things you would not otherwise be able to experience either because of the expense or the safety issues. CS said "you can imagine yourself being in the game and doing yourself without actually having to face the threat of death." Here is another point that could easily translate from the game to the lab. Students could be very happy experiencing certain lab experiences virtually versus none at all. This is not a foreign concept to them. It would be interesting to delve deeper into the question of the students' familiarity with virtual technology and the effect that this has on their ability to work with virtual labs.

When asked to compare video games to virtual labs, EK responded "The controller is different, on the video games you have different types of controllers, on the virtual labs, you just click. They are not really the same. I suppose they could be somewhat similar but not too much."

The second half of the interview was very interesting. Both participants had very interesting comments, some in common and some with very contrasting viewpoints.

C. Virtual versus Traditional Labs Advantages and Disadvantages

EK mentioned that he liked the traditional lab better while the CS preferred the virtual lab. She did say that she would normally enjoy the hands on lab experience more but that in this case she preferred the virtual lab. CS said "The virtual lab kept my interest because I got to see more clearly if it reacted. There wasn't any second-guessing myself and you got to see cool colors that you didn't get to see in the other lab." Both of these students are enrolled in advanced placement chemistry so they both have an interest in

science. EK said that the traditional lab "kept your interest more, it was more enthralling than the virtual lab, there was nothing wrong with the virtual lab, but the traditional lab was better."

In regards to the relationship that they perceived between their extensive experiences with video games and the virtual labs, they both agreed that the virtual labs were somewhat like the games but not exactly. They both said that computer and video games allow the player a lot more flexibility to go outside of the boundaries of the game than the virtual lab. They perceived the virtual lab as more restrictive than the video games. They did agree that familiarity with computers made it easier to learn to navigate the virtual lab than it would otherwise have been.

D. Ease of Doing the Labs

They both found the virtual lab very easy to navigate and very easy to get the results expected. However, they had completely opposite reactions to it. EK found the ease to be a distraction. He said that because the virtual lab was so easy to do, it made it monotonous for him and not very exciting. "The real lab made you have to pay more attention to what you were doing … you have to be careful with what you do." On the other hand, the ease of the virtual lab was the reason why CS thought she liked this virtual lab better than the traditional lab. It is interesting how two students can have the same opinion and yet have opposite reactions to the same thing. EK found the virtual lab a little confusing because it was hard to tell which substance he was working with. CS had the same comment about the traditional lab. She said it was difficult to keep track of which substance was in which compartment.

E. Time Requirement

Both students commented that the traditional lab took a little longer to do due to the time it took to gather all the materials, set up and clean up. However, they both thought that the time difference was not a deterrent to the traditional lab. CS said "It takes longer to do the hands on lab because you are actually doing it yourself whereas in the computer you are clicking and it automatically takes you to where you need and pull it up in a matter of a second and then you go back to the workroom." She goes on to say that the extra time involved in doing the traditional lab is "worthwhile because there is more thinking involved."

F. Safety Concerns

One major theme with 18 occurrences is lab safety. They both could see advantages with the virtual lab when it comes to lab safety because there was no way for the students to get hurt doing the virtual lab, while safety was always a concern when working with chemicals. One thing that was interesting within the safety arena was that EK thought that the safety concerns associated with the traditional lab "keep[s] your attention more because you have to be aware of the safety issues because if you burn your hand off you can't just re-grow your hand so you have to be careful with what you are doing." Safety is always a major issue in Chemistry lab. In fact, many interesting and highly educational labs are never performed by high school students because of safety concerns. Virtual labs could be the best possible option in this setting.

G. Physicality

This was a recurring theme with both students EK and CS. The term was an in vivo code developed from EK's remarks. Many times throughout the interview EK

mentioned the "physicality" of the traditional lab as an advantage. CS also refers to this theme, which she calls the "hands-on" aspect of the traditional labs. They both see this as an advantage of the traditional lab over the virtual lab. EK said that if a person "is interested in science, they would like the traditional labs more because they could feel and see what they are doing."

H. Synergy

Both students said that both the virtual lab and the traditional lab were useful for instruction. They also thought that doing them both would have some synergistic effect since they would complement each other. EK said: "Maybe if you do both it can help to learn the point better." They thought that while the traditional lab is probably the preferred method, the virtual lab was a suitable substitute in cases where there was a cost barrier due to either equipment or chemical costs. EK said "it is better to do the virtual lab if that is the only thing you can do because it is either too expensive or unsafe." Another reason they gave for using a virtual lab, as a substitute for a traditional lab was that there were safety concerns inherent with the traditional lab. In the case where both were used together, the EK didn't mention any difference on which should be done first. CS thought that it would be a good idea to do the traditional lab first to allow the student to discover scientific truths, and then use the virtual lab to verify those truths and avoid making wrong conclusions. This assumed that the virtual lab had all the "right answers" built into the program.

They both agreed that virtual labs would be ideal for science classes for non-science majors because these students were not interested in science and would not

benefit much from the hands on experience that they thought was valuable to the science majors.

I. Conclusions and Discussion

I found these interviews to be very revealing in answering the research questions.

What is the nature of the students' prior experiences with computer and video games?

Before the interviews, I had suspected that I may find major differences between the answers from these two students based on gender differences. When it came to experiences with video games or computer games, while EK seemed more enthusiastic about the subject, they were both very knowledgeable about video and computer games and they had both had extensive experiences playing different types of video and computer games. Maybe there is not as much of a gender differnce in this area as I may have anticipated. This may be an area for further research when more participants of both genders can be included. It appears that because of their extensive experiences with video and conmputer games, they had a great deal of comfort with the technology which allowed them to focus on the labs and not be disturbed by trying to learn some foreign technology.

What is the nature of the students' prior experiences with science labs?

Neither student had too much to say about their previous experiences with science labs. They remembered doing some labs in elementary school and a few more in middle school. They did not see this limited experience as a problem, even though they thought it may have been nice if they had been able to do more labs in their younger years. Future research could focus on discovering in more detail what their elementary and middle

school experiences with labs were and how this may affect their like or dislike for science. However, it appears as if the prior experience with labs was not nearly as important as their experiences with virtual technology in relation to virtual labs.

What advantages or disadvantages do students feel virtual labs and traditional labs have towards each other?

The most mentioned advantage of the traditional lab and disadvantage of the virtual lab was the physical, hands-on aspect of the traditional lab. The most mentioned advantage of the virtual labs was the ability to do certain labs that may otherwise be impossible to do in a science classroom. More research is needed using the virtual technology in a distance learning setting where the presence of the instructor is not available. It appears as if the virtual lab is not a perfect substitute for the traditional hands-on lab but it may a be a suitable substitute where the situation does not permit the hands-on lab such as in the case of Internet-delivered instruction.

The results of this study have major implicatioons for the science educator. It appears as if the virtual lab, in the traditional classroom setting, can be a very valuable additional tool for instruction, not a substitute for traditional labs but an enhancement to the instructional experience.

Research Perspectives and Biases

One of the issues I had to deal with as I conducted this research was the fact that these were own students and I was very familiar with them and their capabilities. I was continually aware that I needed to let the students speak without being prompted in order to stay true to grounded theory methods, even when I knew the students had more to

offer. At times I felt as if I could get much more data if I prompted the students. It was a constant struggle to avoid prompting which would have led away from grounded theory methods.

CHAPTER 4

RESULTS

Themes

The following themes were composite themes across all participants. The codes that led to the following themes were slightly different in wording as grounded theory methods were followed. The wording in these themes was standardized to allow analysis across all twelve participants.

A. Characteristics of Video Games

Attributes assigned to video games, some positive and some negative. Some of the attributes include being addictive, usefulness in teaching and building skills, being shiny and flashy, being fun, and ability to create an alternate reality for the player.

B. Age and Time

Reference made to the students' age when they first started playing video games. Also, the amount of time spent playing video games at different stages in their lives.

C. Types of Video Games Played

One major categorization is education versus entertainment. Another major categorization is computer –based versus console-based. Some of the categories under entertainment include sports, action/adventure, role-playing, and war/shooting.

D. Non Video Games

Included are any non-electronic assisted games. These games can be categorized as indoors versus outdoor games. The outdoor games can be further categorized as sports

like baseball, basketball, etc. versus non-organized play such as hike-and-seek and red rover. Indoor games include board games and unstructured play such as dolls, and army.

E. Games and Social Behavior

Included are any references to playing games with the intention of having social interaction. In early years, this interaction is mainly with family which evolves into family and friends with much more emphasis on friends. It indicates that the social interaction is more important than the game being played.

F. Experiences in Science Classes

Experiences in science classes consist of what the students remember about their science classes from elementary to high school. It includes the types of activities experienced in those classes including lab and other hands-on activities and the students' opinion of those activities especially as it relates to learning scientific concepts.

G. Virtual (Simulation) Games

Several students emphasized the video games that simulate an alternate world. Sometimes the alternate world is similar to the real world and the activities performed in the game simulate the real world. Other times, the alternate worlds are very far removed from reality and place the students in a world where they are capable of performing tasks not otherwise possible.

H. Traditional Labs

Traditional labs are any labs, or other hands-on activities, carried out in a science classroom, that are not computer simulated. Students handle with physical objects in these experiences. The hands-on aspect of these activities is considered to be their defining characteristic. Students found advantages and disadvantages of this type of lab.

I. Virtual Labs

Activities carried out in science classroom that simulate physical lab activities. The simulations used in this study seem very real because there is an element of error built-in. These virtual labs are computer assisted and require a certain minimum level of knowledge of computer equipment and software. Students also found advantages and disadvantages of this type of lab.

J. Labs Synergy

Since for each topic in chemistry, two labs were performed during the study, one traditional and one virtual, knowledge attained from working with the concept twice can have synergistic effects. This theme includes synergies mostly related to the procedural aspect of the activities. Most students found advantages in performing both types of activities.

K. Video Games Labs Synergy

This theme describes how students perceive that skills attained from experiences playing video games translate to skills necessary in performing virtual labs. These skills range from simple handling of the mouse and other computer-related skills to similarities between the experience of playing a video game and that of performing a virtual lab.

L. Labs are a Waste of Time

Only one of the students mentioned that labs in her opinion are a waste of time. She believes they are a waste of time in her personal experience but admits that the lab experience may be helpful to other students in learning scientific concepts. Even though this theme is only present in one student, it is very prevalent in her comments.

Within-case Analysis

Following is the result of the analysis of each case. A short narrative of each student is followed by each of the research questions with the corresponding themes identified in the interviews. After the research questions, there is a discussion of the major connections between the themes.

A. Alice

Alice is a very intelligent girl. While she is quiet and subdued, she is very friendly and pleasant. Academics come easy to her. Because she does not have to struggle in learning science, she feels that she does not know much science. She thinks that in order to learn a person must have had to struggle and worked hard. She told me once that she didn't think she learned anything in my Chemistry class because she never had to work for her grade. However, she went on to take AP Chemistry and performed very well. She did not like labs, either virtual or traditional because she felt that they didn't add anything to what she could learn from the lecture and from reading the textbook. Alice's grade in my class was 97 with a test average of 92. Alice wants to become an environmental engineer. She did not do well in the knowledge evaluation part of the second interview. She scored a total of 57 points of which she received 75 percent of the procedure points and 30 percent of the calculations points.

1. RQ#1 - What are the students' prior experiences with computer and video games?

a. Characteristics of Video Games

Alice believes that video games are attractive to students because of the lights and the dazzle associated with them. She also thinks that video games are addicting, meaning that they cause the player to want to spend a great deal of time playing video games

because they are fun and exciting. However, this addictive quality is seen as a positive rather than a negative characteristic of video games since she doesn't see any harm in spending time playing video games. In fact, she sees video games as tools for skill building especially strategy skills. She said of video game playing: "I look back and realize it wasn't pointless because the games I played taught me strategy."(Alice 1, lines 9-10). As she sees it, it may even lead to improved performance resulting from extended play, especially for the very competitive players who continually strive to improve their game. Nevertheless, Alice feels that spending an excessive amount of time playing video games may be harmful. She doesn't really explain where this point is, just that it exists. When it comes to sports video games, she finds that playing the real sport rather than the video version is better. She wonders why anyone would play a sports video game when the real game is an available choice. "Sports video games are so fake. If you want to play the sport just go out there and play it yourself." (Alice 1, lines 61-62) Another positive characteristic of video games is the improved performance resulting from extended play, especially for the very competitive players who continually strive to improve.

b. Age and Time

Playing video games, for Alice, goes as far back as under age ten or elementary school. She considers the amount of time spent playing video games while in elementary school to be significant, approximately over one hour per day or over five hours per week. As she grew into middle school age, the amount of time spent playing video games was reduced due to various factors, among which are the increased time demands from school and branching out into other activities that also placed an increasing demand on her time. She said: "You have less time. As you get older you get into like other things."

(Alice 1, line 49) There was a significant decrease in the amount of time spent playing video games in high school. As she got older, involvement in other activities as well as increased school load and desire to make good grades, greatly reduced the amount of time available for playing video games. While she feels that she still spends a significant amount of time playing video games, the time has decreased as she has grown up and she considers that there is a point beyond which playing video games can be harmful. However, she doesn't have a good feel for what this vague excessive amount of time that she considers excessive playing is. She also does not elaborate what this "harm" is that would result from excessive video game playing. In addition to playing video games, she remembers working with computers in elementary school for learning purposes.

c. Types of Video Games Played

The games that she considers her favorites, or those she spent the most time playing, are the fighting games such as hand combat games, or any type of violence-related or military action games.

d. Non-Video Games

In addition to video games, Alice has also enjoyed playing non video games, such as board games as well as outdoor active games. In the board game category, she remembers playing Monopoly, which she remembers enjoying. She also remembers enjoying outdoor games such as capture the flag and hide-and-go-seek. She did not remember playing organized sports, but rather the above-mentioned games and other pretend-type games.

e. Games and Social Behavior

Alice prefers to play video games that are played with other people rather than those that are played alone or that one chooses to play alone. “I like the ones that you can play with other people.” (Alice 1, line 58) There is a social component to game-playing whether they are video games or traditional games and part of the enjoyment of game-playing is the interaction with others.

f. Video Games-Labs Synergy

Alice doesn’t see much synergy between the skills learned from playing video games and the skills needed to perform a virtual lab; “not playing virtual games but having used a computer” (Alice 2, line 154). She feels that familiarity with the computer such as knowing where and how to click and being comfortable with operating a mouse is helpful when conducting a virtual lab, therefore, while prior computer skills from using a computer or playing a computer-based game may be helpful, prior video-game playing experience doesn’t help the student with conducting a virtual lab.

2. RQ #2 - What are the students’ prior experiences with science labs?

a. Experiences in Science Classes

In regards to her experiences with science classes over the years, she feels that if the science class is “boring” (Alice 1, line 86), it is “pointless” (Alice 1, line 89) to do it. If the teacher makes the science class fun and exciting, students are not bored and it is easier to acquire science skills such as learning how things work. Alice believes that hands-on science activities are fun and facilitate the learning process, and should be incorporated in science classes whenever possible. She remembers science in elementary school mostly as hands-on and therefore a positive experience. She thinks that science

concepts studied in elementary school are very easy and demand very little knowledge to be absorbed by the students. She perceives the ease of the material covered as somewhat a negative aspect of elementary school science since she feels that challenging material makes for better learning. She has no memory of any specific content that she learned in science in elementary school; the activities could have been fun but they failed to teach her anything. While she feels that having fun in science is positive and leads to improved learning, under the wrong conditions such as a poor teacher, fun can become the main object of an activity diminishing the learning of a concept. “It could distract you from what you are supposed to learn but it depends on the teacher.” (Alice 1, lines 91-91) Also, sometimes, poor or inexperienced teachers focus more on the trivial aspects of an activity requiring perfection, such as in a drawing what the student sees instead of focusing on the overarching science concept. The teacher has tremendous influence on the effectiveness of an activity.

Alice didn’t have much to say about science in middle school except that it was generally positive, except when it involved a great deal of note-taking. High school science is much more lab intensive and therefore more productive. Labs reinforce science content resulting in increased learning. More practice and more in-depth study would make high school science classes even better than they already are. Another positive aspect of high school science classes are the nightly homework assignments, which are connected to the material learned in either lecture or lab as reinforcement. She mentioned that any lab or activity that involves fire or food has to be fun and exciting. One last thought was that students would gain a great deal of understanding of science concepts

from reading the textbook individually at home to reinforce what is being taught in the classroom.

b. Labs Are a Waste of Time

While Alice emphasized the use of hands-on activities and labs as a good component of a science class experience, she seems to contradict herself when she says that she doesn't have any use for lab; she feels that they "are a waste of time" (Alice 2, line 137). She didn't feel she learned much from labs. Since she didn't enjoy labs, she felt she didn't learn much from them, regardless of the format. She could have learned the material without doing the labs. She is obsessed with burning anything. She associates burning with fun and excitement so she feels that in order for a lab to be worthwhile, something has to be burned.

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

Alice felt that the traditional labs were OK; however, she didn't show much excitement about them either. She was pretty unimpressed by lab in general, regardless of the format. She said they were "kind of" fun. She mentioned that doing the calculations in the traditional labs was more difficult than doing them in the virtual labs. The benefits of traditional labs are that "they are more hands on and you actually have to think about what you are doing" (Alice 2, lines 123-124) since you are handling the chemicals. She had previously mentioned that hands-on activities were conducive to learning science content; therefore being hands-on is a good characteristic of a traditional lab. The fact that students are handling real chemicals and real lab equipment requires more

concentration which is also conducive to the learning process and another positive characteristic of traditional labs. The major problem Alice found with traditional labs was that if a traditional lab had to be done over, it was more difficult and required much more time and materials.

b. Virtual Labs

In reference to virtual labs, she saw both benefits and drawbacks in comparison to traditional labs. She thought that having the ability to mess up and restart a lab at a click was "cool." "The infinite supply of [equipment such as] beakers [in the virtual labs] is very interesting." (Alice 2, line 106) Benefits of virtual labs included easier calculations, faster to do, more convenient and no contamination of the chemicals or the equipment so you should not expect anything to go wrong from contamination. The drawbacks of virtual labs are the computer and the instructions. She felt that if you could make sure the hardware worked properly and the instructions were clear, this could be alleviated. She didn't enjoy virtual labs because she had difficulty figuring out what to do.

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

Doing a lab using both the traditional and virtual formats was helpful. Alice felt that once you did a lab in one format, virtual or traditional, you could figure things out, which made it easier to perform the lab in the other format. If the students had the ability to perform each lab using both formats, it would be beneficial to do the lab in the virtual format first because it allowed you to mess up and learn from your mistakes; "if you

screw up you can start all over again." (Alice 2, line 143) Since the virtual lab is easier to restart, you could afford to make mistakes and learn from those mistakes then when you did the traditional lab, you would already have a good idea of what to do and prevent you from messing up since it is more difficult to redo the traditional labs.

5. Connections between themes

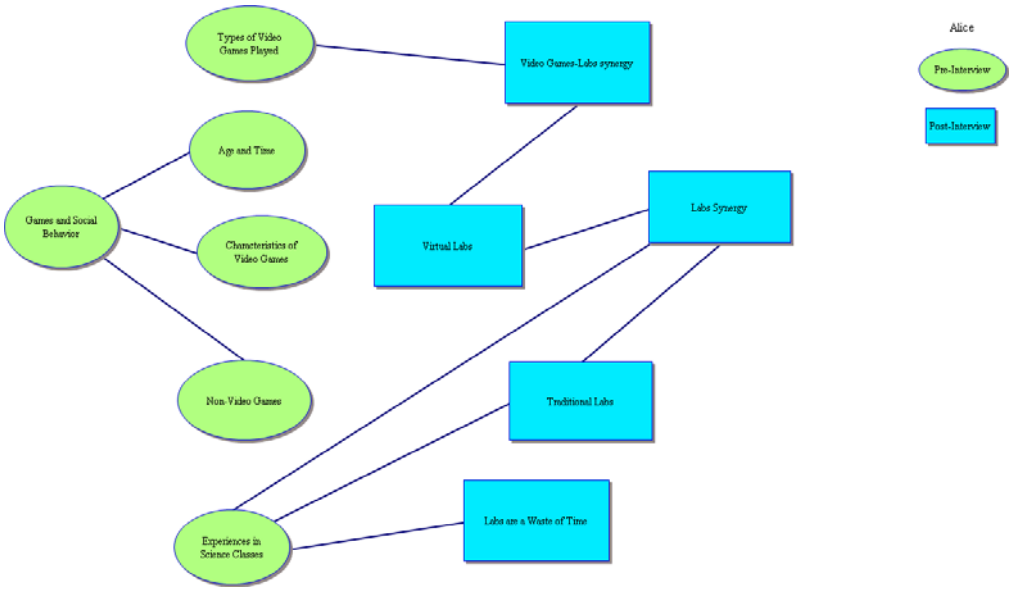

Figure 1 – Alice themes and connections

Further analysis of the data shows connections among several themes (See figure 1, above). One such connection is evident between the Games and Social Behavior theme, Types of Video Games Played and Non-Video Games themes, with Age and Time themes. Alice states that there is a social aspect to game-playing whether you are referring to video games or any other type of game. She, also, acknowledges that the time spent playing games has reduced because she is involved in other social activities that have replaced the social interaction previously provided by games.

Another connection is evident, although weak, between the Types of Video Games Played, the Virtual (Simulation) Games, and Labs Synergy themes. Playing video games on a computer provides experience on how to maneuver through the games. The computer skills from familiarity with operating a computer influence the ability to conduct a virtual lab because they are both executed on a computer. It is not the game-playing skills but the computer skills that are key factors. Furthermore, a well-working computer will make the virtual lab run smoothly.

Further connections exist between the Experiences in Science Classes theme and the Traditional Labs theme, as well as, the Labs Synergy theme. She points out, in the first interview, that hands-on experiences in science class is conducive to increased learning and, in the second interview, she talks about the hands-on attribute of traditional labs. Therefore, doing traditional labs in science class must improve student learning. Doing the labs in virtual format would add to the experience of doing the traditional lab, and consequently help with the learning process.

Likewise, another connection is evident between Virtual Labs and Traditional Labs, and the Labs Synergy theme. Since the labs were similar, there are synergies to be gained from doing a lab in both formats. The connection comes from the similarity between the two labs regardless of the format. Once a lab was performed in one format, either format, then the student would learn from that experience and make it easier to figure out what to do in the other format. Being able to figure out what to do in a lab would be the key issue with this student. While the synergies exist regardless of the order, she still preferred to do the virtual format first, because since the idea was to learn from mistakes made, restarting and redoing a virtual lab was much simpler than a

traditional lab. This allows the student to learn the process from the virtual lab and prevent time intensive redoing of traditional labs.

B. Barbara

Barbara was a student in my chemistry class. While she was not a discipline problem, she was not at all interested in chemistry or any science at all. Barbara has a very outgoing personality and is very friendly. She was involved in Music and Theater because she is very musically talented and has a beautiful voice. She did her work in Chemistry sporadically reflecting in her lack of interest in the subject. When she tried, she performed well. She is interested in pursuing a career in music. On the evaluation portion of the second interview, she scored 57 points, of which she scored 77 percent on the procedures area and 15 percent on the calculations area. This is not unusual for Barbara since she did not pay close attention in class therefore being less familiar with calculations than the typical student in the class. Her overall grade in my class was 78 with a test average of 66.

1. RQ#1 - What are the students' prior experiences with computer and video games?

a. Characteristics of Video Games

Barbara enjoys playing video games and refers to them as being fun and cool, as well as a learning tool. In her opinion, video games were better than other types of games because they were more colorful and, therefore, more appealing. She believes video games "help stimulate your mind because you have to do hand-eye coordination." (Barbara1, lines 6-7) As a middle-school student, she remembers enjoying educational video games. These educational games taught physics concepts because "you had to build a rocket ship every time." (Barbara1, line 80) She also believes that the ability to restart a

video game is a positive feature because it allows the person to play more and therefore build their skills.

b. Age and Time

Barbara remembers playing games, such as Carmen San Diego and Duck Hunt, as early as ten years old or younger. She, specifically, remembers the noises and the gun used in Duck Hunt. At a young age, she played about two hours per day, which she considers to be a significant amount of time for an elementary school child to be playing video games. She also remembers educational games such as Carmen San Diego. In middle school, she remembers spending a lot of time playing games on video games; as much as two to three hours per day. Middle school "was harder and I had to do more work which kept me away from having video game time". (Barbara1, lines 71-72) Still, she played what she considers to be a significant amount of time. Since being in high school, she plays an average of three hours a day. She felt that her parents not being at home contributed to the large amount of time spent playing.

c. Types of Video Games Played

Barbara enjoys the role-playing games because she can do activities that people do in real life, but virtually, such as talking to others, fishing, earn money, etc. In her opinion, role-playing games are happier games because they may have birds chirping and other elements of a happy life. These games are fun and exciting, and place a person in a world happier and more fun than the real everyday world. "It takes you away from real life I guess." (Barbara1, line 110) Another good feature of the role-playing games is that they either run for a long time or have no ending, and they can be stopped and restarted at

any time. If given a choice, she prefers to play video games over board games, or active outdoor games and activities.

She played shooting games in middle school. In high school she prefers role-playing games. She said that at a young age she played games for fun, they were not educational-type games. It was in fifth grade that she started playing some educational games. Barbara's favorite games to play are the role-playing games, especially those where you role-play an entire lifetime of a game character.

d. Non-Video Games

In talking more about non-video games Barbara recalls playing what she called a "Barbie" game, which she said she didn't like. She also remembers playing board games. She didn't like board games because "with board games you have to kind of imagine a lot and it's always, like once you reach the end you can't really go anywhere but for video games you can always do it again and do better the next time." (Barbara1, lines 56-59); the game ends and it can't be restarted. While it can be played again as a new game, each game comes to an end in a relatively short period of time. There was an "army" board game that she remembers having to roll dice to play it. While it was a board game and had, what she perceived, the same shortcomings of any board game, she did like this game. A positive about playing board games is that Barbara played with her father, and remembers that as a valued time. As far as outdoor games, she remembers playing some type of active ball game in middle school. She likes being indoors better, therefore, outside games didn't appeal to her.

e. Games and Social Behavior

Barbara alluded to the social aspect of playing games, both video games as well

as non-video type games. She talked about playing video games a great deal with her father when she was in middle school as well as playing board games with him. She said, "Dad and I played that a lot" (Barbara1, line 46)

f. Video Games-Labs Synergy

It is her belief that having experience playing video games has no influence on virtual lab performance; the only connection between the video games and the virtual labs, in her opinion, is that they both use computer technology. Furthermore, she didn't think knowing how to use a mouse or some clicking device would have any positive effect on the ability to perform a virtual lab.

2. *RQ #2 - What are the students' prior experiences with science labs?*

a. Experiences in Science Classes

Overall, she enjoys doing science labs, whether virtual or real. She enjoys labs because they are generally a group activity. In her opinion, labs help you learn if you become involved in doing them; "you're associating it with something you've seen and done." (Barbara1, lines 169-170) She remembers doing a virtual dissection in middle school, which she enjoyed doing. While she doesn't think her elementary science class experiences were very good, she doesn't really have any suggestions for improvement because she believes the only way to improve would be to do more labs and she believes that elementary school children are too young to do labs, and labs could be too dangerous.

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

When asked about the benefits of traditional over virtual labs, and vice versa, she said “in the traditional you actually get to touch things” (Barbara2, line 106) Both traditional and virtual labs are equally effective in teaching concepts and in keeping your interest because “they teach the same thing, they are the same experiment” (Barbara2, line 101) The drawback of traditional labs is that sometimes there may be harmful consequences because you may have to handle hazardous chemicals or deal with dangerous conditions.

b. Virtual Labs

One of the positives to virtual labs is that they were a lot like the real labs. Students get materials from the virtual stockroom as if it were a real stockroom, for example. She believes virtual and traditional labs are about the same in keeping your interest as well as in teaching you the content because you are, basically, doing the same lab, just in a different format. In the absence of an available traditional choice, a virtual lab would be an acceptable substitute since they are nearly the same. She stated that the benefits of virtual labs are that they can be easily restarted if something goes wrong without wasting time and materials, they are easier to perform, they are more efficient, and you never run out of material. The drawback of virtual labs is that they don’t always work.

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

She thought it beneficial to do both traditional and virtual labs; doing both formats reinforces what you do the first time. She said:" It would be beneficial reinstating what you learned in the other lab." (Barbara2, line 115) It is not important which you do first but it is probably better to do the virtual first so that you know what to do and don't waste time when you do the traditional one since it is much easier to restart a virtual lab than a traditional lab.

5. Connections between themes

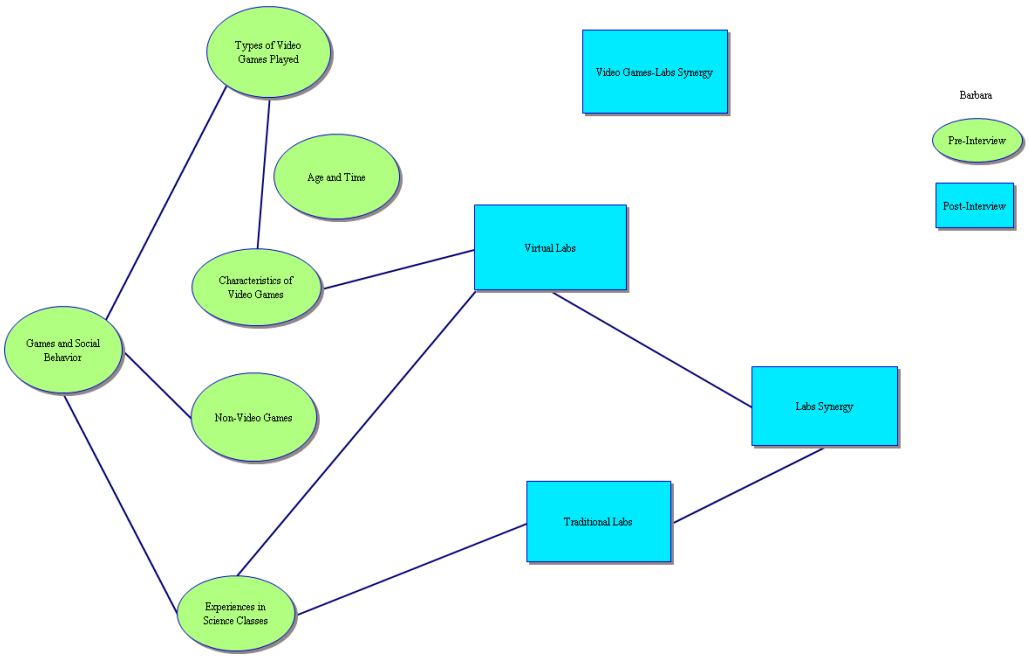

Figure 2 – Barbara themes and connections

In conclusion, several connections are found between the different themes discovered from the Barbara interview (See Figure 2, above). One connection is between the Types of Video Games Played theme and the Characteristics of Video Games theme. This connection exists because while she claims to have played various types of games,

video and non-video games, she prefers the role-playing games that simulate life and last a very long time. These games are always video games because they can be saved and restarted at any time. Secondly, these role-playing games are connected with the Games and Social Behavior theme, since they reflect real life situations just in a virtual setting.

Furthermore, the Experiences in Science Classes theme is connected to the Games and Social Behavior theme. She brings up the fact that she enjoys games because of the social interaction and also one of the reasons she enjoys science class is the social interactions present in lab activities since they are generally group activities. Barbara connects the themes of Experiences in Science Classes, Virtual labs, Traditional Labs and Labs Synergy. She believes that the reason that lab activities help you learn science content is that they actively involve the student, whether those labs are traditional labs or virtual labs since, in her mind, they are the same lab just done in a different format. She also brings up the idea that the virtual and traditional labs reinforce each other, and that whenever possible, it is beneficial to do both. When doing both, it would be a better idea to do the virtual first since it is easier to restart in case something goes wrong.

C. Craig

Craig was a student in my Chemistry class who was very interested in Mathematics, Science and Engineering. He expressed interest in a career in electrical engineering. He competed in Science Olympiad throughout his high school career performing very well as high as the national level. Craig has quiet personality and is not very interested in people. He is very dependable and reliable when he gets involved in a project. Craig was always up for a challenge in the area of math and science. While, Craig is very smart, he didn't always perform up to his potential in class because he was always hurrying through

assessments to try to finish as quickly as possible because he competed with himself to how quickly he could finish the tasks. Craig always enjoyed doing labs. Since he was so adept in computer skills, he enjoyed doing labs both the virtual labs and the traditional labs. On the evaluation potion of the second interview he scored an 86, with a 97% of the procedural questions and 70% of the calculations questions. Craig's overall grade in chemistry was 94 with an 89 average grade in test scores.

1. *RQ#1 - What are the students' prior experiences with computer and video games?*

a. Characteristics of Video Games

While he no longer plays video games, he feels that strategy games can foster multilevel thinking which is a useful skill that can be transferred to the corporate world. These games are useful in experimentation because many scenarios can be tried. The circuit virtual games are a pretty direct correlation to real life circuits. The thinking aspect of a video games makes it challenging and at the same time interesting and engaging. He liked these games even though he doesn't play them because he finds them a waste of his valuable time.

b. Age and Time

Craig remembers playing video games at age seven for the first time. The time spent playing video games has decreased from the longest time when he was young to less time while in middle school to practically no time now that he is in high school; "I play some chess but video games have sort of tapered off since they are not useful to me anymore. It was like this time thing, there is less time and video games take up a lot of time." (Craig1, lines 104-106) Playing video games is useless to him now that he is more focused on school and extra-curricular activities in high school, such as being a member

of the school's Science Olympiad and Math teams. At an early age, he remembers playing very simple games, such as Pong and puzzle games. As he grew older, the difficulty of the games increased. As young as age 10 or 11, he remembers playing educational games such as a circuit-building game. It was really good because you didn't have to mess with real circuits.

c. Types of Video Games Played

He remembers playing a virtual circuitry game where the object was to build circuits. This technology allows the student to build the circuits without the expense. This type of game is educational because it allows the student to experiment and explore with virtual circuits which would not be possible if the circuits were being built with real wires. Craig is a very mature student who looks at efficiency as something to strive for; therefore, any time a game can make an activity more efficient, it is a good reason to play the game. Otherwise, it is pointless. One negative aspect of video games is that they seem to him as fake and not very representative of the real world. He finds video games unpredictable and having an element of surprise or luck, which he dislikes.

d. Virtual (Simulation) Games

Of all the games he has played, Craig likes simulation games, such as battlefield games, where characters have to be moved around. The player acts on the game and observes how other players (computer) react to your action. Simulation games involve virtual scenarios for the characters to interact in. Simulation games require the player to perform certain actions through his character then observe the game's reaction and sometimes predict the game's reactions several steps in advance. He likes this aspect of simulation games.

e. Non-Video Games

Likewise, Craig said that board games are interesting and that of all board games, he prefers chess. “Board games are definitely easier to predict. The video games you don’t know exactly what is involved in like the programming.” (Craig1, lines 97-98) Board games are easier to predict because you can see ahead and know what is coming next, which is not the case in a game controlled by a computer. Board games have set parameters that are much more defined and narrow than computer-based games. He prefers to play indoor games, both video and board games over any outdoor games. He does not consider himself to be an athletic person, so he doesn’t enjoy outdoor games.

2. RQ #2 - What are the students’ prior experiences with science labs?

a. Experiences in Science Classes

When discussing his science education experiences, he remembers doing a few labs in fourth and fifth grades. Before this time, his recall of science is very unclear. Even though there were only a few each year, there were more labs in middle school. Included in lab, he mentions science fair projects which allow the student to work or experiment on whatever topic is of interest. He likes this flexibility afforded by science fair-type projects because they allow him to explore topics he is interested in. The frequency of labs in high school greatly increased to approximately one lab per week. In some labs, the students are allowed to investigate their own question of interest. Again, this is perceived as a positive. Designing and performing your own lab may teach how to do these activities; “you were able to design your own experiment to find out how much water was there and based on that you would be able to learn how to design an experiment and how to manage your time during the lab.” (Craig1, lines 194-196)

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

He was very enthusiastic about labs and demonstrated his definite like for labs. Craig believes that hands-on activities such as labs are useful and enhance learning. Hands-on activities get the learner involved. Even when the activity is somewhat boring or just not very exciting, it is still more interesting than other non hands-on activities. Consequently, doing labs improves the learning experience. Because labs put the student in touch with the science, the student remembers what he learned from the lab. He said: "with the labs you do now they do actually help you learn and you do get to see like the reactions and changes in things like in chemistry this year if we were doing something like combining two _____ together, you could describe it saying that it had a yellow/brown gas coming off, but when you actually see it, you actually see a lot more. The description is actually more vivid to yourself because you actually see what happens." (Craig1, lines 200-204)

Nevertheless, Craig mentioned several drawbacks of doing traditional labs in high school. He said that when doing traditional labs in a high school setting, there are often times when the margin for error renders the data practically worthless. He also said that some labs are too dangerous to perform in a high school setting and that there is also the limiting factor of the expensive equipment sometimes required, and often not available in high schools. He also believes that traditional labs are very time consuming.

However, there are also many benefits of traditional labs including the fact that you actually get to work with the materials hands-on. Sometimes there are more

graduations on the equipment in a traditional lab, increasing the accuracy. He said that while "the virtual labs are easier to actually do but it is a more gratifying experience to do it in real life. You get a thrill of getting a really low percentage of error and actually getting your lab done properly. (Craig2, lines 128-132) According to Craig, "the traditional lab you can have more hands on experience and you are actually doing the lab in real life and you have to accept the fact that sometimes you won't get a perfect lab. (Craig2, lines 151-153) He said that the traditional lab allows you to feel more in control of what is going on in the lab.

b. Virtual Labs

Craig liked doing the virtual labs. He said virtual labs are fast, require little waiting time and they are easily restarted when mistakes are made. The data obtained is pretty good and they even have a built-in error to make them more realistic. He liked that the lab works better because it is programmed to work. Though errors may happen, small errors make the experience more enjoyable. Additionally, virtual labs allow students to experience things they may not otherwise get to experience because of difficulties with traditional labs such as safety concerns. They are easier to perform and they are a lot faster to perform. Because they are faster, you have the opportunity to perform more labs. However, "in the virtual labs you have a tendency, just a slight tendency to try to skip over direction, because you know you can screw up." (Craig2, lines 140-142) He also said that "you lose a sense of exactly how long the lab would take you lose that sense of fun but when you do a virtual lab you have time to get more labs done." (Craig2, lines 146-148) He explained that in the virtual labs you can lose the sense of doing the lab hands on.

The virtual labs use similar technology to video games. Familiarity with the technology should improve a student's ability to perform a virtual lab because they are used to dealing with the technology and the computer equipment. The difference is that the purpose of the lab is purely educational and the game is primarily for entertainment. He believes hat virtual labs are good substitutes for traditional labs. He feels that since the virtual labs are a good representation of the traditional lab, in the absence of the traditional lab, the virtual lab is a good substitute. Everything in the virtual lab seems the same as the traditional lab. It is better to do only the virtual lab than no lab at all. He said: "It is actually better to be able to do the virtual lab than no lab at all because you still gain an experience from the virtual lab. It is a fairly good representation of the tradition lab." (Craig2, lines 187-189)

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

He believes it is good if you can do both types of lab because you get more experience. By doing the virtual lab first, one is able to learn the technique and allowed to perform the traditional lab better to get better data. One is less likely to make mistakes performing the traditional lab after doing the virtual lab.

5. Connections between themes

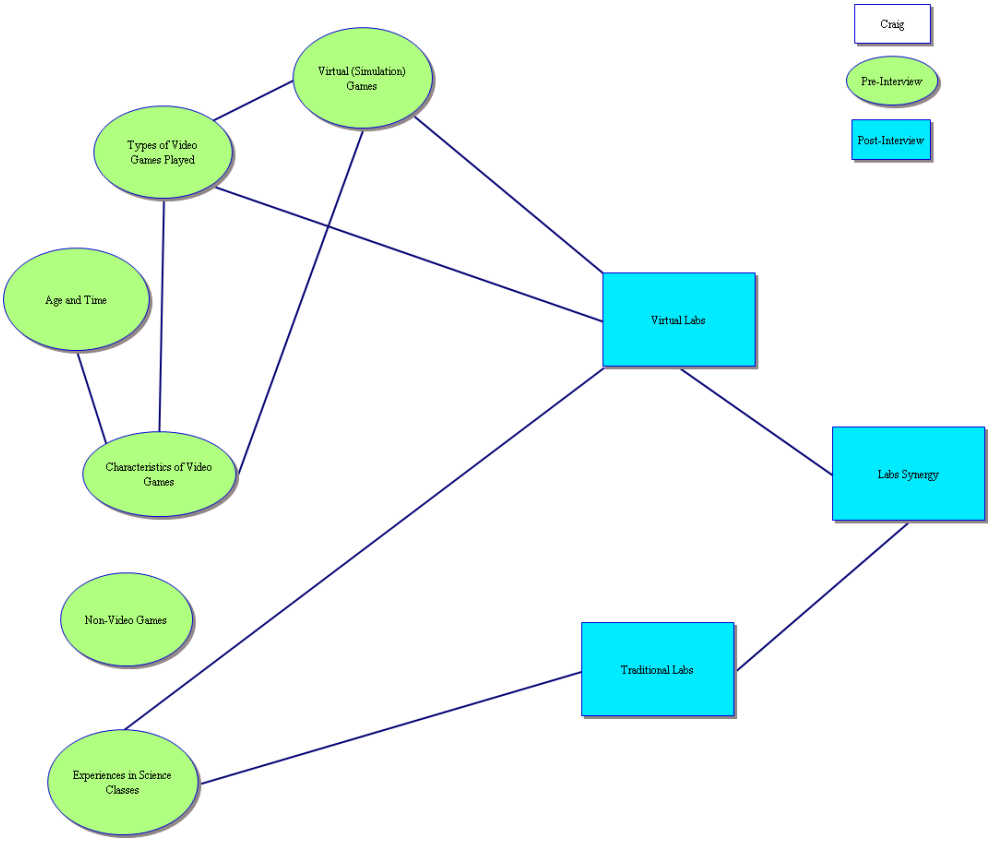

Figure 3 – Craig themes and connections

There is a slight connection between the themes of Age and Time and Characteristics of Video Games. He explained that while he no longer chooses to play video games in high school because of competing activities for his time, he still believes that strategy games foster multilevel thinking which is a beneficial skill that can be transferred to the real world of work. A further connection between Characteristics of Video Games theme and the Types of Video Games Played theme is seen because he believes that if you are going the play a video games, it is best to play simulation games where the player controls a character. These games reflect real life which allows the development of thinking and decision making skills useful in real life. The theme of

Virtual (Simulation) Games is also connected to the Characteristics of Video Games. The simulation games provide a way for the player to mimic real situations in order to learn from them. One such type of game is a game simulating building circuits. It is much cheaper to build circuits using a simulation and the player learns how to build circuits without having to physically build them and waste materials in the process.

Craig makes connections between the themes of Virtual Labs with Types of Video Games Played, Virtual (Simulation) Games and Experiences in Science Classes. He played simulation games such as the virtual circuit games. Similarly, the virtual labs have the same property as the simulation games in that they can be restarted without creating a mess or wasting time and materials. Virtual labs allow the lab experience without the materials expense just like the circuit simulations. He believes that lab experiences greatly enhance the learning process in science classes.

Many times, the number of labs and the types of labs performed in science classes is restricted by cost of materials and lack of equipment. By using virtual labs, the students in science classes can be exposed to more lab experiences without additional cost. A connection, therefore, also exists between the science class experiences and the traditional labs for the same reasons as the connection with the virtual labs. Lab activities enhance learning whether virtual or traditional. If possible, it is even better to perform both the virtual and traditional formats of the same lab. There is synergy in performing more labs on the same topic. The virtual lab and the traditional lab each have its own strengths and by doing both, one can capitalize on the benefits of both. The virtual lab can be used to learn the technique without waste then the traditional lab can provide the hands-on experience.

D. Daniel

Daniel has a quiet personality. While he is friendly, he is shy and not very outgoing, especially when he first meets people. When Daniel first came into my Chemistry class, he felt very intimidated because of insecurities about his academic abilities. As time passed, he became more confident and more comfortable in Chemistry. His overall grade in my class was 92 with a test average of 83. Daniel was involved in Science Olympiad and while he was not the strongest competitor, he was always very dependable. Daniel was committed to the team and placed team performance over his personal preferences. In the evaluation portion of the second interview, Daniel scored 60, with 77% in procedure and 35% in calculations. Daniel is not sure of his future career path; however, he thinks it will in some way involve working with animals.

1. RQ#1 - What are the students' prior experiences with computer and video games?

a. Age and Time

"As far back as I can remember, I guess like, I've always been around them [video games] and they, I mean, it's part of my growing up." (Daniel1, lines 4-5) Daniel remembers the games he played in elementary school, such as Mario Kart and Donkey Kong. In middle school, while he still enjoyed being outside and playing sports, his friends were now playing more video games, which made it more appealing for him to play video games. He didn't consider playing five hours a week to be much time spent on video games. Now that he is older, he plays more than he did as a young child. Now he plays about four to five hours per week, or less than an hour a day. He said he likes video games a lot. He finds them fun. He feels that he spends a great deal of time playing video

games. He finds them so much fun that whenever a new game comes on the market he has to get it.

b. Types of Video Games Played

Daniel mentioned that in elementary school and, then, also in middle school, he liked action and adventure games such as racing games like Mario Kart, Donkey Kong, and Star Wars.

He said he has also played sports video games. Now he plays some interactive (virtual) games such as Wii, and still prefers the action and adventure games. He said: "my mom doesn't like me playing "shoot them up" games so I don't play those." (Daniel1, lines 12-13)

Daniel remembers details of educational video games played as a child. He remembers those games being fun also and found them helpful with school work. He remembers the games that contained language arts and math questions.

He, also, believes that regular sport video games don't really help with skills because using a controller does not resemble the actual equipment or movements needed to play a sport. Yet, he suggests these types of games may be useful in learning the rules of the sport.

c. Virtual (Simulation) Games

Virtual video games where you actually have to stand up and pretend play, like Wii, are more useful in teaching sports skills because you are doing similar motions as you do playing the real sport; "if you're playing the bowling game on there, you're actually like bowling because you have to stand up and actually move like you're actually bowling and stuff. Since that's more like the real sports, that's better but if you're just

sitting there using a controller to play, like you're using A to swing and B to throw it or something, then it's not really too much fun because it's just timing." (Daniel1, lines 172-176)

d. Non-Video Games

As a child he enjoyed playing outdoor games (sports) such as soccer, baseball, basketball, wiffle ball. He liked video games but preferred outdoor games (activities) over indoor activities such as video games. Outdoor activities require more physical activity. As a person who engages in active sports, he thinks that video baseball is fun but not as much as playing the real thing. Daniel said that his "theory is why play it on video games when you can do it in real life. I think personally that playing for real is more fun than just getting in front of TV and playing it. I'd rather play real baseball. " (Daniel1, lines 165-176)

e. Games and Social Behavior

Based on his comments, he finds games a good social activity with both family and friends. Daniel remembers playing the educational games with his mother. He also said that he plays video sports games with his father and brother. He mentioned that one of his favorites was "probably the racing games because me and my dad and my brother would play Mario Karts." (Daniel1, lines 49-50) The best part of playing these sports video games was not the game but playing with his father and brother. He remembers playing board games with the family but only when there wasn't another alternative. He plays more video games when friends come over and spend the nigh because the friends like to play and it's a social activity.

f. Video Games-Labs Synergy

In regards to the similarity between virtual labs and video games, he doesn't feel that they have much in common. Virtual labs are only somewhat like a video game in that they are both done on computer equipment. A virtual lab is like a video game in that you are playing the part of a scientist as if in a video game. Virtual labs are not boring even if they may not be as exciting as a video game.

2. RQ #2 - What are the students' prior experiences with science labs?

a. Experiences in Science Classes

Daniel has no memory of doing science labs in elementary school. The closest he remembers to a lab is doing hands on activities outside that he says could have been labs. He remembers doing mini-field trips by just going outside in elementary school and doing hands-on activities. He doesn't remember if it was science, he said: "I don't really know if those were labs but it was fun because you got to do something other than sit inside the classroom and just talk about the stuff. We'd actually go see it and talking about it helped." (Daniel1, lines 101-103) These outside activities were fun and helped with learning.

He associates his memories of hands-on activities with science because he sees science as a hands-on discipline. He sees value in doing hands on activities over note taking, "like I said you're experiencing the stuff and you can see the stuff for yourself and see how you created it instead of when you take notes it's all, not theory, but like somebody else did it, good for them, but you want to see it for yourself instead of taking their word for it." (Daniel1, lines 131-134)

Middle school science classes that concentrated in taking notes rather than labs were not as good in his opinion either and led to lower grades, which is a likely sign of less learning. “Like in Biology in seventh grade, I always had high A’s and in the eighth grade class I had low, not low, but like mid range B’s. I wasn’t bored with this stuff because I thought the stuff was really cool but it was just the way that it was given to me. I think it was learned a little bit more.” (Daniel1, lines 136-139) He even remembers some of the specific activities such as dissecting worms and squid in seventh grade. He believes that these labs were fun and translated into good grades, which means more learning took place, in his eyes. Daniel considers eighth grade science experience inferior because there was more note-taking, very few labs and often these were mostly teacher demonstrations. He described eighth grade science as not “very fun.” (Daniel1, line 127)

He has enjoyed high school science and finds it fun “because we do a lot of labs and last year we did a lot of labs like dissecting a pig and stuff like that which helped it show, basically, it put all we had learned that year into practice. It was a good example of that. I think high school is probably tougher in the stuff that we’re learning, but it’s easier than in eighth grade because of the way that it’s given to us.” (Daniel1, lines 143-147) He feels that doing the labs allows students to put the content learned into practice, even when what is learned isn’t really interesting, and it

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

His strong belief on the importance of hands-on learning is evident in his views on traditional and virtual labs because he thinks the traditional is better. In the traditional

lab, “there is something about doing the hands-on stuff …. you could actually see it first-hand instead of, not a reenactment, but a simulation. (Daniel2, lines 88-91) This again supports his belief that doing something hands-on and experiencing it first-hand is beneficial to learning. However, he realizes traditional labs are time consuming and sometimes carry over more than one class period meaning more than one day which can reduce accuracy.

As far as keeping his interest, the traditional lab kept him interested because of safety concerns and the virtual lab kept his interest because of the additional things you were able to do. Traditional labs keep his interest because he had to make sure they are under control and that safety is monitored.

b. Virtual Labs

Daniel sees several benefits of virtual labs including the ability to perform some labs that may have otherwise been out of reach for a high school class because of safety or cost concerns. They are quicker because there is no competition to get the lab equipment. Virtual labs are also easier and more convenient. Daniel also enjoyed the ability to do other activities within the virtual lab once he was finished with the scheduled activity. “Just that you could do different stuff after we were done with the labs we had to do. I like to goof around with the stuff, like putting cesium with water and blowing it up,” (Daniel2, lines 75-77) this was only possible in the virtual setting. Virtual labs are also much faster because students don’t have to wait for things to happen such as heating substances. The only drawback to virtual labs was the fact that it wasn’t hands-on so you didn’t get to see the science in action. Daniel thought both lab formats “were pretty much the same, because you learned the same thing from each one because you were doing the

same thing, one was on the computer the other wasn't. So it was about the same on that level." (Daniel2, lines 81-83) Virtual labs keep his interest because of all the things you can do with them. If a traditional lab is not available, a virtual lab is a good substitute since you are still doing a lab and learning the concepts from the virtual lab, as he sees it. He explained that virtual labs are fun and he liked doing them.

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

Daniel thinks that if you do both the traditional and virtual labs, you get the hands-on experience from the traditional lab as well as the quickness and convenience of the virtual lab. He said: "I think it would probably be better if you did both because you get the best of both worlds. You get the hands on with the quickness and convenience of the computer one." (Daniel2, lines 114-116) Daniel said he "would probably do the virtual one first because that way you have a basis for doing the traditional so it's not like you are blindly going in there and doing the stuff. Even with the instructions you can still mess up. With the virtual one it's better because it will save your time from not having to go back and do it all with the traditional." (Daniel2, lines 123-127) Doing the virtual lab first would give you the opportunity to learn the procedure from the virtual lab which is easier and quicker if it has to be redone. However, if the traditional was done first, the virtual could be used afterwards to check the accuracy of the traditional since the virtual is more accurate because it is a simulation. Overall, he believes that doing the virtual lab first would be a better idea.

5. Connections between themes

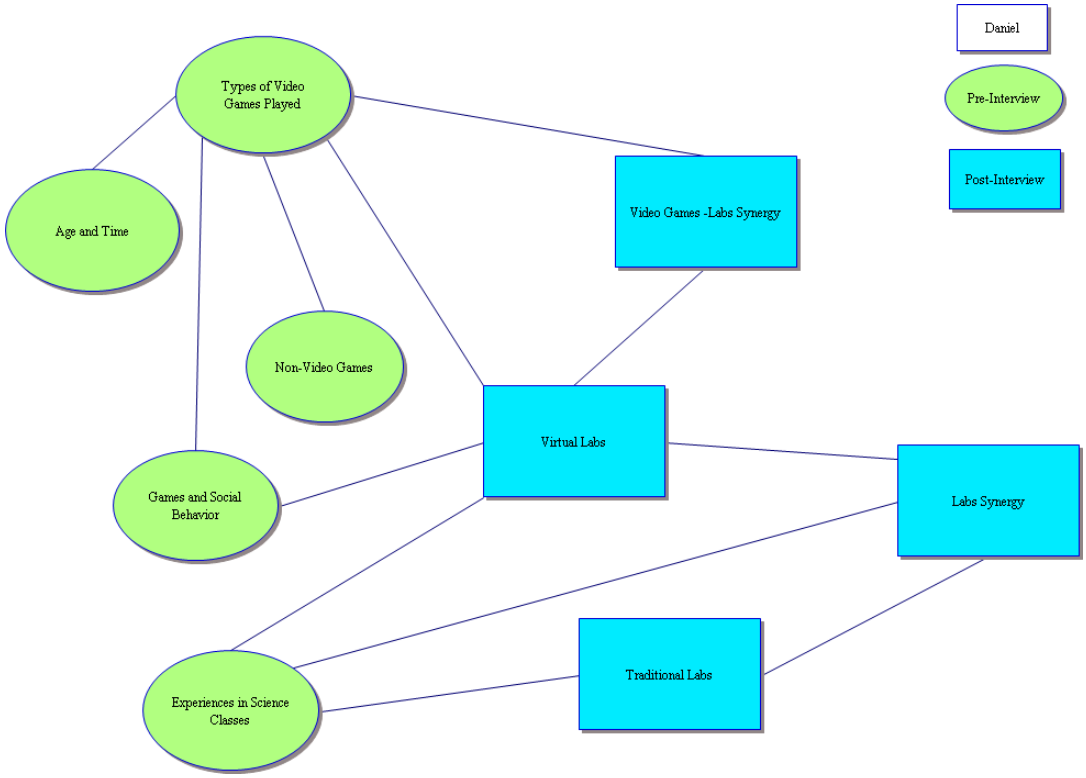

Figure 4 – Daniel themes and connections

Daniel clearly makes a connection between the Types of Video Games Played and the Games and Social Activity themes (See Figure 4, above). Whether the games are video games or non video games, he places emphasis on the social aspect. He likes playing games that are played with other people, both family and friends. He mentioned that he remembers enjoying educational games with his mother when he was young. Another issue brought up was that when he played sports video games with his father and brother, the game played was not as important as the time spent with his father and brothers. Daniel also mentioned playing board games with his family and playing video

games with friends when they came to spend the night at his house. It seems as if Daniel always talks about people when he talks about playing games.

There is also evident a strong connection between Age and Time and Types of Video Games themes. He considers video games as part of his upbringing. He doesn't remember a time when there were no video games. Being such an integral part of his upbringing means he likes video games a great deal, enough to be on the lookout for new game releases to try to purchase the new games.

Additionally, Daniel makes several connections between the Virtual Labs theme and other themes, such as Virtual (Simulation) Games, Games and Social Activity, Experiences in Science Classes, as well as to Video Game-Labs Synergy and Labs Synergy themes. He believes that virtual video games are useful for teaching skills, especially the activity-based games such as those played on the Wii, just like virtual labs are useful for teaching science concepts and skills. As far as the social activity is concerned, he enjoyed being able to finish the scheduled lab activity then exploring with the virtual lab just as if it were a game. He finds that doing hands-on activities in science classes greatly improves understanding; hands-on activities would include virtual labs as well as traditional labs. He feels that virtual labs are much like a video game in that the student in a virtual lab is role-playing the part of a scientist in much the same way a student role-plays any role in a video game.

Lastly but not less important, is the connection made between Virtual Labs and Traditional Labs through the Labs Synergy theme. He explained that the virtual and traditional labs complement each other because they each have different strengths; for example, while the traditional lab provides a richer hands-on experience, the virtual lab

offers speed and convenience. The virtual lab can be very useful because of its convenience in teaching scientific procedures; multiple trials can be performed with very little time.

E. Frank

Frank was an intelligent student, who did not always perform up to his abilities. Frank is very outgoing and friendly. It is easy for Frank to approach people and to make friends. Because of his extremely outgoing personality, he found himself involved in many aspects of high school life including social and academic clubs and societies as well as community service activities. Outside of school, Frank was involved in various activities through his church which many times took him abroad. Frank did not show much interest in science, which when combined with the enormous time demands from extracurricular activities probably lead to a final grade in Chemistry of 88, with a test grade average of 85. In spite of his lack of interest in science, Frank expressed interest in pursuing a career in engineering. He scored eighty five on his overall performance in the evaluation portion of the second interview, with a 95% on the procedures section and 70% in the calculations part.

1. RQ#1 - What are the students' prior experiences with computer and video games?

a. Characteristics of Video Games

Frank mentions that some of the skills used in playing these video games, such as precision and forecasting, may be useful skills in life. At any rate, he is not much of a video game player. Overall, the games he used to play were low skill games. They were good as a fun pastime, but nothing more. He explained: "I think just a fun way to pass the

time. I never really got into them, it was just to have some fun whenever it was a rainy day and I couldn't play outside it was just something to do." (Frank1, lines 41-43)

b. Age and Time

Frank remembers playing specific video games as a young child. These games were simple. He said: "nothing really too complicated just moving bricks around and forming walls and bouncing balls and, you know, simple little games like that." (Frank1, lines 5-7) He never played over two hours per week, or maybe 30 minutes a day at a young age. When he went to middle school, there was less time for games because he joined the school band so "I would practice instruments a lot more than playing any games." (Frank1, lines 63-64) Actually, he thinks he stopped playing video games around age ten, since around fifth grade, because he doesn't have time and finds them useless. Now he enjoys hanging out with friends more and prefers to spend his free time this way rather than playing video games.

c. Types of Video Games Played

Frank did not like fighting games, more specifically; he did not like bloody games. He said: "I never really like fighting games, you know, bloody stuff. " (Frank1, lines 95-96) As far as educational video games, he remembers playing Oregon Trail, an educational, history game. As a fourth- or fifth-grader, he started playing simulation games in which characters are manipulated in a virtual world. He did not like virtual games; "because I never did want my brain to get sucked into like a world that doesn't exist." (Frank1, lines 96-97)

d. Virtual (Simulation) Games

He thinks that while he doesn't enjoy virtual games, virtual sports games can improve skills. Playing a virtual sports game such as those in a WII system can serve as a practice without having to go outside, "like baseball. You don't have to get up and go outside and pick up a bat and have someone throw balls at you. You can just sit down in your room and get out your WII and just hit at virtual balls and even though they are different moves all together they are annulus enough so that you really could learn something about real sports from these virtual sports just because that is what they are modeled after." (Frank1, lines 109-113)

e. Non-Video Games

Frank remembers playing board games, such as Scrabble and Monopoly, and outdoor games. He enjoys board games because they are slower paced games, last longer, and are therefore more fun to play because they are more of a social activity. He also enjoys active outdoor games, he said: "I have always been active enough not to enjoy sitting down and staring at a screen for more than a really long amount of time. I had a great creek and some woods behind my house so I would run around and play in the creek and play in the woods and capture snakes, chase dogs, go hiking. We had two small waterfalls near our house that were part of the creek so you could slide down them." (Frank1, lines 50-56)

f. Video Games-Labs Synergy

He believes that experience with video games helps with virtual labs because, then, the familiarity with the technology used in video games will make it easier to perform a virtual lab.

2. *RQ #2 - What are the students' prior experiences with science labs?*

a. Experiences in Science Classes

When asked about his science class experiences, he does not feel like he had good elementary experiences and he does not remember doing any experiments in elementary school science. The closest thing he remembers to science was in health class. He thinks that more science should be taught in elementary school because it is important to teach science at a young age since kids are very impressionable then. Children are capable of learning at high enough levels to do science and a good teacher will know what this level is and teach at the highest level appropriate for the children.

Frank had, definitely, some strong feeling about science in elementary school; he explained: "Experiments? We never did any. They just weren't existent. Once he brought in a sort of, I don't remember what it was called but this guy came in and he set up five stations in our classroom in fourth grade and we did these mini experiments. Looking back I remember one of them was fill a two- liter container with water and we made a tornado and then we emptied it a little bit so the tornado would get wider and we would say, Oh, that is a level five tornado, or category five, whatever, however you classify tornados. So that was one lab and then another lab might have been inflating a balloon with hot air and the cooling it down and watching is shrink or something like that. Elementary school was pretty lame in terms of science. I think if they would have taught us more, because elementary school kids are not dumb. They can learn more than Mercury, Venus, Earth Mars, Jupiter, Saturn, Uranus, Neptune and Pluto, poor Pluto. They can learn more than stuff like just electricity is just a random force. They can learn that there are protons, neutrons and stuff. So I think in elementary school stuff they

would teach more of that when we are more easily impressionable it would be good education in science." (Frank1, lines 139-155)

In contrast, he felt middle school science was better. He remembers doing Physical Science in sixth grade, Biology in seventh grade, and Geology (Earth Science) in eighth grade. He feels that the teachers in middle school took science more seriously because they actually had the students perform more experiments. However, he felt that science in eighth grade, Geology, was pointless because it was done at a very low level. Very little new information was revealed in this class. As far as his experiences in high school science thus far he feels high school science is hard. In his opinion, there is so much involved in high school science that it blows your mind, and Chemistry is hard because it is very mathematical. It is important for teachers to point out the relevancy of science to students in their daily lives, since students tend to want to learn material that seems relevant to their lives.

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

Frank believes that traditional labs keep your interest better than virtual labs because "as changes occur you can see them happening in real life, not on an 800 x 600 little window on a computer screen, you can actually see the little things moving around, or the molecules reacting with each other and the reaction taking place." (Frank2, lines 112-114) You can probably learn more from the traditional labs especially when learning from your mistakes; "you just learn from your mistakes better when they are real mistakes, not virtual mistakes." (Frank2, lines 134-135) He also said that students must

learn how to handle lab equipment from traditional labs. However, there are drawbacks such as clean up time, time spent gathering and using safety equipment, and traditional labs are also more likely to be affected by external factors and always have the potential for spills and other safety and hazard concerns.

b. Virtual Labs

From his point of view, the benefits of virtual labs include the ability to do more experimentation virtually because of safety issues. Since the virtual labs are computer simulations and do not involve any chemicals, there are no safety issues to deal with as is the case in traditional labs. In "virtual labs you can experiment a lot more with potentially risky chemicals and not have to worry about safety or protocol or anything." (Frank2, lines 138-139). Therefore, virtual labs can be used to build a foundation for true experimentation later.

He felt that you can experiment with virtual unsafe chemicals and not have to be concerned for your safety. He also felt that virtual labs are more exact on their results. Frank explained: "If you want a specific thing to occur it will always occur on the computer. There are not going to be external factors that are going to affect it." (Frank2, lines 143-145) He said that the drawbacks of virtual labs are that you do not see things as clearly and you also miss on some details such as texture. They appear less real. He felt that virtual labs are good substitutes for traditional labs in the absence of an available traditional lab due to safety, costs or equipment issues, a virtual lab should be adequate in reinforcing the science concepts. Since Frank is such a social person and social interactions are so important to him, he noted that virtual labs lack the social/community aspect of traditional labs but it must be kept in perspective that it is being used not as the

real thing but as a good substitute. He explained: “you can’t let the virtual labs be all you do because the real world of chemistry actually takes place in the real world and if you only learn how to do it on a computer then you are missing the point completely.” (Frank2, lines 198-200)

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

Additionally, he explained that it is beneficial to do both, virtual first, then the traditional. Doing both will reinforce the concepts taught in the lab. By doing the virtual lab first, one can learn about the instructions since the instructions are identical. If one makes a mistake, nothing bad will happen with the virtual lab. It gives insight on what to look for and do in the traditional lab. He believes that experience with video games helps with virtual labs because, then, the familiarity with the technology used in video games will make it easier to perform a virtual lab.

5. Connections between themes

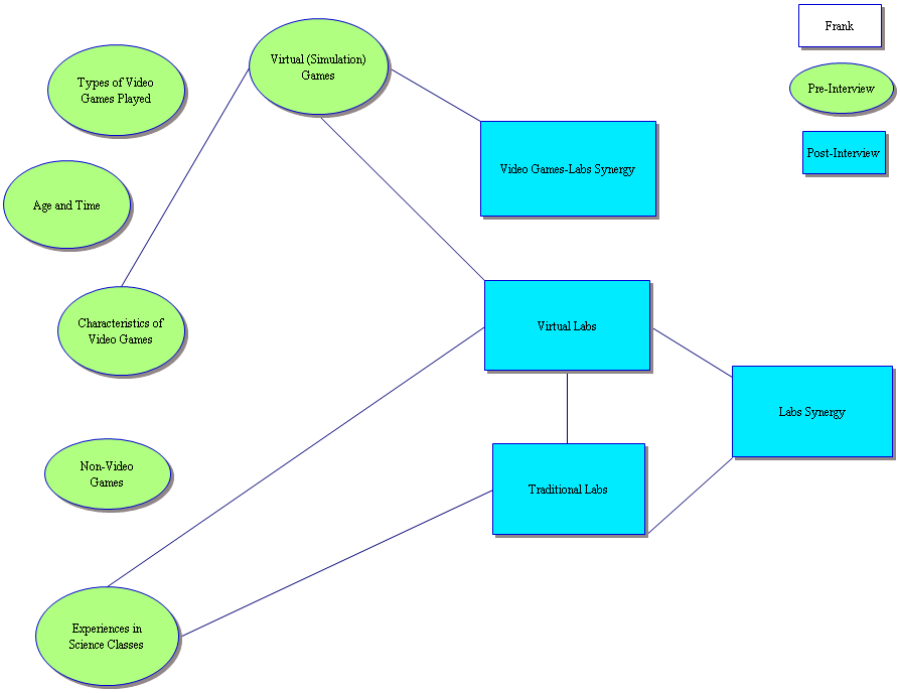

Figure 5 – Frank themes and connections

Only a few connections surfaced between the themes in this case (See Figure 5, above). There are connections between the Virtual (Simulation) Games theme and the Characteristics of Video Games, Video Games-Lab Synergy and Virtual Labs themes. Frank thinks that a benefit of playing video games, especially interactive sports games, is the acquisition of skills such as precision and forecasting. Another such connection is his belief that experience with video games can improve the ability to run virtual labs because the familiarity with the computer technology obtained from playing video games is translatable to virtual labs. Because virtual labs are essentially simulations, much like video games, they allow students to experiment with dangerous chemicals and situations without risk.

Frank also makes connections between the Virtual Labs theme and the Experiences in Science Classes, Traditional Labs and Labs Synergy themes. He associated good science teaching with conducting more labs and he explained that virtual labs allow science teachers to see more labs in their teaching that would otherwise not be possible due to mostly safety issues. While he believes that traditional labs are better teaching tools, virtual labs are also useful in getting science content across to students. Similar connections exist between Traditional Labs and Experiences in Science Classes since it is the practical aspect of labs that are useful in teaching regardless of the format of the lab.

F. Haley

Haley is a basketball player. She is a very outgoing, very friendly girl. She was interested in doing well in school but did not have much interest in science. Her career goals were to become a professional photographer. Haley worked hard enough in Chemistry to earn a good grade, not because she liked Chemistry, or Science, but because she was interested in earning good grades. Her grade in Chemistry was 91, with a test grade average of 82. Her responses to the evaluation questions of the second interview earned her 59 points, with 78% for her answers about lab procedures and 30% of the calculations questions.

1. RQ#1 - What are the students' prior experiences with computer and video games?

a. Characteristics of Video Games

According to Haley, sport video games help one learn the rules of the sport. However, it will not help with coordination since one is not actually doing it. It can help the player learn to play the game, the moves, and the plays. They are a learning

experience but not effective for such things as conditioning in the way that running is. She explained: “if you’re playing a basketball game, you can learn, like the moves that they do, you can try to pick them up and then if there are plays and stuff you can learn from that but it’s not like it’s going to help you get outside and run.” (Haley1, lines 112-114)

b. Age and Time

Haley played video games often under age ten. In elementary school she played video games around two hours every other day. She remembers spending less time playing video games in middle school because she was busier; she said: “I played video games a lot when I was younger. I don’t play as much now, but I used to play for probably two hours every other day, or something like that.” (Haley1, lines 6-7) As she has become older, the games have become harder. In high school, she “just started getting busier with school work and stuff.” (Haley1, line 62)

c. Types of Video Games Played

When she was young, she played Oregon Trail both at home and at school. She now plays Guitar Hero. She still plays with her brother. Guitar Hero “is fun.” (Haley1, line 62)

d. Non-Video Games

In elementary school, she preferred playing outside games with her neighbors and she also enjoyed running around outside. She also remembers reading and watching TV in addition to playing video games and other games. She said that given the choice, she always chose playing outside over either video games or any other inside non-video game.

e. Video Games and Social Behavior

While in elementary school she played video games with her brother and she played whatever he wanted to play from shooting games to sports games. It was more about spending time together than about what they played. “I played a lot with my younger brother so we would play whatever he wanted to play, like, he had a snowboarding game and a shooting game and all sorts of other sports games that I always played.” (Haley1, lines 16-18)

f. Video Games-Labs Synergy

She also felt that familiarity with computers helps the students to be able to perform virtual labs. Familiarity with the equipment, such as video games on the computer may be helpful in performing a virtual lab. But she thought that “anyone can do it because the directions are pretty straightforward. It would help if you actually knew what you were doing on the computer but I don’t know about video games.” (Haley2, lines 278-280)

2. RQ #2 - What are the students’ prior experiences with science labs?

a. Experiences in Science Classes

Haley didn’t remember much about science in elementary school, or doing labs either. While she liked science in elementary school, she believes doing more labs, and having less discussions and book work would be better and would help students learn better “because you get to actually work with the stuff so you actually learn better.” (Haley1, line 157) She liked earth and life science in middle school. She mentioned doing dissections and remembers them as being fun. However, she didn’t like physical science

in sixth grade because “it just felt harder, what they were trying to teach you and you couldn’t really learn it that well. (Haley1, lines 179-180)

In high school science has been more difficult; however, working with the concepts in the lab made it fun and easier to learn. Haley finds that doing experiments improves learning in science and believes that teachers should continue to do as many labs as they can.

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

In her opinion, traditional labs are hands-on meaning students have to be careful and follow the instructions. To her, the drawback of traditional labs is the time required. Haley did not think that there was any significant difference between the traditional labs and the virtual labs “because you’re pretty much doing the same thing, just one you’re actually like touching it and stuff and the other one you’re just doing it on the computer.” (Haley2, lines 207-208)

b. Virtual Labs

She mentioned several benefits of virtual labs. Virtual labs take less time so there is less time to get bored and one is better able to complete it in limited class time. She explained: ” you don’t have to wait as long, since you have a short class period it’s easier and it’s better for you” (Haley2, lines 222-223) They are better especially for the longer labs. Another benefit is that there is not a mess when mistakes are made. Dependence on the computer is a drawback of virtual labs. If something goes wrong with either the hardware or the software, it could ruin the virtual lab. Virtual labs are about the same

difficulty as traditional labs because the instructions are very similar. She thought that students learn about the same from either the traditional format or the virtual format. Therefore, virtual labs are good substitutes for traditional labs. They are the same labs, teaching the same concepts, with the same set of instructions, just with a different format so they would be good substitutes. She doesn't seem to find the difference in hands-on versus computer simulation very important.

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

She felt that doing a lab in both formats is beneficial and improves learning, because repetition is good to help students learn concepts. By doing the virtual lab first, which is less time consuming and easier to redo, you learn what to do before you actually try to do the traditional lab with real chemicals. She explained "there is a benefit [to doing both] because you can kind of learn it twice but I think you would do the virtual lab first because then when you get to actually use all the stuff you know what you're doing. Because when you're doing the traditional lab you're actually using the different chemicals and stuff so if you do the virtual lab, you know what you're doing so it's a little easier." (Haley2, lines 247-255)

5. Connections between themes

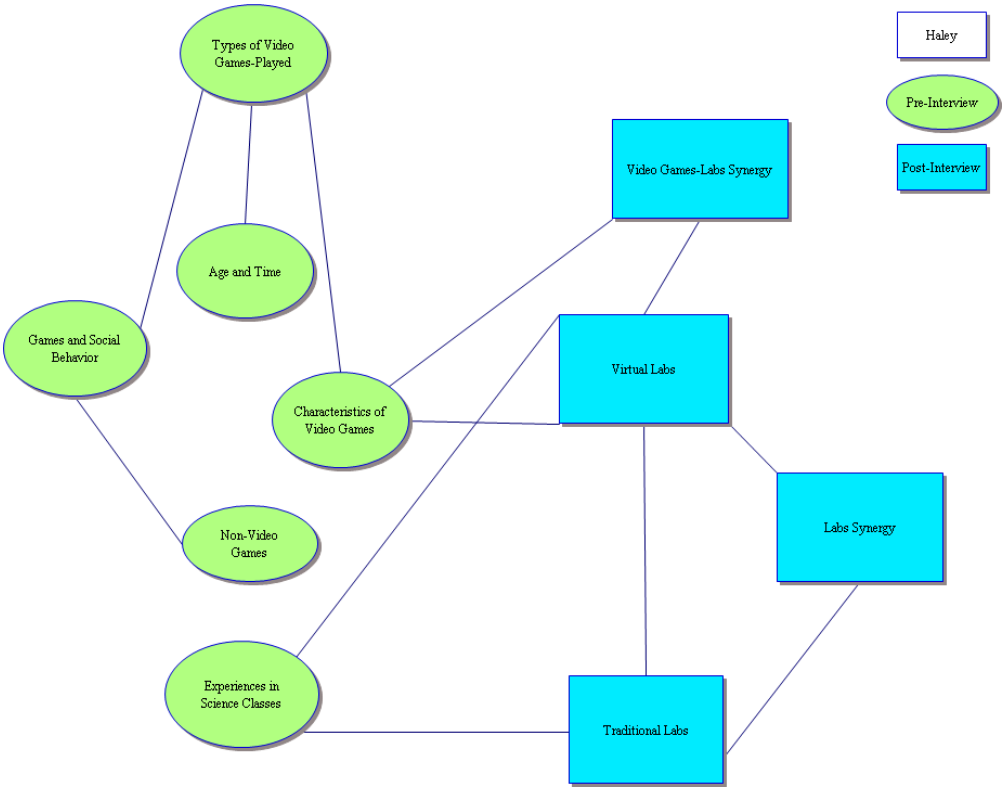

Figure 6 – Haley themes and connections

Haley's statements show connections between the theme Types of Video Games Played and the themes Games and Social Behavior, Age and Time and Characteristics of Video Games (See Figure 6, above). As she has grown older, the amount of time playing video games has diminished because Haley is busier and the games have become harder to play. Because she feels that the reason for playing games is for social interaction, she now prefers the less complicated games such as Guitar Hero which can also be played with a partner in a group of people. Although, she feels that some video games, such as the sports games are beneficial in learning how to play a sport, she does not see them as substitutes for actually engaging in sports. Furthermore, there is also a connection

between Characteristics of Video Games and Video Games-Lab Synergy as well as Virtual Labs themes. In her opinion, being familiar with the equipment used in video games can be helpful in improving a student's ability to perform a virtual lab.

There is also a strong connection between the themes of Experiences in Science Classes, Virtual Labs, Traditional Labs and Las Synergy. Haley felt that doing labs whether virtual or traditional helps students learn science concepts, because labs make learning science more fun and therefore easier to learn. This is also true because it involves the student in the learning process in a more active way. Her most vivid memories of science learning were those that involved labs.

G. Harrison

Harrison has a quiet personality. He is very easy going and friendly. Harrison is very interested in environmental issues and volunteered his time to help with recycling efforts. Harrison is very interested in music and plans to pursue a career in music. While he did not have an interest in science, he was willing to put forth enough effort to achieve average performance. His overall grade in my Chemistry class was 78 with a test average of 68. On the evaluation section of the second interview, he scored an overall grade of 70, distributed as a 90 in lab procedure and 40 in calculations.

1. RQ#1 - What are the students' prior experiences with computer and video games?

a. Characteristics of Video Games

Harrison brought up that video games have the ability to place the player in a different reality. Some of the more realistic games are less shiny and more like the real world. These games can more easily help a player enter an alternate virtual world and escape their current reality. They games contain humor, horror and a lot of action. He

said that such games "gets you to do something that you might not always get to do, like when we were little we would play cops and robbers. For a long time people would play cops and robbers, cowboys and Indians and basically use their imagination to put them somewhere else. In this it puts you somewhere else but there are like some places you can make yourself and press it, like in World War Craft you are in a giant world built with six million people that are playing this or like nine million now, and you can go around and talk to other people and make friends across the world and do quest and you feel more successful because you are actually doing something, I guess. It might not be the best way to put it but you feel like you are actually accomplishing something important sometimes." (Harrison1, lines 137-145)

b. Age and Time

Harrison remembers playing video games since he was three years old, sitting in his uncle's lap. During this time he became a heavy gamer. He played computer games such as World War II Nazi Shooter, Metal of Honor, Call of Duty, Star Wars Republic Commando. He operated pistols, rifles, machine guns of different types, and grenades. Now, he continues to spend a lot of time playing video games in high school, much more than when he was a child. Now that he is in high school, he estimates that he plays around four to six hours per week. He describes himself as an "adequate [video gamer]. "Not a really good gamer, I just – I do it for fun. I am decent. I am not the best person." (Harrison1, lines 194-195)

c. Types of Video Games Played

When Harrison was very young, he played games such as Wolfenstein 3D, Doom, and Sega Genesis games. In third grade, he started playing games on the computer "because I liked how the controls were and how the graphics were and it seemed like a lot better games were coming out on the computer more for me." (Harrison1, lines 10-12) He played games such as Medal of Honor, World War II shooting games, and some Play Station games. He remembers playing some educational games such as the Thomas trains because they made him think. He felt that computer puzzle games were educational because they made him think. He also remembers playing games that were not video games while in elementary school, such as Lego's.

During the middle school years, he became a heavy gamer. He played computer games such as World War II Nazi Shooter, Metal of Honor, Call of Duty, Star Wars Republic Commando. He operated pistols, rifles, machine guns of different types, and grenades. Harrison remembers that in the games, he had to fight virtual Russian armies, and the games became more realistic. He mentioned that in those games the player carried virtual passports and orders, just like their real-life counterparts.

He refers to the games played in high school as hard core. He has become more of a heavy gamer as he has grown older, meaning he plays the games more seriously and even now, with competition from high school activities and a much heavier study work load, he still manages to play four to six hours per week, mostly on weekends. He said "Some weeks—like I don't play on the weekdays except for Friday or if we have a day off, but I will play a lot on Saturday and Friday and maybe a decent bit on Sunday's, somewhere between four and six hours a week." (Harrison1, lines 108-110) Some of the

games played in high school include High Life and High Life II, Orange Box, Team Fortress II, World War Craft, Zelda. Harrison is "not as big into the sports games as I am into Fantasy and High Five stuff or the fantasy action games." (Harrison1, lines 171-172) He does not believe playing sports video games improves skills in sports. He believes that it is better to play a sport in real life than in a virtual video game.

d. Non-Video Games

Harrison also remembers playing games that were not video games while in elementary school. He remembers playing with Lego. He preferred playing with Thomas trains over any other games because he had control of the trains. They were his favorite.

e. Games and Social Behavior

Whether video games or non-video games, he has played both types with friends and family members. From a very young age, he played video games with his uncle. He played whatever games the uncle wanted to play. He said he used to "sit on my uncle's lap and watch him play." (Harrison1, lines 4-5) Also, "I do remember every day – I used to live with my grandmother, like after lunch she would watch her soap operas and we would either play Bingo or put a puzzle together." (Harrison1, lines 37-39) It seems as if for Harrison the game was not as important as the social interaction.

f. Video Games-Labs Synergy

He did not believe that experience in playing video games have any effect on virtual lab performance. He felt that there are not enough similarities between a video game and a virtual lab that having experience playing video games would not help a

student in performing a virtual lab. The main concern with virtual labs is the specificity and he feels that in video games you have much more flexibility.

2. RQ #2 - What are the students' prior experiences with science labs?

a. Experiences in Science Classes

Harrison remembers elementary school being very easy altogether. He doesn't remember much about science in elementary school except for dissections in fifth grade. He enjoyed science hands-on activities because things are seen first-hand. He feels that t is more interesting to see things up close. About dissecting owl pellets he explained: "we found little skeletons, stuff you don't usually see. You've only seen them in pictures, stuff that is more interesting to see it up close, like, in some ways like get dirty and use your hands for stuff." (Harrison1, lines 226-228) Other topics he remembers from elementary school science are magnetism and photosynthesis.

He really enjoyed middle school Physical Science and Biology. He remembers doing a lot of experiments. This made science fun for him. He said in Physical Science "We did a lot of experiments at the beginning of the year. We talked about why candles go out and – like we put stuff in the container and let it warm up in there. Like we would take a match and blow it out and put it in there and let it fill up with air and then try and light another one in there." (Harrison1, lines 233-236) He seemed to remember a great deal of details from middle school science classes, especially the labs.

He thinks that science in high school is a lot better than in previous years because of the large amount of lab work. Labs help you grasp scientific concepts because you are actually doing something and learning through hands-on and examples. He has learned a great deal in high school science which he attributes primarily to the large lab

component. He explained, “Some people can read it and understand what it’s going on. Some people can watch it and understand what it’s going on. Other times it takes actual doing it in order to understand it because you can say something, but if you do it you can actually see what is going on and you have to pay attention to it or else you mess up and it is not right.” (Harrison1, 274-277)

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

Harrison believes that traditional labs keep his interest better because they are hands-on and appear to give the student more control of the lab. You have to do more things and pay attention to what you are doing to avoid making a mistake. He explained, “you are actually doing more stuff, so like with the [virtual] lab all you had to do were press a couple of buttons and you were done with the entire lab. Meanwhile this would take a longer process and instead of you clicking a couple of buttons and looking off and talking to a friend you had to actually watch the experiments.” (Harrison2, lines 118-121) He said that while the traditional lab takes longer to complete, the student knows it is working as results are obtained. He also felt that traditional labs are more effective teaching tools because students have to pay more attention to what they are doing due to possible safety issues.

Regardless of the benefits, he believes there are some disadvantages. He feels that a drawback of traditional labs is an increased likelihood of making mistakes. Another disadvantage of traditional labs is that they require more time to set up, perform, and clean up. Additionally, it is practically impossible to start over a traditional lab if a

mistake is made. Harrison explained that "if you mess up it is probably going to screw you over… like if you have three days to do a lab because it takes three days to do the whole transition and stuff, if you mess something up or it explodes on you half way through the second day, then you can't really start over" (Harrison2, lines 161-165) because there is not enough class time available for this. Also, traditional labs expose students to chemicals and conditions that could be harmful. In spite of those drawbacks, he felt that he learned more from the traditional labs because they were hands-on and he is a hands-on learner. Given all the benefits and drawbacks of both formats, Harrison prefers the traditional labs because he is a hands-on learner.

b. Virtual Labs

Harrison believes that one of the most important benefits of virtual labs is the ability to re-start it if a mistake is made because of the absence of clean up. Another benefit is that since it can be performed quicker, there is more time to focus on other learning activities or even perform more labs. With virtual labs, he said that, at first, it was hard to get used to the computer system which created problems. He explained "If you are not used to the system it takes a while to learn how to use it. Again it is very specific so you could spend five minutes trying to figure out what it wants you to do. The [virtual] labs also seem in a sense kind of crowded" (Harrison2, lines 154-156)

He complained that the simulation program would not allow certain things to be done. The instructions were very specific and could cause students to become bored with trying to follow the directions. He mentioned that the virtual labs seemed more complicated probably because they were something new and there was a learning curve. Harrison feels that virtual labs are not good substitutes for traditional labs. He said that in

the absence of a traditional lab "it would be better not to do it [virtual lab]" (Harrison2, line 207) because it is not hands-on.

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

With this in mind, he believes that doing both traditional and virtual versions of the same lab would allow the student to focus on the best of both and enhance the learning process. He said he "would prefer virtual and then actual. I think it would be most logical to do virtual and then actual…because I want to get the calculations out of the way. I want to get the hard stuff done. Then I could go into the actual lab and be able to focus on that more than worrying about the calculations." (Harrison2, lines 184-189). In the traditional lab, the procedure could be the main focus since the calculations have already been dealt with on the virtual lab. He also mentioned that the reverse sequence could also work out to do the virtual lab second and use it to perfect the procedure before actually doing it and to check the calculations on the traditional lab.

5. Connections between themes

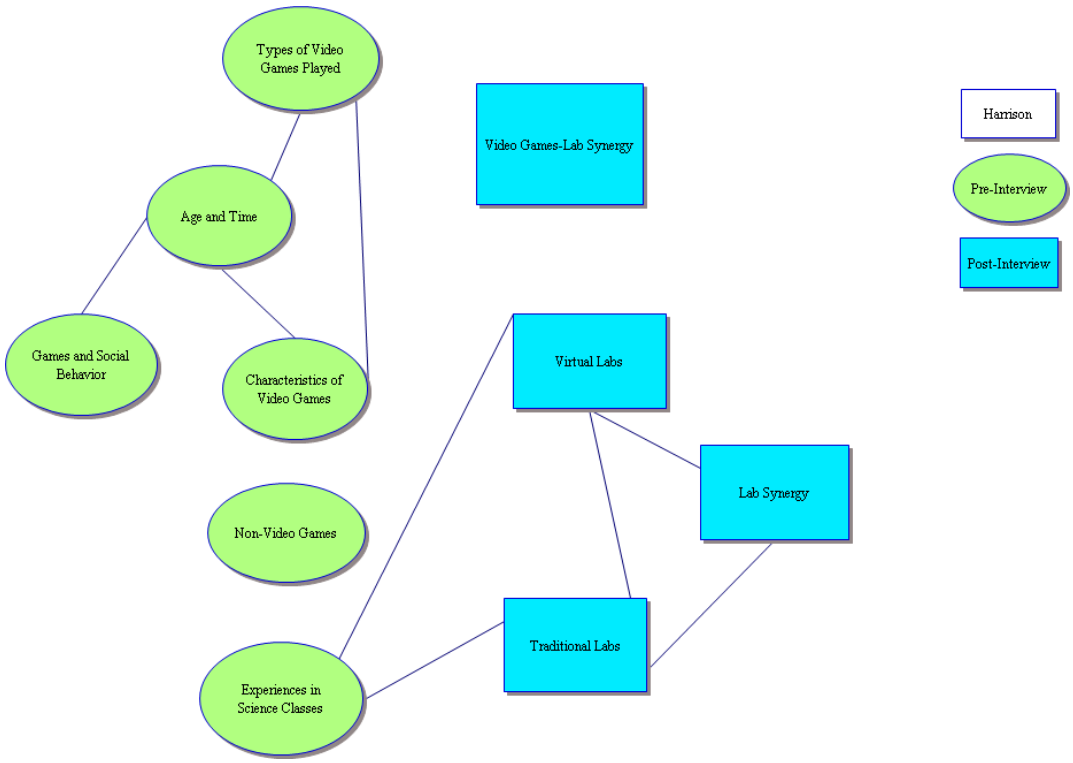

Figure 7 – Harrison themes and connections

There are connections between the Age and Time theme and the themes Games and Social Behavior, Characteristics of Video Games and Types of Video Games Played (See Figure 7, above). From a very young age, he played video games that allowed Harrison to use pistols, rifles, machine guns and other weapons that people don't normally operate in daily life, especially a child so when he was playing these games, he was existing in a virtual world that allowed all these activities that otherwise he was forbidden from. He seemed to prefer the types of video games that placed him in this alternate reality that seemed very real because they required the player to use passports and military orders as if in the real military environment. Also, from the time he was very young, he played video games with his uncle; he mentioned that he played whatever his

uncle wanted to play. Since that young age, it was more about the relationship than the game itself.

Another set of connections identified in Harrison's interview was the connections between Experiences in Science Classes and Virtual and Traditional Labs and the Lab Synergy themes. He remembered very specific details of those classes where more labs were conducted and he remembered very little from classes with no labs. For instance, he only remembered that the classes that did not include labs were an inferior learning experience. This was especially true of traditional labs. He feels that the main role of virtual labs is to enhance the traditional lab experience and should be done whenever possible to minimize the negative aspects of traditional labs such as the difficulty in re-starting especially in light of the large amount of time required to do some traditional labs.

H. Josh

While Josh expressed interest in a career in a science-related field such as psychiatry or genetic engineering, he did not show an interest in science while he was a student in my chemistry class. Josh has a fairly quiet personality; he is friendly once you get to know him but he is not overtly friendly. He is easy-going and he puts enough effort into school work to earn average grades. His overall grade in Chemistry was 80, with a test average of 72. He was an average student in my class. In the performance evaluation of the second interview, he scored an overall grade of 75, which included 100% in the procedures questions and 38% in the calculations section.

1. *RQ#1 - What are the students' prior experiences with computer and video games?*

a. Characteristics of Video Games

Josh prefers video games over any other types of games because of the virtual aspect of video games. One can do things that are not possible or advisable in real life such as shooting fire balls, flying around, starting fights, killing and getting killed, and other activities that can only be experienced in a simulation. He explained: "You had more control, like you could do more in video games than you could do in real life. Like you can't really go out and shoot a bunch of people and blow stuff up. You can't just go out and start random fights or fly around and shoot fire balls." (Josh1, lines 49-53) In middle school he played Grand Theft Auto, which fits this description. He likes to have total control over the game. Those games are realistic in the sense that the player assumes an identity in the game and controls that identity in doing normal everyday things such as buying and selling. He likes the idea of creating the illusion that the game is the real world. He said: "those simulation games I was talking about, just walking around and you have a bunch of control. You can do pretty much anything that a normal person couldn't do. Just things that would kill you, like jumping off a building and getting shot." (Josh1, lines 64-68)

b. Age and Time

Josh has "been playing video games for as long as I can remember." (Josh1, line 2) In elementary school he played three to four hours per week. He liked playing just because it was a novelty. He said the reason he started playing video games as a young child was that "way back then it was more of just the novelty of the computer itself and seeing the images on the screen, not so much the same reason I play it now." (Josh1, lines

37-39) In middle school the play time increased greatly from three hours per week to three hours per day; during this time period, the amount of time playing video games peaked. However, since starting high school, he plays much less time because he is busier and has less available time for video games. Instead, he now spends a lot of time doing web design.

c. Types of Video Games Played

He likes the games that are easy to get into and not require very much time to learn how to play the game. He remembers getting his first video game console when he was in fourth or fifth grade. He played some games like Putt Putt and Mickey Mouse that were educational only because you learn about shapes. Some of the games he likes to play now include a wide variety of games such as Guitar Hero, Mario, and Dragon Ball Z. He explained: "if it's like nicely out together, just the fluency of it, the game play. If it's easy to pick up and to start going with it, "cause I don't like games that take a long time to get into, like now, like Grand Theft Auto I don't play a lot now because it takes a long time to get going with it and do missions and stuff. For example, Guitar Hero, I could pick that up and I could play one song and then I could go do something else." (Josh1, lines 96-102) He considers himself to be really into video games, he finds them "cool." (Josh1, line 10)

d. Virtual (Simulation) Games

He likes virtual reality games, but not if they are hard to get into such as Sims and Second Life. He sums up his feelings about video games in the following quote. "It's like you're taking the real world, except doing the things that you wish you could do in the

real world in the game but you wouldn't be able too. It's still creating the illusion that it's like the real world." (Josh1, lines 157-159)

e. Non-Video Games

When asked about non-video games, he did not have as much to say. Josh answered "A lot of board games. I loved board games. I played outside games, I never did play sports that much, I kind of did but not so much for fun. I liked to play hide-and-seek, tag, and stuff like that. I did play sports, I played soccer, baseball." (Josh1, lines 42-44)

f. Video Games-Labs Synergy

Furthermore, Josh believes that since a virtual lab is just like a simulation game, experience with computer games should help with virtual labs. He explained it this way: "virtual [lab] is [like] a simulation game. All it is, it's basically a simulation game where you are directly manipulating as if you actually there. It's supposed to be simulation normal reality. I think any experience with computers or game consoles would help with those virtual labs, seeing that they are on a computer. Yeah I mean that's pretty much it." (Josh2, lines 166-175)

2. RQ #2 - What are the students' prior experiences with science labs?

a. Experiences in Science Classes

Josh didn't like science in elementary school because it was mostly memorizing facts about earth and space science. Josh likes science better when you can experiment. He explained: "there was a lot of book work, memorization, and not much application. Mostly learn about the moon, the ocean, stuff we wouldn't get to see or experiment with.

We just had to know. I don't like it. I like experimenting." (Josh1, lines 167-171) He believes that some experiments are too dangerous for elementary school age children, but simple experiments can be conducted any way. In middle school, while they performed a few more experiments, which was better than elementary school, they still did very little in the way of experiments. He believes that high school science is much better because of the lab component. He said: "High school science I like a lot better because there's a lot more hands on stuff and labs and stuff and you never really got to do that before. You get to see what's going on and it's not all theoretical. It gives me something to remember. Simple as that." (Josh1, lines 195-200)

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

Hands-on activities are better, they help the student remember the material such as titrations in Chemistry, he believes that the reason he remembers is because he actually did it himself; hands-on activities give him something to remember.

Josh feels that the main drawbacks of traditional labs are diminished accuracy and the increased likelihood to make mistakes and if a mistake is made, it is very hard to restart a traditional lab. Among the benefits of traditional labs is his idea that they are easier and faster to maneuver. Traditional labs make it easier to keep your interest and remember the traditional lab because it is more hands-on. Josh feels that physically handling the lab helps him remember it so he prefers it. He explained "I'm more interested in the real one because I remember it better if I am actually physically doing

something. (Josh2, lines 94-95) He thinks he learned more from the traditional labs because it is easier to remember things you physically do.

b. Virtual Labs

While he still saw it as a negative, he admitted that part of the reason he didn't like the virtual labs better was because he didn't know how to use the software. The learning curve of the software can be perceived as a negative aspect of the virtual labs. Josh mentioned not knowing what was going on and being hard to move the pieces of equipment around in the virtual labs. It was difficult to figure out where to place things so you had to learn the software. Virtual labs are limiting in a sense because you can't move around the lab and the stockroom and pick up any chemicals as in real life. He explained this when he said: "the virtual ones you still …learn how to use the software itself as far as, there are some limitations like you have to know where to put the things to get them to work. We all had a hard time getting the HCl and the NaOH out of the lab room. And that was difficult just because you didn't know the exact spot to put it in." (Josh2, lines 108-112) He perceived the ability to diverge from the intended procedure mostly as a negative. However, he did say that it can also be seen as a benefit of virtual labs that it is possible to do other things not necessarily in the lab procedures because doing this may be fun.

Nevertheless, he felt that once you learn the software, the virtual labs are easy to do. Virtual labs can teach the main idea of the lab. He mentioned he enjoyed virtual labs somewhat, but was not particularly enthusiastic. He felt he was able to learn from both equally; he was able to learn from the virtual lab in spite of diverging from the intended procedures. Josh saw virtual labs as good substitutes for traditional labs; he explained: "I

think it would be nice to be able to do it virtually than not do it at all." (Josh2, lines 157-158) The virtual lab is capable of helping students learn the concepts.

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

Josh expressed that it is beneficial to do both the virtual and traditional versions of a lab because it reinforces the concepts being learned. He said: "just replication in general I retain more and I understand more of what I am doing." (Josh2, lines 139-140) He believed that it would be better to do the virtual first. Since the virtual is easier to restart if mistakes are made, it is possible to get a good understanding of what is going on from the virtual lab before doing the traditional lab which is easier to mess up and harder to redo. Depending on the lab, it would be OK to do the traditional first.

5. Connections between themes

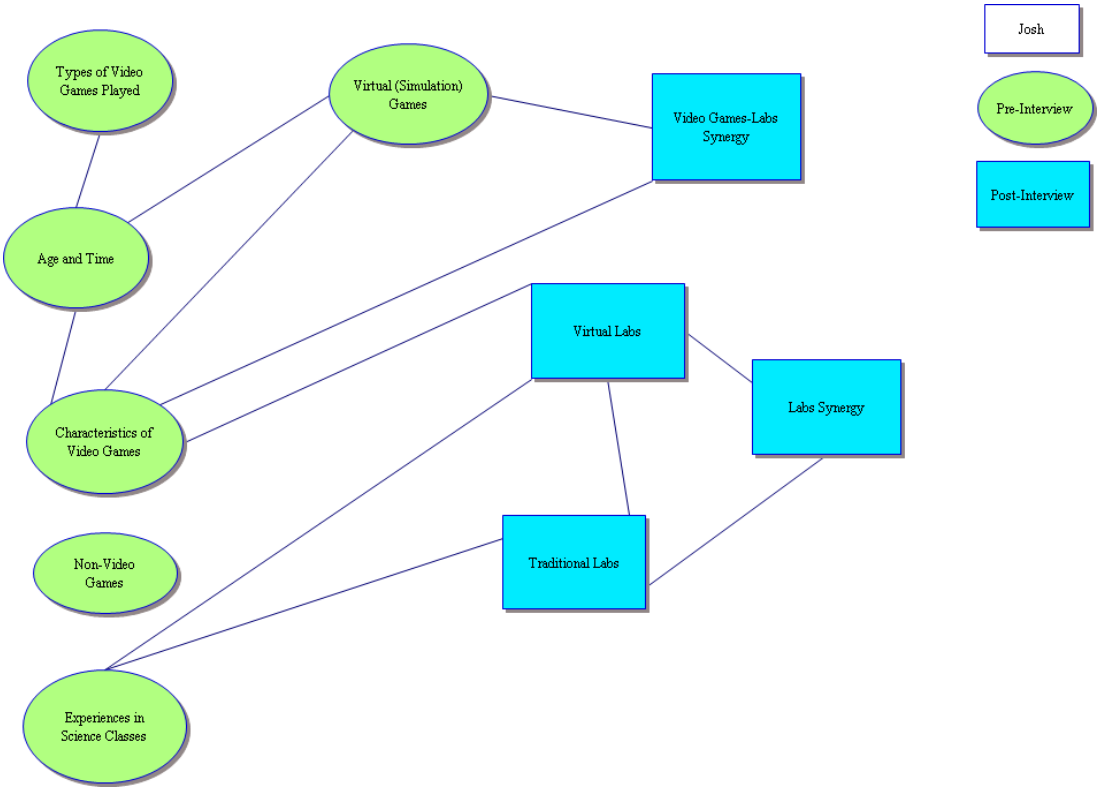

Figure 8 – Josh themes and connections

There are several connections between the theme Types of Video Games Played and the themes Age and Time, Virtual (Simulation) Games, and Characteristics of Video Games (See Figure 8, above). He has always had a great deal of interest in video games, even to the point that he does not remember a time in his life when he did not play video games. He highly emphasized the simulation aspect of video games that allows the player to escape the limitations of reality. One of the best characteristics of video games, according to Josh, is that they allow one to do things that are either not safe, legal or socially acceptable. Therefore, he prefers those games that place the player in a virtual, alternate world or reality.

Several connections also exist between the theme of Experiences in Science Classes and the themes of Traditional Labs, Virtual Labs, and Labs Synergy. Josh associates good science class experiences with hands-on activities such as labs. He feels that hands-on activities help him better remember science concepts. According to Josh, traditional labs are the best hands-on activities; however, the virtual labs are quite comparable in reinforcing science concepts once the software learning curve is overcome. Since he feels that labs are very importance in science classes, the more labs performed the easier it is for students to understand the concepts. Each lab format, traditional and virtual, have their own strengths and weaknesses and Josh feels that the ability to perform both builds on their strengths and minimizes their weaknesses because the two formats complement each other well.

Another set of connections made is that between Video Games-Labs Synergy theme and the themes Characteristics of Video Games and Virtual (Simulation) Games. Josh is very comfortable with simulation games because he enjoys playing them and has grown up around them. He also feels that the best characteristic of video games is their ability to simulate the real world. Josh has a great deal of experience immersing himself in a virtual environment; therefore, he finds that the experience with this type of technology helps him with the virtual labs.

I. Mark

Mark was a very interesting student. While I believe he is very intelligent, he is quite an underachiever. He has a very charismatic personality; he is very talkative and friendly. Sometimes his exuberance aggravates the people around him. He is very confident but places very little importance on school performance. He is not interested in

pleasing people with his grades; he does what makes him happy, regardless of the consequences. In spite of his lack of dedication to his classes and his sometimes-unacceptable behavior, his charismatic personality makes him an overall likeable young man. Mark admitted that he did not know what he wanted to do for a career; he said that he would consider mechanical engineering to follow in his father's footsteps. He also said he was interested in a possible law enforcement career. Mark failed my class with an overall grade of 62, with a average test grade of 61. On the evaluation section of his second interview, he scored 73 with a 97% in lab procedures and 38% in the calculations part.

1. *RQ#1 - What are the students' prior experiences with computer and video games?*

a. Characteristics of Video Games

Mark liked video games more as a child. While he played sports, he preferred video games because "it was a lazier way for me to do stuff," (Mark1, lines 41-42) they required less physical activity. From the very start he describes video games as "awesome." (Mark1, line 58) He is very enthusiastic about video games. He also describes video games as cool and fun.

b. Age and Time

He remembers playing video games as far back as seven years old. He liked video games more as a child. He estimates that he spent about half of his time on video games and the other half playing sports, such as soccer. While he played sports, he preferred video games because he could be lazier, required less physical activity.

c. Types of Video Games Played

According to Mark, virtual fighting games are awesome because they allow you to do things you can't do in real life, such as drop kick and shoot fireballs. In the ninth grade, he started playing computer games more.

In computer games, the virtual reality technology allows the player to play much more like real life. There are also computer games that resemble real life, for example, in some games you can build a village from scratch. Also, computer games have more levels and are therefore more challenging. These games, allow the player to do things that cannot be done in real life because they are illegal, unethical or just impossible. One can do whatever one wants or be whoever. With virtual technology the player can try things just to see what happens, without risk. He has a great deal to say about the thrill of doing things in virtual reality and getting to experience what it would fell like to kill, steal or doing any other things that are unethical to do in real life.

He goes on to say that no matter how close to reality they might be, video sport games are not a perfect substitute for real sports. He says that since you cannot do as much in a video game as in the real games, they do not help improve skills unless the person is a very bad sports player and can use help with very basic skills. He explained "As far as performance goes, I would much rather prefer real life because you can do as much as you want. You can do all the moves that you want. Like in soccer, in the game you can't do a _____, which is where you put your foot on top of the ball and you just spin and then you roll it back, and basically all it does is it makes you pass the person and you juke them out, and certain moves like that they don't have in the game just because there is only so many buttons to have so many moves. So you can do a lot more stuff in

real life. I think it [virtual sports game] can help. If you are really, really bad, it can help. You can watch. They do everything right in the games. They do the motions right and everything. But it is kind of like riding a bike. You can look at it and it looks easy. But it is not easy until you actually do it." (Mark1, lines 128-140)

d. Virtual (Simulation) Games

Mark enjoyed playing computer virtual reality games such as Lord of the Rings, Madden Sports, Mortal Combat and Grad Theft Auto because all these games allow the player to be in an alternative reality where the player can do activities not otherwise possible or acceptable. This feature seemed to be one of the most important aspects of video games for Mark.

e. Non-Video Games

Mark said that he spent about half the time playing video games and the other half playing sports such as soccer. He played in a jungle gym. No matter how close they might be video sport games are not a perfect substitute for real sports. When he became bored with video games, he turned to sports. He played t-ball, football and soccer. Mark attributes his enjoyment of sports to the fact that he has good skills in all the sports he has played.

f. Games and Social Behavior

He believes sports are better for your health because they require being outdoors and physical exertion. He also believes that playing sports fosters social relations with other kids.

g. Video Games-Labs Synergy

Both virtual labs and video games allow someone to do many things that in real life would cause harm or in some way be unacceptable but not in the virtual reality world. Also, both in virtual labs and video games it is possible to manipulate conditions such as speed up and slow down time. However, the only real benefit obtained from having experience playing video games to performing virtual labs is familiarity with the technology, otherwise there is no benefit. Doing a virtual lab felt as if you were playing a video game.

2. RQ #2 - What are the students' prior experiences with science labs?

a. Experiences in Science Classes

Turning to Mark's experiences in science classes, he did not remember doing much in the way of science in elementary school. Looking at dirt or grass or watching the teacher dissect a worm is all he can remember from science class in elementary school. In spite of the rather simple things he considered as science in elementary school, he was grateful for them. He explained: "I like it because it meant we got to move around a lot more. We didn't have to sit in a desk all day. I hate sitting in a desk, and moving around and getting to see what a bunch of stuff is, I think it was very beneficial. It helped me learn because I am a hands-on learner. I liked to be doing something. I don't like to be looking at somebody else do it. I had rather be doing it myself. Some things she would let us touch and look at and some things she wouldn't just because they were too dangerous. I liked it a lot because it was more hands on work. It was just really cool." (Mark1, lines 277-285)

In middle school, he remembers more labs, including dissections. As stated before, Mark prefers doing activities than sitting; therefore, he really enjoyed doing labs in middle school. They helped him learn because they were hands-on. He also remembers being in an accelerated class where they did some type of lab (hands-on activity) almost daily. He said of middle school science class: "we did more labs that had a lot more to them, a lot more parts. We learned more about the scientific method and how you are supposed to make hypothesis and all this stuff. It got a lot harder to do these labs but it also got a lot more fun as long as you did everything correctly because you could do more stuff." (Mark1, lines 305-308) Doing things hands-on helped him learn. He liked hands-on activities and thought they were cool.

Labs in high school are more involved, such as working with chemicals and fire. He felt that in high school, he was allowed to do much more in lab than ever before. He explained: "it is a lot more stuff that you can do. Like now you can deal with chemicals that could potentially burn you. You can deal with fire now, they wouldn't let you do that, like and open flame. They wouldn't let you do that. And basically what I am learning is as you get older there are more things that you are allowed to do but there is always that limit right there and in the labs it is more fun because you deal with more stuff that you have never done before and I actually put more thought into my hypothesis because I wonder so much and I would really want to know what is going to happen, so I might go home and do a tad of research, just a little bit, just to get slightly educated" (Mark1, lines 318-325) Labs are hands-on so they help you learn what you need to know. He described science as very cool several times and how it made him wonder how things worked. He said: "It helps you learn and it is really fun because you don't have to sit in a

desk and take notes all day. You get to actually get up and do something." (Mark1, lines 336-337)

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

Mark mentioned some negative aspects of traditional labs such as the student having to be very aware of what is going on at all times because making mistakes can cause harm. He said: "you have to be very aware in traditional labs because if you mess up then it is your life that you are putting in the balance along with two other people." (Mark2, lines 129-130) There could be major consequences of not following directions exactly in a traditional lab. However, there are also major benefits associated with traditional labs. The most important benefit is the hands-on characteristic. There is also a higher level of error in traditional labs, which is a positive because it is real life and students need to be able to control the factors leading to these errors as much as possible as they learn lab procedures.

b. Virtual Labs

On the other hand, de did not find many drawbacks associated with virtual labs, other than that it is not hands-on. The students are not able to physically touch the materials they are working with. The benefits of virtual labs include speed and increased accuracy. Virtual labs keep the students' interest better and therefore improve learning. They can also be easily restarted after a mistake and there is no risk of harm to the students if anything goes wrong. Additionally, virtual labs can be sped up in slow parts to

avoid boredom. There is always something to do. If you make a mistake you can restart and you won't get hurt. You are not exposed to possibly hazardous substances. Virtual labs don't have much error. He explained: "because you can actually kind of speed up time in the virtual lab if you want. You speed it up, get to the point a little before where you need to be and then you slow it back down, and you can go like that and that way you are always doing something. Not like in real life where you have to wait for 10 to 15 minutes and you have nothing to do. You do labs a lot faster. It kept my attention a lot better." (Mark2, lines 121-125)

He liked the virtual labs; he found them to be and fun interesting. It seemed to him as if were in a real lab with a lot of equipment and chemicals; therefore, he thought that virtual labs are good substitutes for traditional labs; he said: "I think it would be good to do the virtual lab even if you couldn't do the traditional because you have to know what would happen and it is important to have that knowledge so you know not to do anything that is messed up or that will hurt you later if you happen to come across it. It is still good experience. You still get all the knowledge you would get in traditional." (Mark2, lines 163-167)

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

Mark believes that it is advantageous to perform both the traditional and the virtual versions of the same lab. He explained: "I like doing them both because you can see how it is supposed to be and then you can see how you are doing it and see how you

need to improve maybe. It is a pretty good comparison." (Mark2, lines 150-152) When doing both, he felt that doing the virtual first, the student can know how the lab should be done and is better able to perform the traditional lab. The virtual lab provides a good model to follow since the procedures are essentially the same, just being performed on two different platforms, a real one versus a virtual one.

5. Connections between themes

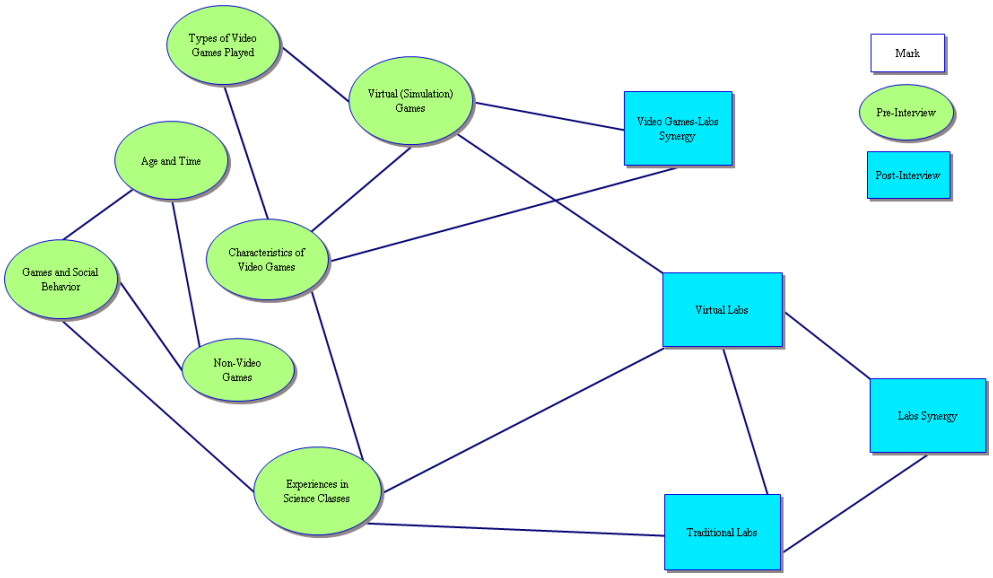

Figure 9 – Mark themes and connections

There is a connection between Virtual (Simulation) Labs and Characteristics of Video Games (See Figure 9, above). Both virtual labs and video games allow someone to do many things that in real life would cause harm or in some way be unacceptable but not in the virtual reality world. Also, both in virtual labs and video games it is possible to manipulate conditions such as speed up and slow down time. However, the only real benefit obtained from having experience playing video games to performing virtual labs

is familiarity with the technology, otherwise there is no benefit. Doing a virtual lab felt as if you were playing a video game.

Another connection exists between the themes of Age and Time, Games and Social Behavior and Non-Video Games. Since a very young age, Mark enjoyed playing both video and non-video games equally well. The reason he said he liked playing sports was that they required him to be outside and because sports foster social interactions with other children and he enjoyed the social aspect of sports.

Another set of connections exists between the Types of Video Games Played, Virtual (Simulation) Games, Characteristics of Video Games and Types of Video Games Played. In the video games category, he enjoyed any video game that involved a simulation because simulations allowed him to be able to do many things that are not possible in the real world for many reasons such as physical inability, legal issues, moral issues or safety concerns. These activities appealed to Mark because of the thrill of doing that most people are not able to do and feel and understand what it is like to do them. This seemed to be a recurring theme with Mark. There is also a connection between Virtual (Simulation) Games and Video Games-Lab Synergy. He believed that there was a relationship between a video game and a lab simulation because they both were simulations of life situations, even if those in the video games are sometimes unrealistic. However, he felt that the only benefit from familiarity with video games in performing virtual labs was the familiarity with the computer-related equipment.

Lastly, there is a connection between the themes of Experiences in Science Classes, Virtual abs, Traditional Labs, and Labs Synergy. Mark felt that the best experiences in science class were those that involved hands-on activities such as labs,

whether they are virtual or traditional labs. There is a synergy between the virtual and traditional labs because they each allow the students to learn the science concepts from different perspectives and each has its own strengths in helping students learn. While he preferred traditional labs, he also felt that virtual labs could be acceptable substitutes because they taught the same concepts in mostly the same manner.

J. Melinda

Melinda is very outgoing and friendly. Melinda has a very bubbly personality. While she is intelligent, she lacks confidence. She was involved in Science Olympiad for a year as a sophomore. During that year, she constantly compared her performance with that of the other team members. When she could not perform at the level some of the seniors performed at, she became very upset and withdrawn. Melinda expressed that she would like to become a surgeon. From my observations of Melinda, I am not sure how genuine her dedication was to becoming a surgeon. On her second interview, she scored an overall 77, distributed as a 95% on procedure-related questions versus 50% for calculations-related questions.

1. RQ#1 - What are the students' prior experiences with computer and video games?

a. Characteristics of Video Games

Melinda liked playing educational computer games in class "because they were relaxing and got you out of class. You weren't doing things you were graded on, you were just like having fun. And you could compare how well you did to other people and you could be like I did better than you." (Melinda1, lines 20-25Age and Time

Melinda remembers playing video games only about two hours per week while in elementary school; she does not feel as if she has ever played video games much. In

middle school, she did not play video games much, except for some flash card-type and other educational activities on the computer. She found these games more interesting and fun than the alternative lecture in class. As she grew up into middle school and high school, she stopped playing sports; therefore, she has more time available to play video games. She now plays a little more but not much. She likes to play sports video games such as soccer and football.

b. Types of Video Games Played

One such game is Oregon Trail. She said she liked playing computer games. She liked those computer games like Tetris and Solitaire that are fun and relaxing and do not require much thought.

c. Non-Video Games

When asked about non-video games, she remembers playing board games and playing dolls when it was rainy or otherwise not good to play outdoors, she also remembers hanging out with family and acting. She recalls playing a lot of sports and outdoor games such as hide-and-seek. As she got older, she played more sports, both recreational and informal, pick-up games. In high school, she does not play sports so there is more time available to play video games. She plays video games a little more now, but not much. When Melinda was younger she played sports; she said: “I think the real thing is more fun because you are really doing it but on the computer you can have professionals doing it how you think it should be done, compared to you really do it and it also keeps you playing even if you can’t play outside. Probably doesn’t help your performance as much as it helps you mentally, like being able to play the game. It probably helps you mentally not physically.” (Melinda1, lines 96-103) Melinda said she

also played board games and played with dolls when it was rainy or otherwise not good to play outdoors, she also remembers hanging out with family and acting. Melinda said she also played board games and played with dolls when it was rainy or otherwise not good to play outdoors, she also remembers hanging out with family and acting.

d. Games and Social Behavior

Melinda remembers playing some non-video games with her cousins. She said: "me and my cousins would always play hide-n-seek and tag and run around outside because it was fun hanging out with all of your friends. You didn't get yelled at for being too loud with your friends inside." (Melinda1, lines 37-39) She plays sports video games with her cousins. It appears that Melinda has had a great deal of social interaction with her family and friends playing both video games and non video games.

e. Video Games-Labs Synergy

There is a connection between virtual lab and video game. Melinda thinks that many things can be carried out in a video game or in a virtual lab that may not otherwise be possible in the real world such as the ability to manipulate conditions like speed up and slow down time. However, the only benefit from playing video games that relates to performing virtual labs is familiarity with the technology, otherwise there is no benefit. Doing a virtual lab felt to Melinda as a similar experience to playing a video game.

2. RQ #2 - What are the students' prior experiences with science labs?

a. Experiences in Science Classes

When talking about her experiences in science classes, she had little to say about her elementary school years. There were no labs in elementary school; all she remembers

is burying a leaf to observe for decay. Most of her science experiences in elementary school consisted of looking at pictures mostly of the solar system. She said "it was kind of boring. After a while I was like I know this, can we move on to something new? (Melinda1, lines 130-131)

Middle school was a little better than elementary school because they watched videos, which she felt was an improvement over looking at pictures, they were more "entertaining." (Melinda1, line 135) There were some teacher demonstrations. In her opinion, instruction could be improved probably by, at least, building models because it would help the students to see better what the content was about. There were a few labs in eighth grade but not much improvement over elementary school. Science consisted mostly of lectures.

She finds high school science much more interesting. There are a lot more labs and hands on activities. She explained "High school is a lot more fun because we get to do a lot more labs and more hands on." (Melinda1, lines 152-153) She says that it is easier to retain the material being taught when you do it yourself and see it firsthand. This approach would definitely improve science in middle school, also.

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

Even though, she feels strongly about labs being important in science learning, Melinda believes that it is imperative to be constantly aware of what is going on in a traditional lab because mistakes can have harmful consequences. There could also be major consequences of not following directions exactly in a traditional lab. In spite of

these drawbacks, traditional labs also have benefits. The most important benefit is that they are hands-on and she believes that hands-on activities are better in helping students learn science concepts. There is a higher level of error in traditional labs because there are many variables that cannot be controlled especially in a high school setting. This unpredictability is seen by Melinda as a positive characteristic of traditional labs because it is real life.

b. Virtual Labs

In her opinion there are not many drawbacks to virtual labs. The main disadvantage is that they are not hand-son. The students cannot physically touch the materials they are working with. That having been said, she sees benefits of virtual labs. She said: “the benefits of the virtual lab, it’s less likely for you to screw up and you’re still able to do the lab and also it’s less expensive than the traditional one because if you screw up you can click refresh and it fixes it for you.” (Melinda2, lines 125-127); she believes virtual labs are faster and more accurate. “The virtual lab kind of kept my interest because it didn’t take as long, everything that happened, if I got lost for one second I didn’t screw up the whole thing.” (Melinda2, lines 111-112) She believed that since virtual labs are better able to keep the students’ interest, they are better able to learn. Virtual labs can also be easily restarted if a mistake is made. Additionally, mistakes in a virtual lab cannot cause harm. Virtual labs are good substitutes for traditional labs because students can get all the knowledge from a virtual lab that they would get from a traditional lab. She explained: “You will still be able to do the experiment to see how it’s supposed to go even though you cannot do it hands on. Just seeing that helps you to

visualize it better." (Melinda2, lines 152-154) A virtual lab is still a good experience even if it is a simulation.

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

It is a good idea to do both the virtual and traditional versions of the same lab. Doing both can help students improve and also allows them to compare results. She thinks the virtual lab should be done first; this way the students can see how it should be done and are better able to perform the traditional lab. The virtual lab provides a good model to go by. She said "do the virtual one first because then the students can see how you do it and then re-create it themselves in a way." (Melinda2, lines 144-145)

5. Connections between themes

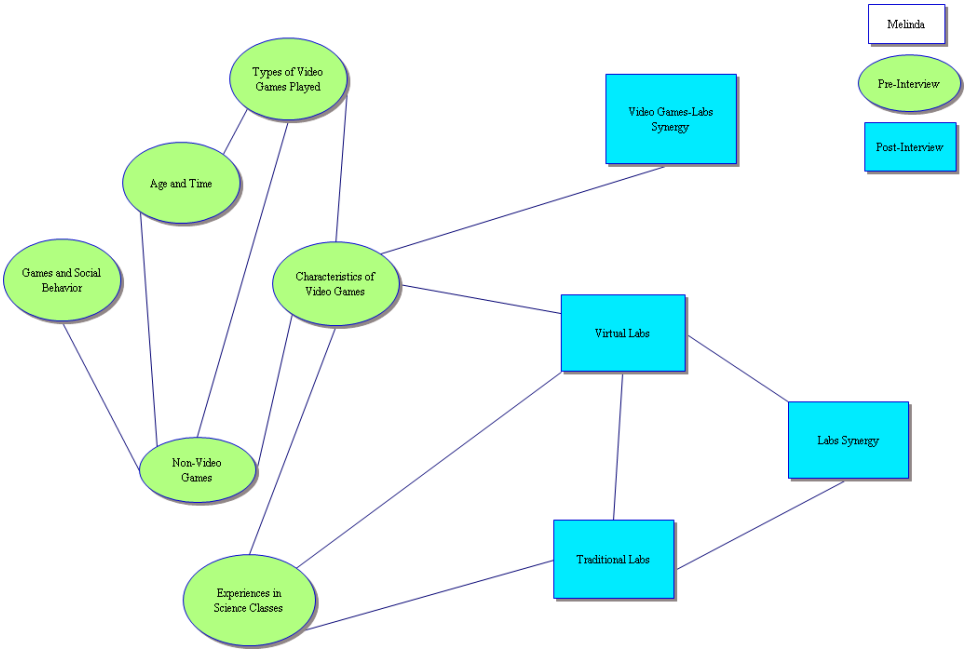

Figure 10 – Melinda themes and connections

A connection exists between the themes Types of Video Games Played, Age and Time, Non-Video Games, and Characteristics of Video Games (See Figure 10, above). Melinda has played video games but not as much as most of the other students; however, she seems very familiar with video games and has played enough to feel comfortable talking about video games. Video games are not very important to Melinda; therefore she prefers those games that are easy to play and require very little attention. While she has played sports video games, she believes that playing the real sport is much better. Most of the games she has played are educational games that she feels are a better alternative to doing other educational activities such as listening to a lecture or taking notes.

Another set of connections exists between the theme Characteristics of Video Games and the themes of Non-video Games, Experiences in Science Classes, Virtual

Labs, and Video Games-Lab Synergy. Melinda feels that students learn better in science classes when they perform hands-on activities such as traditional labs. She also believes that non-video games are better because the person is actually, physically performing something and feeling what they are doing. Furthermore, she feels there is not much that can be translated from a video game to performance of a virtual lab other than familiarity with the equipment.

One more set of connections exists between the themes of Traditional Labs, Virtual Labs, Experiences in Science Classes, and Labs Synergy. It is clear that she believes labs are important for understanding science concepts. Traditional labs are superior to virtual labs because of the hands-on aspect. However, virtual labs are close enough to provide a good substitute for a traditional lab because they are very similar and able to teach the concepts. Additionally, Melinda feels that there is synergy in performing both types of labs because they complement each other. If possible to perform both, it would be better to do the virtual lab first in order to learn the procedure because it is easier to perform and also cheaper and less time consuming. Doing a virtual lab first could contribute to a much better experience when doing the traditional lab.

K. Pamela

Pamela was one of those students who appear to have it all. She was very intelligent but she did not rely on her intelligence alone; she was very driven to earn good grades, therefore, she worked very hard and always prepared for any evaluation. Pamela has a beautiful personality; she is very friendly and outgoing and also very likeable. In addition to her dedication to academic performance, she was involved in sports and in a variety of clubs which required her to have a very active social life which included doing

community service activities. Pamela's overall grade in Chemistry was a 97 with a test average of 93. On the evaluation portion of the interview she performed well; she had an overall score of 84 which included 65 in calculations questions. She expressed interest in a science-related career, possibly medicine.

1. *RQ#1 - What are the students' prior experiences with computer and video games?*

a. Characteristics of Video Games

Games, video, sports, or board games, have been a part of Pamela's life. She sees them as vehicles for learning, development, and in providing valued social interactions. She believes that whether in a science class or playing a sport, doing an activity helps the students learn compared to reading about it.

b. Age and Time

Pamela remembers playing video games as far back as she can remember which she thinks was around second grade. She said she played video games all the time, whenever there was any free time either at home or at school. She said she played video games three times a week in elementary school; she didn't say how long per session only that she played three times per week. As she transitioned from elementary to middle school, while she still played video games such as Dance Revolution, she played much less time because she was more focused in school and therefore had less time for video games. This trend has continued into high school.

c. Types of Video Games Played

Pamela enjoyed playing educational games in elementary school when she was in third grade because she knew she was playing the same games her sixth grade sister played; therefore, she felt smart. Some of the games she remembers playing over time are Sonic PlayStation, Dance Revolution, Rock Band Guitar Hero, Call of Duty and Oregon Trail. Now that she is in high school, there are "cooler games I think, because now they have that Rock Band and that's pretty cool just because you're with all of your friends and whenever I go to my friend's house, we always play it just because it's really cool to be with them and have fun and I'm not really good at it but it's cool. The Guitar Hero, once I went to my cousin's house and played it for the first time and it's really addicting because once you start playing you just want to keep getting better. I think they've just come out with a lot more choices." (Pamela1, lines 85-91) Pamela believes that these games can be addicting and make the player want to get better.

She finds educational games and computer games more entertaining than just killing type video games. She feels that she has always been mature for her age and that is why she prefers thinking type games. Pamela likes working with numbers. Even though she played a lot of video games, she said she preferred family games just because interacting with my family and playing the same games as my sister who is older than me played, I thought that was cool." (Pamela1, lines 50-52); one such game was Monopoly.

d. Virtual (Simulation) Games

She believes video sports games are pretty realistic and are good simulations of what happens in real life and while they are not a perfect substitute, they can help a person with sharpening sports skills and learn to play the sport.

e. Non-Video Games

She has played sports since she was five years old. Sports are very time consuming. She has played softball and swam competitively. Now, I do track and I still do softball and it's really fun to just be with a team and accomplish something and you're getting physical activity and you're being healthy and you're having fun at the same time. I guess I just know that it's better for you. I like it better." (Pamela1, lines 109-113) She no longer plays family games much because the family members have different schedules and are not often together.

f. Games and Social Behavior

Even though she played video games a great deal, she said she preferred family games, such as Monopoly because of the social interaction with other family members. In her opinion, sports not only provide social contact, they also help in being healthy while having fun at the same time. Being a more social person as she grows older, she likes sports and other outdoor activities because of their social aspect. Pamela explained: "I think I like the outdoor games better just because it's more of a social environment, like with the video games compared with the single ones.

g. Video Games-Labs Synergy

There is a connection between virtual labs and video games, in that, students are trying to solve problems on both. A computer screen is used in both and some of the skills translate from video games to virtual labs. She said: "I do see a connection [between video games and virtual labs] because they are both like, you're both looking at pictures and you're trying to do things, like if it's winning a game or whatever, or if you're trying to solve a problem on a lab, you still have to focus on a computer screen of

a game screen or whatever, and you have to, I don't know, it's just more like you're hands aren't really connecting with your brain because you're hands are clicking or controlling and it's the same thing, I guess, like the video games and the labs, the virtual lab." (Pamela2, lines 234-240) Other than clicking the mouse and having some familiarity with the equipment, having experience with video games is not really much of an advantage when performing a virtual lab; it only takes a little practice to get the mechanics of the virtual lab.

2. *RQ #2 - What are the students' prior experiences with science labs?*

a. Experiences in Science Classes

In elementary school, she remembers watching videos that explained science content and doing labs. She says that these hands-on activities were engaging and helped her learn the material. Hands on activities resemble real life. Whether in a science class or playing a sport, doing it helps you learn compared to reading about it. In middle school, while she remembers doing experiments, she remembers more book work. She didn't like middle school science as well. She explained that they "did a lot of text work, which I really didn't like." (Pamela1, line 154) She said that doing experiments helps students visualize the concepts they are learning. It helps to understand what scientists did throughout the years. She believes that following the steps while performing an experiment helps the students learn science concepts because it helps understand the process and know why things are happening. She believes that science instruction in elementary and middle school can be improved through doing more science and more labs. It is beneficial to actually do things. Doing labs in school is a social activity. You have to learn to depend on both, other people and your own knowledge. You have to

know what you are doing in order to carry out an experiment. Doing labs in school is a social activity. She explained: "I'm more of a social person and I guess in a lab setting, you have to be social and you have to depend on other people and you have to depend on your knowledge to actually conduct the experiment so it takes more education to do that." (Pamela1, lines 193-196)

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

Pamela believes that traditional labs are superior to virtual labs as a learning tool because they are hands-on. You learn more because you understand the process. She said: "I think the virtual labs are cool but I actually like doing the traditional labs better because you learn more because it's actually hands on. So instead of just clicking "I want twenty milliliters of HCl," you actually have to measure it so you understand it more and you understand the processed." (Pamela2, lines 143-146) Traditional labs are a little more difficult because equipment and chemicals have to be gathered before the lab can be started. You actually have to do it, the experiment isn't going to do itself, so you can't just sit back and let your partner do it. You actually have to be engaged and be pouring, or stirring, or mixing, or whatever. So I think that that one shows…You have to be more cautious so it helps you concentrate more." (Matini2, lines 171-178)

Traditional labs are more of a group effort and use the strengths of each of the group members. They, also, require the students to be focused on what they are doing. Traditional labs have the disadvantage of not knowing what is going to happen. Another

disadvantage of traditional labs is that they require more time and time is usually short in high school classes because they are only approximately fifty minutes long.

b. Virtual Labs

Pamela believes that one of the advantages of virtual labs is that they are not messy, there are no chemicals and there is no glassware to clean up. Also, virtual labs allow students to experiment more and try things they would not normally try. "You don't actually have to worry about ruining equipment and stuff because we had some beakers and things break just because of some different experiments and so you don't actually have to worry about the cost and stuff of the beakers and chemicals. You don't have to worry about the hazardous chemicals or anything." (Pamela2, lines 165-169)

There are, however, some disadvantages with virtual labs. One of those disadvantages is that the students can become bored sitting in front of a computer screen. Another disadvantage can be that if there are hardware or software problems it becomes a bad experience. Also, unless there are enough computers available so there are no more than two students per station, it is hard to see the results of the virtual lab because of the physical size of the computer screen. Another disadvantage is that only one person has control of the mouse at any given time. Nevertheless, Pamela liked virtual labs, especially, that she did not have to get messy. She felt that the directions were good for both the virtual and traditional labs so they were actually about the same difficulty. She believes that virtual labs are good substitutes for traditional labs as long as each student has their own computer.

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

One of the benefits of doing both virtual and traditional labs is that not all students learn the same way and each format may be more helpful to different types of learners. It makes it possible for all students to learn at their pace. The virtual lab is easier to do so all the bugs can be worked out of the procedure doing the virtual lab, then it is easier to do the traditional lab later. The virtual lab is easier and faster so learning from it makes it easier to do the traditional lab. She explained: "I think that I would do the virtual and then the traditional like we've done because the virtual is more like a taste of what we are going to do or a preview. You know what you have to do on the computer so it's easier to perform just like, if you know that something's not going to work out, like, oh, if I put this in, I can just change it. But if you actually do it in the lab, you have to rinse and just get different beakers and stuff so it's easier getting all the flaws and stuff out of the experiment first and then just being able to perform it efficiently in the traditional lab." (Pamela2, lines 200-206)

5. Connections between themes

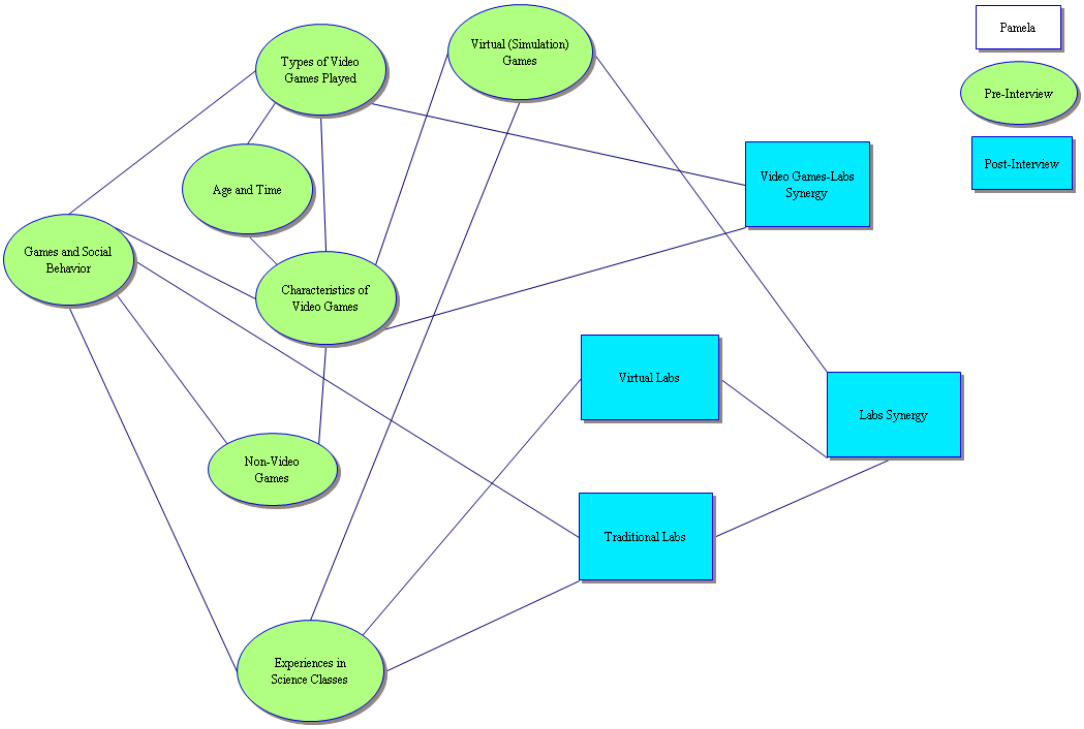

Figure 11 – Pamela themes and connections

Connections were found between the Characteristics of Video Games theme and the themes of Non-Video Games, Types of Video Games Played, Age and Time, Virtual (Simulation) Games, Games and Social Behavior, and Video Games-Lab Synergy (See Figure 11, above). Pamela has never really liked killing-type games and as she has grown she has gone from liking educational games to liking more social games, such as Guitar Hero and other games that lend themselves to playing in a group. Over the years, she has preferred family-type games, such as Monopoly, over any other games. Whether these games are video games or board games is not important. What is important is that they provide a social activity with family and/or friends. She felt that the realism of virtual

games and labs makes them useful in learning either how to play a sport or how to perform a lab.

Another important set of connections discovered through Pamela's interviews are the connections between the themes of Games and Social Behavior, Experiences in Science Classes, Traditional Labs, Virtual Labs, and Labs Synergy. Pamela explained that hands-on lab experiences are important in learning science concepts and therefore should be a major component of science classes. She believed that labs are a social activity which keeps students like her interested. Traditional labs may be superior to virtual labs; however, both provide a social activity. Combining both types of lab is beneficial because students learn differently and, also, because virtual labs may provide a good preparation for doing a traditional lab by familiarizing students with the procedure.

L. Steve

Steve is quiet and reserved. He is also very intelligent. Steve is very interested in performing his best in academic endeavors. He does not rely solely on his intelligence; he works very hard. Steve, while quiet, he is willing to help those students around him who struggle. He is modest and unassuming. He performs at very high levels but does not expect praise and recognition for his performance; he is confident and does not try to impress the people around him; he is happy knowing he is doing his best. Steve's overall grade in chemistry was a ninety nine, with a test average of ninety eight. In the evaluation section of the interview, he scored very high; his overall score was ninety five with ninety five percent on both lab procedure and calculations questions. Steve does not only perform at very high levels in math and science, he performs at these levels across the academic spectrum. He is interested in a computer programming career.

1. *RQ#1 - What are the students' prior experiences with computer and video games?*

a. Characteristics of Video Games

Steve has always liked playing video games. He is very knowledgeable about video games. Steve said "I know a lot about video games, which I think I do." (Steve1, line 5) He knows a lot about video games because he likes them and plays a lot. He talked about the sense of accomplishment he feels when he beats a video game. He just enjoys the games, no particular reason why, they just keep him having fun. He even liked educational games that taught different subjects. He liked playing educational games because they were games so they were fun, and his parents didn't restrict the time because they were educational. He spoke of games that took a very long time to beat as being good. Some of these games may take the player years to beat but the challenge and the sense of accomplishment when they finally beat the game keeps them interested.

Video games are fun. He referred to them as not being work. He said his parents couldn't get him away from the video games so he spent as many hours as he could play them. He added that he liked them as well as "watching TV. TV is great. You are watching TV and playing video games. I just loved it. You practically couldn't get me off it." (Steve1, lines 34-35) He feels that time spent on video games has resulted in better grades because he makes sure the homework is done first, which led to approval from parents.

Plus there was so much stuff you could do with just one game. Well, you play the game and maybe you didn't beat everything but due to the processing of the old games you had to start over. Well, this time you know where everything is but you have to find out all the secrets and stuff. When you find all the secrets you get a special thing and then

you beat the game again you feel such an accomplishment. That takes a long time. It takes a long time. Like this game I am playing now. I got this game maybe four years ago and I beat it two weeks ago." (Steve1, lines 22-31)

b. Age and Time

Steve started to play at age five or younger. As a young child, he played using a hand-held game. At middle school age, he played more games. He would do homework at school in order to be able to spend more time on video games at home. He played the same type of games as in elementary school, just more time. Steve said his parents could not get him away from the video games so he spent as many hours playing as he liked. He liked them as well as watching TV. He spoke of games that took a very long time to beat as being good.

c. Types of Video Games Played

Steve has played many different games such as Sega Genesis, Sonic II, Play Station, Play Station II, Game Cube, Nintendo II, Game Boy, PSII, X Box and WII. He said that educational games were useful in teaching different subjects. He liked playing educational games because they were games so they were fun and, additionally, parents did not restrict the time because they were educational. In high school, Steve likes to play character games. These games are platform games where the player assumes the identity of a character which performs prescribed tasks characteristic to the game as it moves from level to level.

d. Virtual (Simulation) Games

He said he never played sports games, but he does like virtual reality games. In these games the players move their bodies as if they were really playing the sport, therefore, it is a good source of exercise. These games are cheaper and smaller and provide a family activity. They provide a sense of doing something. The player can do a variety of activities from driving to bowling to tennis, and boxing. The virtual reality action games are not a perfect correlation to the real activity but they are relatively close.

He explained: "what really interested me is the fact that it was a game. It didn't happen in the real world but you could play it on your TV and it was right there.

e. Non-Video Games

Steve admitted that he has spent very little time on outside or board games. He played some basketball but soon got tired of it. He also played some board games with his younger brother but only a little. He said: "I played basketball for a while and then I got tired of it. We played board games from time to time. I played with my brother." (Steve1, lines 57-58)

f. Video Games-Labs Synergy

Furthermore, Steve thought that video games help perform virtual labs because the only difference between a video game and a virtual lab is the objective, virtual games are for fun and virtual labs for learning. They are very similar because they both use computer technology, so knowledge from one would help you with the other, especially computer based video games. Another similarity is that both, video games and virtual labs, can be restarted when mistakes are made. Steve explained: "That's how it pretty much compares to a game, the only difference is that with a game you're playing a game

but with this you're not so much playing. I'd say a lot of people had fun with it but when it comes down to it, it's more work oriented." (Steve2, lines 150-152)

2. *RQ #2 - What are the students' prior experiences with science labs?*

a. Experiences in Science Classes

When discussing his experience in science classes, Steve feels that demonstrations are good for elementary science. Teacher demonstrations and experiencing as much as possible followed by teacher's questions would get children interested in science. If it can be applied and the kids have fun with it, they will remember it. He did not remember much from science class in elementary school. However, what he remembered he felt was appropriate. Doing labs in middle school was good. He thinks that it is good to see concepts proven and a lab is a good way to prove science content. Anything that can be proven is good and helps the student remember it. But, he made a distinction saying only fun exciting labs help learn concepts. Labs that are too hard to understand or too complicated are not helpful. Labs need to be simple and exciting in order to help students learn the concepts. Others get so complicated they may cause the students to lose interest. He explained: "labs can help you learn science content but only if the lab is either fun or inspires kind of excitement within the _____. Wanting to do the lab, wanting to see what happens, they are going to do it. If they walk into the lab and they don't even know what they are doing but they are doing something fun, and at the end of the lab they are like, oh, that is what this was. They are going to enjoy it. They are going to remember it." (Steve1, lines 253-257)

3. *RQ #3 - What advantages or disadvantages do students perceive virtual labs and traditional labs have in comparison to each other?*

a. Traditional Labs

Steve had very little to say about traditional labs. He believes that they are better for people who learn best using hands-on activities. He didn't really see any advantages or disadvantages of traditional labs when compared to virtual labs.

b. Virtual Labs

He enjoyed the virtual labs because they were done in a computer, meaning they weren't hard to do and you couldn't really mess up. If you did make a mistake, it was easy to restart. Virtual labs kept his interest because they were computer based. They were also easier because everything was pre-arranged. Steve explained: "if you like computers and you like sitting down and getting something done then the virtual lab is the way to go." (Steve2 lines 126-127) He believes that there were similarities between virtual and traditional labs in that they both take about the same amount of time and both are equally useful in teaching science concepts. He also believes that virtual labs are good substitutes for traditional labs.

4. *RQ #4 - What, if any, synergies do students perceive in performing both virtual labs and traditional labs versus performing one or the other type with respect to learning chemistry content and/or laboratory skills?*

a. Labs Synergy

He thought it would be beneficial to do both the traditional and virtual labs. The virtual lab should be done first since it's easier to perform and restart if necessary. Virtual labs can be useful in learning the procedure before doing the traditional lab.

5. Connections between themes

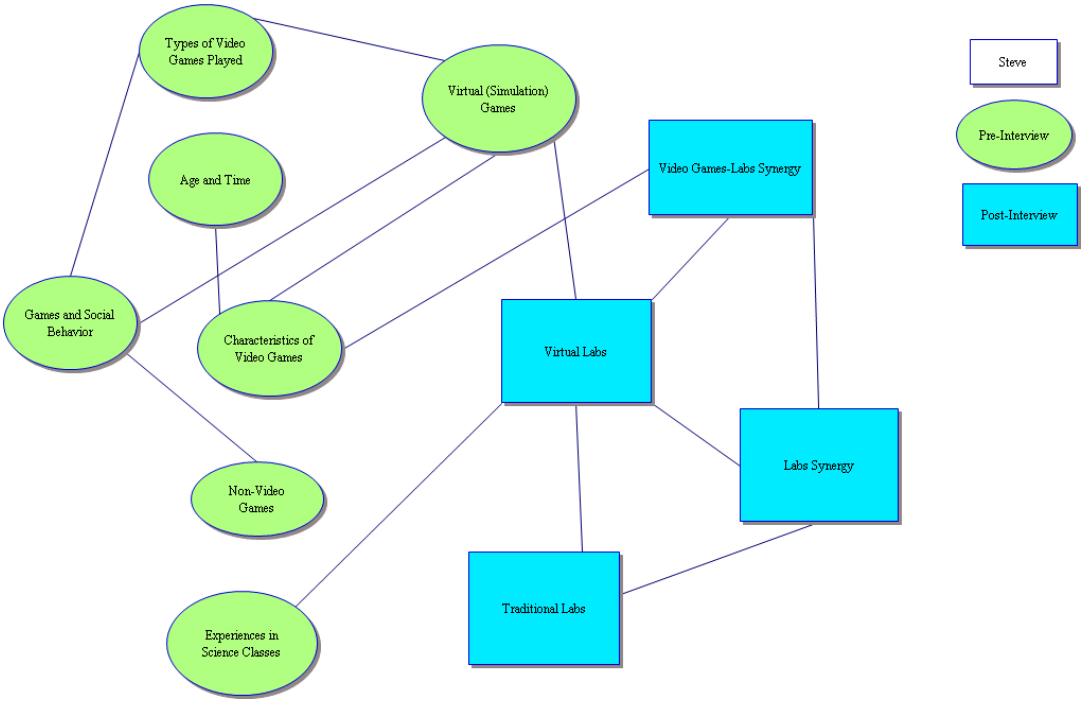

Figure 12 – Steve themes and connections

One set of connections exists in Steve's interviews between the theme of Characteristics of Video Games and the themes of Types of Games Played, Age and Time, Games and Social Behavior, and Virtual (Simulation) Games (See Figure 12, above). Steve is very familiar with video games; he has played video games most of his life and he has played a great deal of time. He prefers platform games where the player assumers a character's identity and performs tasks as the character moves up from level to level. Steve doesn't play video games for social interaction; he only played some non-video games with his younger brother. Additionally, Steve spoke of playing simulation games such as simulation sports games since he never played real sports. Steve is very

comfortable in the realm of video games and is very well versed in any type of video game.

Another set of connections was discovered between the theme of Virtual Labs and the themes of Virtual (Simulation) Games, Traditional Labs, Video Games-Lab Synergy and Labs Synergy. Steve is so comfortable in the virtual arena that he did not have much to say about traditional labs, except to say that he found them to be comparable with virtual labs. He did, however, agree that there is synergy between the traditional labs and the virtual labs if both are performed. The virtual lab is self sufficient in his opinion, but if done in conjunction with a traditional lab, it can serve to familiarize the student with the procedure in such a way that the traditional lab will be easier to perform. He also felt that the virtual lab is easier to perform if the student is familiar with virtual technology from playing virtual games. After all, he feels that the only difference between the game and the lab is the purpose.

Cross-case Analysis

Table 2 – Themes Summary from Cross-case Analysis

	Alice	Barbara	Craig	Daniel	Frank	Haley	Harrison	Josh	Mark	Melinda	Pamela	Steve	Explanation
Characteristics of Video Games	√	√	√		√	√	√	√	√	√	√	√	Addictive, usefulness in teaching and building skills, shiny and flashy, fun, alternate reality
Age and Time	√	√	√	√	√	√	√	√	√	√	√	√	Students' age when they first started playing video games and time spent playing video games at different ages
Types of Video Games Played	√	√	√	√	√	√	√	√	√	√	√	√	Education versus entertainment, computer –based versus console-based. Sports, action/adventure, role-playing, and war/shooting.
Non Video Games	√	√	√	√	√	√	√	√	√	√	√	√	Non-electronic assisted games, indoors versus outdoor games, sports versus non-organized play such as hike-and-seek and red rover, board games and unstructured play such as dolls, and army.
Games and Social Behavior	√	√		√		√	√		√	√	√		Playing games with the intention of having social interaction, family and friends. Social interaction is more important than the game being played.
Experiences in Science Classes	√	√	√	√	√	√	√	√	√	√	√	√	Types of activities experienced in science classes including lab and other hands-on activities and the students' opinion of those activities especially as it relates to learning scientific concepts.
Virtual (Simulation) Games			√	√	√			√	√		√	√	Video games that simulate an alternate world, sometimes similar to the real world and other times, very far removed from reality, where students are capable of performing tasks not otherwise possible.
Traditional Labs	√	√	√	√	√	√	√	√	√	√	√	√	Any labs, or other hands-on activities, carried out in a science classroom; students handle physical objects. The hands-on aspect is their defining characteristic. Advantages and disadvantages
Virtual Labs	√	√	√	√	√	√	√	√	√	√	√	√	Computer-assisted activities carried out in science classroom that simulate physical lab activities. Advantages and disadvantages.
Labs Synergy	√	√	√	√	√	√	√	√	√	√	√	√	Synergies mostly related to the procedural aspect of the activities. Most students found advantages in performing both types of activities.
Video Games Labs Synergy	√	√		√	√	√	√	√	√	√	√	√	Whether skills attained from experiences playing video games translate to skills necessary in performing virtual labs.
Labs are a Waste of Time	√												She believes they are a waste of time in her personal experience but admits that the lab experience may be helpful to other students in learning scientific concepts.
Class Grade (%)	97	78	94	92	88	91	78	80	62	90	97	99	
Class Test Average (%)	92	66	89	83	85	82	68	72	61	86	93	98	
Overall Interview Assessment	57	52	86	60	85	59	70	75	73	77	84	95	
Proceess Questions	75	77	97	77	95	78	90	100	97	95	97	95	
Calculations Questions	30	15	70	35	70	30	40	38	38	50	65	95	

There were several similarities as well as several differences across the twelve students with respect to their experiences with video games (See Table 2, above). With respect to their ages when they first remember playing video games all students recall playing video games as young as elementary school age or younger. Some of the students said they have been playing video games "as far back as they can remember." (Daniel1,

lines 4-5). He says “As far back as I can remember, I guess like, I’ve always been around them and they, I mean, its part of my growing up.” Josh made a similar remark. Others, recall playing video games since age three but all remember playing video games as young as age ten or younger. Four of the students, Mark, Daniel, Harrison and Steve mentioned that they spend as much or more time playing video games in high school as they did in the younger years. These four students have a much greater interested in video games and their playing has evolved such as Harrison who said “in high school I started getting really into the hard core stuff.” (Harrison1, line 98). Steve said that “the reason I would do it (homework) at school is so I could have more time to play at home. That has been my work ethic” (Steve1, lines 77-79). The rest of the students explained that the time spent on playing video games has decreased with time since middle school, mostly because they have much less available time to play for many different reasons. “Definitely [play] less because I would actually have to do work to get an A, kind of but not really. You have less time. As you get older you get into more like other things.” (Alice1, lines 48-49) Pamela said that her reason was that she “was just more focused on school” (Pamela1, lines 59-60). Two of the students, Frank and Craig, have stopped playing video games as they moved from middle to high school. “When high school came along I got a job working at Grace Fellowship Church doing stuff so at that point I had really no time because between homework and work I just couldn’t really do much because I want to hang out with my friends and stuff so I don’t play video games.” (Frank1, lines 83-86) Craig says that video games “are not useful to me any more” (Craig1, lines 105-106).

While all the students started playing video games at a very early age, as they have grown up, the interest in video games has changed dramatically from those that have greatly increased their involvement with video games to those on the other end of the spectrum who have completely stopped playing.

There is a great deal of diversity in the types of video games enjoyed by each of the subjects. They range from educational games, to role-playing games, to war and shooting games, to sports games. The types of games played in many cases changed as the students grew up. In many cases, it appears as if they played more educational games as younger children as their parents chose the games purchased. As they grew older, they started choosing different types of games but mostly for entertainment. Some students, such as Steve never play sports games and some, like Daniel, like playing sports video games. However, in all cases they seemed to agree that if a person was to play a sport, the actual sport was always preferred over the video version of the sport. Alice said "Sports video games are so fake. If you want to play the sport just go out there and play it yourself." (Alice1, lines 61-62) "I think the real thing is more fun because you are really doing it but on the computer you can have professionals doing it how you think it should be done, compared to you really do it and it also keeps you playing even if you can't play outside." (Melinda1, lines 96-98) Some students mentioned the fact that virtual reality allows a person to things they may not otherwise be able to do because it is extremely dangerous, illegal or morally unethical. Mark expresses this idea very clearly, "In real life if you die you are gone. It is over. In real life you can't go just out and kill somebody and steal their car and completely lose a police raiding and you are free forever. You know, they are going to chase you down, they are going to catch you and they are going to put

you in jail. So it is a lot freer and funnier in games because you can do stuff that you are not allowed to do…. like you can go in and steal a car right off the lot and run over 20 people as you are pulling out and you get one start, then you run over this little patch and the star goes away, so you have nothing, no police record or anybody after you. In real life if you steal a car you are going to jail for a long time. It is just being able to do stuff that nobody will let you do." (Mark1, lines 187-193) On a related idea, Barbara said that "I think I like all the colorful things that happen and when you get items you can put them in your house and they always have a function or something like a bird will chirp and shooting games are always dark and you're killing things. I don't know. Role playing are always happier…. it takes you away from real life I guess." (Barbara1, lines 104-110)

Several of the students spoke about the social aspect of video games. Pamela mentioned the social aspect of playing games both video and non-video games as well as sports. She has always preferred the games that bring her more social interactions. This social aspect of games has become more and more important as she grows older. She said she preferred "the family games just because interacting with my family and playing the same games as my sister who is older than me played, I thought that was cool." (Pamela1, lines 50-52) She said "I guess sitting by myself playing Sims is not what I like to do now because I'm more social in high school and I want to be with people … I think I like the outdoor games better just because it's more of a social environment" (Pamela1, lines 94-95, 109-110) Daniel also mentioned his father and brother as well as his friends whether playing video or non-video games or sports. He said "sometimes when my friends come over, when they sleep over and its night time, we play that for like five hours." (Daniel1, lines 75-76) Another student that brought up the social issue was Alice,

she said: “I like the classic characters like Super Smash Brothers which is like a fighting game. It is really involved. They are pretty good. They get boring after a while you know. I like the ones that you can play with other people.” (Alice1, lines 56-58) Other students that mentioned their family and friends were Harrison, Barbara, Haley and Melinda. There appeared to be very little correlation between the participants’ experiences with video games and their perceptions of virtual or traditional labs. Several students mentioned that the relationship between video games in virtual labs was limited to the familiarity with the use of technology such as a mouse and a keyboard.

A trend that is very evident across all the students is that most of them either did not remember doing any science in elementary school, or just remember very little and what they remembered was boring, such as looking at pictures or videos, no labs, except for very few in the fifth grade. Only Pamela remembers doing hands on science activities, which she said helped her remember the material. She said: “I remember a lot of the hands on activities…. they actually get you to understand it without just reading the text and they really install it in your memory and because it’s more real life.” (Pamela1, lines 144-147) Even though students are several years removed from elementary school, this trend is disturbing. Barbara didn’t “remember doing science in elementary school. I remember making bubbles a lot. I guess that helped to entertain us.” (Barbara1, lines 124-125) To Frank, “Elementary school was pretty lame in terms of science.” (Frank1, line 147) Harrison said he remembered “that we dissected the owl pellets in 5th grade which I thought was really fun…. Because it is just like—you don’t – we found little ____ skeletons, stuff you don’t usually see. You only seen them in pictures. Stuff that is more interesting to see it up close, like, in some ways like get dirty and use your hands for

stuff. " (Harrison1, lines 223-228) All the students reported a more positive experience in science class in middle school, some a little more positive while about half reported much better experiences in middle school science. "In middle school we started to do some more dissections…. our labs they were a lot more sophisticated and you had to be a lot more responsible to do a lab in middle school" (Mark1, lines 287-291) According to Daniel "in seventh grade it was fun because it was biology [and] we did a lot of labs. We dissected worms and toward the end we would dissect a squid and that was fun. It was a lot of hands-on stuff." (Daniel1, lines 121-124) High school science was by far the most positive science experience for all the students. Melinda really sums it up well; she said "High school is a lot more fun because we get to do a lot more labs and more hands on, where in middle school and elementary school is more of the teacher doing it. Now the teachers let us take it into our own hands and be like don't screw up.

I like doing more hands on things and it's just more hands on where it's more like just me doing it, not someone else showing me. I learn better that way… it's more fun and you remember it better." (Melinda1, lines 152-161) Daniel said: "I think it [high school science]s fun because we do a lot of labs and we are allowed to do stuff that we weren't allowed to do like handling beakers and chemicals you can't really trust that with little kids. It's fun because we do a lot of labs and last year we did a lot of labs like dissecting a pig and stuff like that which helped it show, basically, it put all we had learned that year into practice. It was a good example of that. I think high school is probably tougher in the stuff that we're learning, but it's easier than in eighth grade because of the way that it's given to us." (Daniel1, lines 141-147)

Throughout the interviews about their experiences in science classes throughout the years, it is evident that these students feel that hands-on lab activities are very beneficial to learning science and the presence or absence of lab activities seems to be the defining component of a good and productive experience in science classes. The different experiences in science classes in elementary and middle school did not appear to influence students' perceptions of virtual labs or traditional labs. All students had less than ideal science class experiences in elementary and middle school. There was no difference in the perceptions of virtual and traditional labs between the students that had the better experiences and those who had the worse experiences.

It was clear across all the interviews that students thought that one of the benefits of traditional labs was that they offered a hands-on experience in science. Pamela said that "traditional labs are more beneficial because you actually have to do it, the experiment isn't going to do itself, so you can't just sit back and let your partner do it. You actually have to be engaged and be pouring, or stirring, or mixing, or whatever…. you have to be more cautious so it helps you concentrate more." (Pamela2, lines 170-178) Melinda said that she "learned the most from the traditional [lab] because it is more hands on and you see it better." (Melinda2, lines 116-120) Further Josh was "more interested in the real one because I remember it better if I am actually physically doing something." (Josh2, lines 94-95) These comments are representative of the feelings of all participants. Students also explained that while traditional labs were good because they were hands-on, they had some drawbacks. Several students stated that one of these drawbacks was the hazards involved in dealing with chemicals. Craig said that you "probably won't be able to do labs dealing with extremely toxic substances and things

requiring extremely expensive equipment and that sort of thing." (Craig2, lines 161-163) and Mark explained that "there could be some major consequences for not following directions in traditional labs where as the virtual labs you don't follow directions, you just restart and keep going." (Mark2, lines 143-145) Another major negative of traditional labs raised by most students was the time needed to set up, perform and clean up, especially if a mistake was made that required the lab to be redone. Sometimes, they require multiple days to perform. Josh stated that "you can't really mess up and just restart [traditional labs]" (Josh2, lines 132-133) "The big [drawback] on traditional lab is clean up and the fact that a lot of time you do have to go through -- you do have to put on goggles and there is potential for things to spill. There are things that could go wrong. There is definitely external factors that could inhibit what is going on. Just changing temperature in the classroom could affect it." (Frank2, lines 147-151) Additionally, Harrison also spoke about the drawbacks of traditional labs "If you mess up it is probably going to screw you over…if you have three days to do a lab because it takes three days to do the whole transition and stuff, if you mess something up or it explodes on you half way through the second day, then you can't really start over…also there is more possibility of being hurt in an actual lab." (Harrison2, lines 161-167) The time concern was brought up by most students in addition to some of their other individual concerns such as safety, diminished accuracy, lack of equipment and expense of chemicals and equipment.

Most students thought that virtual labs were not as good as the traditional labs because they lack the hands-on component. However, in the absence of a traditional lab, the virtual lab was a good substitute. They also agreed that virtual technology has become

good enough that it closely resembles real life. She said they were a lot "like a real lab, like the [stock] room, how we had to go get the different salts from this room and that's cool." (Barbara2, lines 80-81) While the virtual labs lacked the hands-on aspect of the traditional labs, most of the students agreed that the virtual labs are very useful because they provide experiences for the students that would not be otherwise possible due to the safety, cost and time associated with certain traditional labs that cannot be performed in a high school environment. Several of the students referred to the time savings associated with virtual labs because they could be restarted very easily. Craig said that "virtual labs are a lot faster. You can get them done a lot faster. I think it is good and bad because you lose a sense of exactly how long the lab would take you lose that sense of fun but when you do a virtual lab you have time to get more labs done." (Craig2, lines 144-148) Daniel thought that the virtual and traditional labs "were pretty much the same, because you learned the same thing from each one because you were doing the same thing, one was on the computer the other wasn't. So it was about the same on that level. But the convenience was a little bit better on the computer because since all the stuff you just had to click and drag it instead of going to get the stuff. When you wanted it to be at a specific temperature, when you put something in the oven instead of having to wait a half and hour for it to heat up, it would be done in a couple of seconds so it reduces the amount of time it takes to heat stuff up and all that." (Daniel2, lines 81-88) He saw a great benefit in the fact that the virtual labs were much less time consuming. Frank "liked the fact it [virtual lab] was a much safer environment that you could blow things up in. It was really more true experimentation because in a school situation you can't really light something on fire and put a bunch of chemicals on it and see what happens where this,

the simulations really did allow for you to see what happens when you put two random things together. It was a more true experimentation that could develop a more true foundation for more real and safer experimentation." (Frank2, lines 101-106) Several students finished doing the lab they were assigned and proceeded to experiment on their own outside of the lab activity because they had extra time and there were not safety concerns with trying something dangerous in a virtual environment such as putting alkali metals in water and watching the virtual laboratory explode on the screen. Most students felt that the virtual labs were difficult at first but once you learned how to navigate the software on the computer, they were very easy. Josh said, "the labs themselves were about the same. But the virtual ones you still how to learn how to use the software itself as far as, there are some limitations like you have to know where to put the things to get them to work. We all had a hard time getting the HCl and the NaOH out of the lab room. And that was difficult just because you didn't know the exact spot to put it in. Once I learned how to do it, it wasn't as difficult." (Josh2, lines 108-114) Most of the students felt that the virtual labs were good substitutes for traditional labs "because it's pretty much the same things except you're not actually doing the hands on experience but it's the same exact directions and stuff." (Haley2, lines 157-158) Steve thought he "learned the same from both of them…. [he] thought they were the same." (Steve2, lines 115-116)

The synergy between virtual and traditional labs was the theme that all students agreed on. All twelve students agreed that it was beneficial to the students to perform both formats of the same lab whenever possible. Barbara said that "it would be beneficial [to do both formats] reinstating what you learned in the other lab. (Barbara2, line 115) Mark said he liked "doing them both because you can see how it is supposed to be [from

the virtual lab] and then you can see how you are doing it and see how you need to improve maybe. It is a pretty good comparison." (Mark2, lines 150-152) All the students agreed that whenever both virtual and traditional labs are performed, the virtual lab should be done first for a variety of different reasons. Harrison mentioned that by doing both you could learn more by "focus[ing] on the best parts of both." Harrison2, line 179) Frank explained that "there is a benefit to doing virtual first and then traditional because virtual – once you have done the traditional… it will not only hammer in the concepts more it will also help you with the directions. Following the direction because if you mess up in the virtual nothing bad is really going to happen. If you mess up in the real world you could waist chemicals or get hurt, you know. So I would definitely say you do the virtual first because that will help you to understand the concepts and then you do the traditional." (Frank2, lines 159-166) According to Craig "doing both you are able to get – if you do the virtual lab first and then you go do the real lab, I think I have a tendency to allow you to be more able to do the real lab because you have a general idea of what is going to happen and what you are doing. It also helps because when you do the real lab after doing the virtual lab you end up getting a lot better data because you know what you are doing and you have less of a tendency of making mistakes." (Craig2, lines 166-171) Also agreeing with the rest of the students, Pamela said: "it is beneficial to do both because different kids have different ways of learning so if maybe someone learns more from looking at the computer and just reading it and watching it, like watching a video or something, I guess then that's better but if someone is more hands on and they have to actually see it and do the experiment to learn then I think that it's good because you give everyone soft of an opportunity to learn at their own pace. I think that I would do the

virtual and then the traditional like we've done because the virtual is more like a taste of what we are going to do or a preview. You know what you have to do on the computer so it's easier to perform just like, if you know that something's not going to work out, like, oh, if I put this in, I can just change it. But if you actually do it in the lab, you have to rinse and just get different beakers and stuff so it's easier getting all the flaws and stuff out of the experiment first and then just being able to perform it efficiently in the traditional lab." (Pamela2, lines 195-206) Daniel sums up the thoughts of all the students when he said that "it would probably be better if you did both because you get the best of both worlds. You get the hands on with the quickness and convenience of the computer one. And plus if you made any mistakes with the traditional one and you got an answer you thought was right and then you went to the virtual and did it, the virtual one would probably be more accurate because of the computer and it doesn't too much room for human error for us to mess up the stuff. I would probably do the virtual one first because that way you have a basis for doing the traditional so it's not like you are blindly going in there and doing the stuff. Even with the instructions you can still mess up. With the virtual one it's better because it will save your time from not having to go back and do it all with the traditional. (Daniel2, lines 114-127)

Students were split in their opinion as to whether having experience with video games influence the students' ability to perform virtual labs. Several of the students said that there is no connection between video games and virtual labs and that having experience with video games does not necessarily help a student in performing a virtual lab. However, those students who expressed that video games would in any way help a student perform a virtual lab said that this was limited to familiarity with use of the

technology and that while this might offer a slight advantage, students without any prior with video games would easily and quickly become familiar with the technology to be able to perform the virtual labs. Steve said: “if you’re more used to computer generated games then you’d be more used to a computer generated lab. (Steve2, lines 155-156) Daniel sees the strongest connection between video games and virtual labs. He said that if “you’ve played the video games you are used to, not the controls, but you kind of have a basis what you are going to be doing. Like if you’ve never played video games in your life and you wanted to do the virtual lab, it would be pretty tough, because even if you’ve used the computer to do work, it would still be tough because it’s so different than basic writing stuff.” (Daniel2, lines 146-150) Harrison said that video games and virtual labs involve “a very different set of ideas. Like in several games you just pick up a gun and shoot. In this you have to click and drag a lot of stuff. Like, there are some games that would support the click and drag things but this virtual lab, it is too specific and meanwhile in a lot of other games there are fewer limitations.” (Harrison2, lines 234-237)

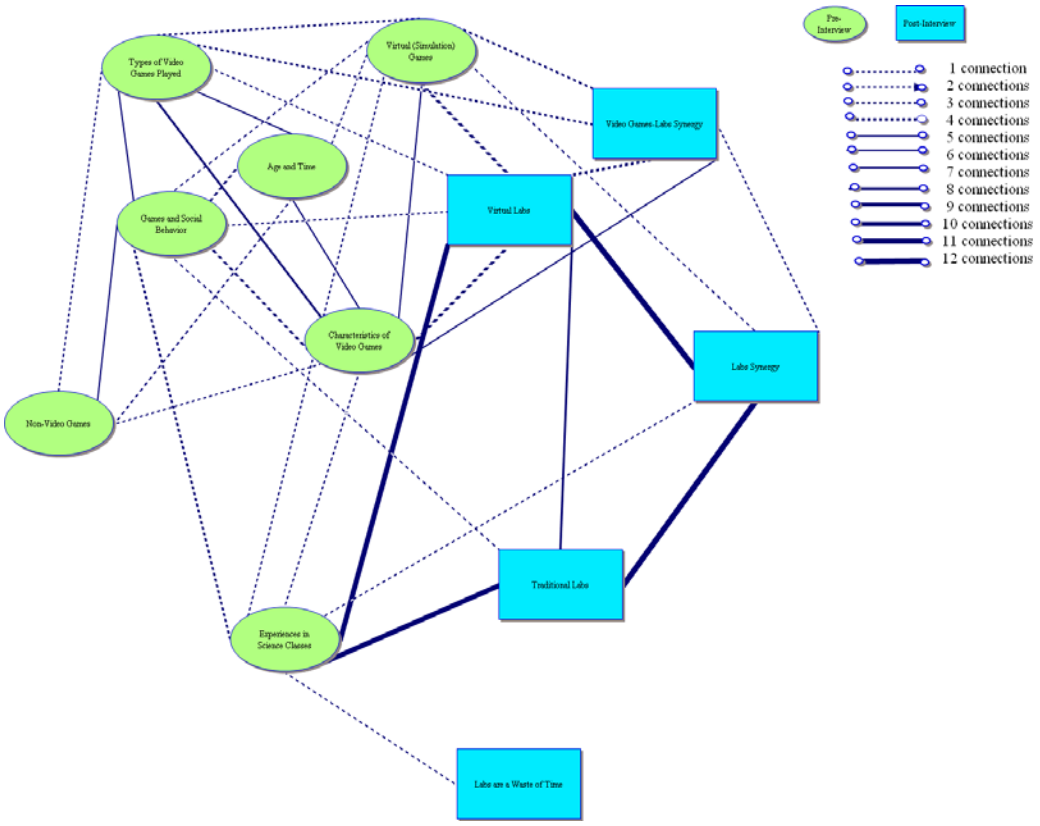

Figure 13 – Connections between all themes

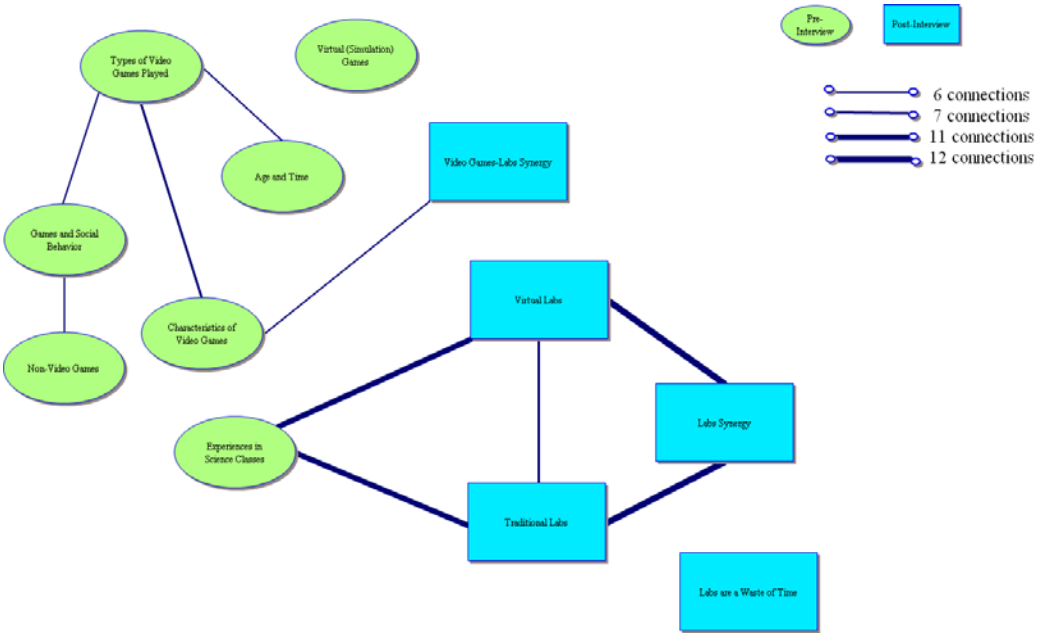

Figure 14 – Major connections between themes

As shown above (Figures 13 and 14), there some connections between themes that appeared in just a few of the interviews. However, there several connections that appeared in at least half of the interviews, with some of these appearing in eleven or twelve of the twelve interviews.

A moderately strong connection exists between the theme Games and Social Behavior with both Types of Video Games Played and Non-Video Games. At least half of the students expressed that part of the reason for playing both video games and non-video games was the social interactions during the games. These students believed that the social interaction was more important than the actual game being played, whether a video or non-video game. An important reason for choosing to play a game was the social interaction brought about by the game. These social interactions sometimes included family members and sometimes friends. As the students grew older, the social interactions with the friends became more important.

Moderately strong interactions also exist between the theme Types of Video Games Played and both Characteristics of Video Games and Age and Time. The types of video games played by the students sometimes changed as the students grew older. Several students played more educational video games at an early age only because they were the types of games their parents chose for them. As they became older and more able to choose the games they played, some switched from educational games to different types of video games such as sports, action/adventure, role-playing, and war/shooting games, depending on the personality of the students and their likes and dislikes. Each of these video games has different characteristics and offer different experiences to the player.

Another moderately strong connection exists between the themes Characteristics of Video Games and Video Games-Labs Synergy. Several students believed that there are enough similarities between the characteristics of video games and virtual labs that experience playing video games would have a positive influence in the students' ability to perform a virtual lab, they believed that a certain amount of synergy existed. In some cases, the synergy was limited to the mechanics of using electronic technology such as operating a mouse or navigating through a video game or a virtual lab.

Another moderately strong connection was found between the themes of Virtual Labs and Traditional Labs. Several students found that the similarities between the traditional and the virtual labs outweighed the differences between them. They especially felt that way in regards to the instructions since they were very similar with the exception that one was performed literally with chemicals and lab equipment and the other was performed in a computer-based platform but yet with chemicals and lab equipment.

The strongest connections were found between the themes of both Virtual Labs and Traditional Labs, each with Experiences in Science Classes and Labs Synergy. Practically all students found some connection between these themes. Students felt that both traditional labs and virtual labs were beneficial in learning science concepts because they were some form of hands-on activity, the traditional lab being more so than the virtual lab. Both of these hands-on activities allowed the students to experience and thus reinforce what they were learning in their science class. They felt that activities beyond lecture and reading assignments contributed to a higher level of learning science concepts. They also felt that the traditional labs and the virtual labs complemented each other. Each has advantages which serve to diminish the disadvantages of the other lab

format. They felt that the enhanced level of learning went beyond the fact that doing both formats means more practice. While most students believed that either the traditional or the virtual can be a worthwhile substitute for the other, doing both would capitalize on their individual strengths for increased learning. For example, the virtual lab was a good choice for learning lab procedure, which contributed to a much better experience when doing a traditional lab. While most students felt that doing the lab in both format whenever possible was more advantageous, they also felt that the most likely sequence was to do the virtual lab first followed by the traditional lab since the virtual lab was easier to start over and students are more likely to make mistakes at the beginning when they are unfamiliar with the lab.

CHAPTER 5

DISCUSSSION

Major Findings

Labs are important in science classes. Experience improves with years because of larger lab component. Most of the students who participated in the study believed that labs are a very important component of any science class. Labs bring scientific concepts to life for the students. Lab experiences convert abstract ideas into more concrete images. The students felt that the weakest science experience was in elementary school because of the lack of lab activities. As they moved into middle schools, the science class experiences improved as the number and quality of labs increased. In high school, the lab is a much more important component of science classes thus creating a much better experience.

Virtual labs are relatively comparable to traditional labs especially in the absence of a traditional lab. The students felt that there was a great deal of similarity between the virtual labs and the traditional labs conducted during the study. The directions were practically the same except that one was conducted with real chemicals and equipment and the other with virtual counterparts on a computer screen. Given the similarity between the two types of labs, students felt that virtual labs could be a good substitute for traditional labs in the absence of an available traditional option.

Traditional labs are best option because of the hands-on component. There are advantages and disadvantages of both virtual and traditional labs. Among the advantages of virtual labs are cost and time savings and lack of safety concerns. Since no chemicals and equipment are necessary, other than computer equipment and software which are reusable, cost is greatly reduced. Time savings result from the ability to restart a lab without need for set up and clean up. In addition, if necessary, time could be sped up in the virtual lab. The most important advantage of traditional labs is the hands-on characteristic. Students felt that the ability for things to go wrong in addition to the safety concerns forced students to pay closer attention when performing traditional labs. They also felt that the fact that the students could see and feel what was happening in the lab helped them to better learn the concepts taught in the traditional labs.

There is synergy between traditional and virtual labs and whenever possible, both enhance learning. Most suggest doing virtual first followed by traditional. Students felt that synergy exists between the traditional and virtual labs. They point out that doing a lab using both formats improves learning more than from merely increased practice. They expressed that the strengths of the traditional labs overcome the weaknesses of the virtual labs and vice versa. For example one of the strengths of virtual labs is the time savings and one of the major drawbacks of traditional labs is the large amount of time necessary to perform some of the labs. Virtual labs can then be used to perfect procedural skills because of the reduced amount of time, which will result in reducing the amount of time spent on the traditional lab thus decreasing one of its weaknesses. Most students thought that whenever possible, it is advantageous to perform both types of labs for any given concept. While they feel that benefits would result from doing them in any order, it

would be better if the virtual version of the lab were performed first. The virtual lab does not require set up or clean up and is easily restarted; therefore, if done first, students could learn the procedure before doing the more time consuming, and more complicated to set up traditional lab. Students can tune their skills with the virtual version of the lab before trying the traditional lab.

Perhaps one of the key findings was the idea that the issue may not be whether virtual or traditional labs are superior but the idea that they complement each other. It should be the goal of the instructor to optimize the use of both virtual and traditional labs to enhance student learning. Since the virtual technology is available, the teacher should become familiar with its use and how to maximize its impact on student learning.

There is only a slight connection between video games and virtual labs in terms of familiarity with electronic equipment. All students had at least a fair amount of experience with video games. While they thought that familiarity with computer technology, such as the use of a mouse or a game controller, would be slightly beneficial to students performing a virtual lab, it was not necessary in order for a student to be able to perform a virtual lab. They felt that there was enough difference in video games and virtual labs that experience with the games would not affect someone's ability in performing a virtual lab.

A Retrospective Look

In retrospect, following are some changes that would improve a similar study in the future. Upon reflection on this study, these changes could possibly lead the researcher to obtain more and better data.

More structured interviews. In an effort to stay as true to a grounded theory methodology, the interviews were not structured. The questions asked were relatively general in order to seek student feedback in certain areas. Follow up probing questions were very limited except where students' comments indicated a need for follow up. In some cases students were not very forthcoming with information; they just simply answered the questions with very few words. I feel that if such students had been probed more actively with follow up more specific questions, their responses would have shed more light on how they felt about the subjects. This should only be used for those students not easily forthcoming.

Written, instead of, verbal assessments, especially with calculations questions. When assessing students' knowledge on the concepts taught in the labs, verbal questions were used in the form of an interview. Most students were able to answer questions regarding lab procedure adequately. However, their ability to answer questions related to the calculations used in the lab was greatly diminished. I think this was a poor method to assess their knowledge of calculation problems because students are used to work problems out using paper and pencil and not answering verbal questions. I believe students would have been much more successful in answering calculations questions if those questions had been given as a written assessment.

Mixed methods. I believe it would be better to establish the students' knowledge of the topics in Chemistry using quantitative methods. Instruments should be developed and tested which can be valid and reliable without interfering with the instructional process. I felt that the number of items needed in an assessment tool to make it valid and reliable was excessive to administer after each lab experience. Such practice would have

been too time consuming and would have reduced the amount of instructional time for the sake of the research. Maybe alternative ways to achieve validity and reliability without compromising instruction could be designed.

Future Research

Study the use of lab in the elementary school or middle school science classroom. It appears from the students' responses that the amount of lab-related activity in elementary school science is minimal at best and just a little better in middle school. It is difficult to determine if the apparent lack of lab activity is the result of the students forgetting over time or not realizing that some activities were age-appropriate labs, where the students are judging them based on the more recent high school lab experiences. It would be useful to study the science class experiences in elementary or middle school by direct observations of those classrooms.

Compare students' performance on lab procedures when doing only traditional labs and only virtual labs. Assessing the students' lab procedure knowledge after performing a virtual lab versus a traditional lab could be accomplished by studying a science classroom over an entire school year. In such a long term study, it would be possible for the teacher to use virtual labs with multiple topics over the course of a year and also multiple traditional labs on other topics. The knowledge could be assessed over a year minimizing the possibility that the differences arose from the topics being easier or more difficult. The teacher could choose to use virtual labs as well as traditional labs for some easy topics and for some more difficult topics. The topics of virtual versus the topics of the traditional labs could alternate in different classes.

Qualitative knowledge assessment. It is difficult to assess knowledge via a lab quiz because a quiz that is valid and reliable would require too many questions. This would essentially mean taking instructional time to administer the quizzes, which is unacceptable. The goal could be accomplished and the time issue avoided by incorporating the lab questions with ongoing chapter or unit testing. If this was done over the course of a school year, it may be possible to obtain valid, reliable quantitative data.

Conclusion

While traditional labs are generally thought to be the better format for lab activities, they are not the only one. Virtual labs offer an alternative to the traditional labs. In many cases, performing some traditional labs in a high school setting is impossible for a myriad of factors. In these cases, a virtual lab provides a plausible alternative which is capable of enhancing student learning. Also, combining the right mixture of virtual and traditional labs may provide the best possible learning environment by combining the strengths of each. Teachers should strive to incorporate any available tools, including virtual technology to provide the best learning environment for all their students.

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APPENDIX A

Interview Questions

First 30-minute interview section

(Use follow up questions and prompts only when necessary to elicit answers)

- Tell me about your experiences with video games or computer games.
    - How early in your life do you remember paying video games?
    - How good are you at video games?
    - How much time do you spend playing video games?
    - What is it about video games that interest you?
    - How do you see the differences between video games and more traditional games including paying activity outdoor games?
- Tell me about your experiences with labs in science classes?
    - Explain how labs are done in your previous experiences.
    - Do you enjoy labs?
    - What is that causes you to enjoy or not enjoy labs?
    - Do you find labs helpful in learning science material?
    - How could labs be improved from what you have experienced in the past?

Second 30-minute interview section

- Tell me about your recent experiences with virtual labs.
    - Did you enjoy them? Explain.
    - How do you compare the virtual lab with the traditional lab in terms of keeping your interest, ease, and amount of learning?
    - What do you perceive the benefits of each to be?
    - What do you perceive the drawbacks to be?
    - Is there any benefit or drawback to conducting both? If so, which should go first and why?

APPENDIX B

Analysis of Evaluation Interview

Freezing point depression lab – 25 points total

Able to explain the procedure without prompting – 15 points max

Including: Measuring initial temperature of the liquid

Adding solid (salt) to the liquid

Measuring final temperature of the liquid

Able to explain procedure with prompting – 12 points max

Able to answer specific questions regarding the procedure when prompting failed – 10 points max

Able to explain calculations without prompting – 10 points max

Including: Temperature change equals concentration times constant

Able to explain calculations with prompting

Able to answer specific questions regarding the calculations when prompting failed

Heat of reaction lab – 25 points total

Able to explain the procedure without prompting – 15 points max

Including: Measuring initial temperature

Adding reactants together (acid and base)

Measuring final temperature of the liquid

Explain acid-base reaction

Reason for insulated cup

Able to explain procedure with prompting

Able to answer specific questions regarding the procedure when prompting failed

Able to explain calculations without prompting – 10 points max

Including: Heat of reaction equals specific heat of water times mass (or volume) times temperature (change).

Exothermic or endothermic?

Able to explain calculations with prompting

Able to answer specific questions regarding the calculations when prompting failed

Calorimetry lab – 25 points total

Able to explain the procedure without prompting – 15 points max

Including: Measuring initial temperature of the liquid

Heating metal object (ball)

Putting metal object in water cup

Measuring final temperature of the liquid

Importance of transferring metal quickly

Able to explain procedure with prompting

Able to answer specific questions regarding the procedure when prompting failed

Able to explain calculations without prompting – 10 points max

Including: Heat capacity equals the total amount of heat divided by the temperature change.

Where does heat absorbed by water come from?

Does water / metal heat or cool?

Able to explain calculations with prompting

Able to answer specific questions regarding the calculations when prompting failed

Acid – base titration lab – 25 points total

Able to explain the procedure without prompting – 15 points max

Including: One reactant (acid) in beaker (flask)

Other reactant (base) in buret (long tube)

Indicator

Adding from the buret into the flask until color change

Explain equivalence point and how it is recognized

Able to explain procedure with prompting

Able to answer specific questions regarding the procedure when prompting failed

Able to explain calculations without prompting – 10 points max

Including: Concentration of acid times amount (ml) of acid equals concentration of base times amount (ml) of base.

Able to explain calculations with prompting

Able to answer specific questions regarding the calculations when prompting failed

APPENDIX C

Specific Heat of Two Metals (Virtual)

The amount of heat required to raise the temperature of 1 g of a substance by 1 degree is called the *specific heat capacity* or *specific heat* of that substance. Water, for instance, has a specific heat of 4.18 J/K□g. This value is high in comparison with the specific heats for other materials, such as concrete or metals. In this experiment, you will use a simple calorimeter and your knowledge of the specific heat of water to measure the specific heat of aluminum (Al).

Procedure:

1. Start *Virtual ChemLab* and select *The Specific Heat of Al* from the list of assignments. The lab will open in the Calorimetry laboratory.

2. Click on the *Lab Book* to open it. Record the mass of Al on the balance. If it is too small to read click on the *Balance* area to zoom in, record the mass of Al in the data table below, and return to the laboratory.

3. Pick up the Al sample from the balance pan and place the sample in the oven. Click the oven door to close. The oven is set to heat to 200°C. Record this as the initial temperature of the metal.

4. The calorimeter has been filled with 100 mL water. The density of water at 25°C is 0.998 g/mL. Use the density of the water to determine the mass of water from the volume and record the volume and mass in the data table.

Make certain the stirrer is ***On*** (you should be able to see the shaft rotating). Click the thermometer window to bring it to the front and click ***Save*** to begin recording data. Allow 20-30 seconds to obtain a baseline temperature of the water. You can observe the temperature in the calorimeter as a function of time using the graph window.

5. Click on the *Oven* to open it. Drag the hot Al sample from the oven until it snaps into place above the calorimeter and drop it in. Click the thermometer and graph windows to bring them to the front again and observe the change in temperature in the graph window until it reaches a constant value and then wait an additional 20-30 seconds. Click ***Stop*** in the temperature window. A blue data link will appear in the lab book. Click the blue data link and record the temperature before adding the Al and the *highest* temperature after adding the Al in the data table. (Remember that the water will begin to cool down after reaching the equilibrium temperature.)

6. Click inside the *Stockroom* to return to the Stockroom. Once inside, click on the *Clipboard*.

7. Click on Preset Experiment #1 Heat Capacity of a Metal – Pb

8. Click on *Return to Lab*.

9. Follow steps 3-5 above.

Data Table

Aluminum

mass of metal (g) _____

volume of water (mL) _____

mass of water (g) _____

initial temperature of water (°C) _____

initial temperature of metal (°C) _____

max temp of water + metal (°C) _____

6. *Calculate the change in temperature of the water* (Δ*Twater*). _____.

7. *Calculate the heat (q), in J, gained by the water using the following equation:*

$q_{water} = Cp_{water} \times m \times \Delta T$

8. *Calculate the changes in temperature of the Al (ΔTAl).*

9. *Remembering that the heat gained by the water is equal to the heat lost by the metal, calculate the specific heat of aluminum in J/K @g.*

$q_{water} = q_{metal}$

$q_{metal} = Cp_{metal} \times m \times \Delta T$

10. The accepted value for Al is 0.903 J/ K□g. *Calculate the percent error in the specific heat value that you determined experimentally.*

% error = [(actual – theoretical) / theoretical] x 100

11. When finished with the sample of Aluminum, click on the Stockroom to return to the stockroom.

12. Click on the Clipboard. When it opens, click on Preset Experiment #11, Heat Capacity of a Metal – Pb.

13. Click on Return to Lab and repeat steps 3-5 above.

Data Table

Lead

mass of metal (g) _____

volume of water (mL) _____

mass of water (g) _____

initial temperature of water (°C) _____

initial temperature of metal (°C) _____

max temp of water + metal (°C) _____

6. *Calculate the change in temperature of the water* (Δ*Twater*). _____.

7. *Calculate the heat (q), in J, gained by the water using the following equation:*

$q_{water} = Cp_{water} \times m \times \Delta T$

8. *Calculate the changes in temperature of the Al (ΔTAl).*

9. *Remembering that the heat gained by the water is equal to the heat lost by the metal, calculate the specific heat of aluminum in J/K @g.*

$q_{water} = q_{metal}$

$q_{metal} = Cp_{metal} \times m \times \Delta T$

10. The accepted value for Pb is 0.130 J/ K□g. *Calculate the percent error in the specific heat value that you determined experimentally.*

% error = [(actual – theoretical) / theoretical] x 100

APPENDIX D

Specific Heat of Al and Pb (Traditional)

The amount of heat required to raise the temperature of 1 g of a substance by 1 degree is called the *specific heat capacity* or *specific heat* of that substance. Water, for instance, has a specific heat of 4.18 J/K□g. This value is high in comparison with the specific heats for other materials, such as concrete or metals. In this experiment, you will use a simple calorimeter and your knowledge of the specific heat of water to measure the specific heat of aluminum (Al).

Procedure:

1. Add 300-400 ml of water to a beaker and heat to boiling in a hot plate.

2. Weigh a metal ball and record the weight.

3. Very carefully place the metal ball in the beaker of hot water. (you do not have to wait until it boils to place the metal ball in the beaker).

4. After the water has been boiling for 10-15 minutes, place a thermometer in the boiling water. Record the temperature as the initial temperature of the metal object.

5. Add 100 ml of water to a Styrofoam cup. Place a thermometer in the cold water in the cup and record the temperature as the initial temperature of the water.

6. Carefully, and quickly to avoid heat loss, using tongs, transfer the hot metal ball from the boiling water to the Styrofoam cup with the cold water and quickly place a thermometer in it.

7. Watch the temperature of the thermometer until it reaches its highest point and record this temperature as the final temperature of the water + metal.

Data Table

Aluminum

mass of metal (g) _____

volume of water (mL) _____

mass of water (g) _____

initial temperature of water (°C) _____

initial temperature of metal (°C) _____

max temp of water + metal (°C) _____

8. *Calculate the change in temperature of the water* (Δ*Twater*). _____.

9. *Calculate the heat (q), in J, gained by the water using the following equation:*

$q_{water} = Cp_{water} \times m \times \Delta T$

10. *Calculate the changes in temperature of the Al (ΔTAl).*

11. *Remembering that the heat gained by the water is equal to the heat lost by the metal, calculate the specific heat of aluminum in J/K @g.*

$Q_{metal} = Cp_{metal} \times m \times \Delta T$

12. The accepted value for Al is 0.903 J/ K□g. *Calculate the percent error in the specific heat value that you determined experimentally.*

% error = [(actual – theoretical) / theoretical] x 100

13. When finished with the sample of Aluminum, repeat all steps with a lead ball.

Data Table

Lead

mass of metal (g) _____

volume of water (mL) _____

mass of water (g) _____

initial temperature of water (°C) _____

initial temperature of metal (°C) _____

max temp of water + metal (°C) _____

6. *Calculate the change in temperature of the water* (Δ*Twater*). _____.

7. *Calculate the heat (q), in J, gained by the water using the following equation:*

$q_{water} = Cp_{water} \times m \times \Delta T$

8. *Calculate the changes in temperature of the Al (ΔTAl).*

9. *Remembering that the heat gained by the water is equal to the heat lost by the metal, calculate the specific heat of aluminum in J/K @g.*

$q_{metal} = q_{water}$

$q_{metal} = Cp_{metal} \times m \times \Delta T$

10. The accepted value for Pb is 0.130 J/ K□g. *Calculate the percent error in the specific heat value that you determined experimentally.*

% error = [(actual – theoretical) / theoretical] x 100

APPENDIX E

Molar Mass Determination by Freezing Point Depression (VIRTUAL)

If you dissolve a substance such as ordinary table salt (NaCl) in water, the freezing point of the water will decrease relative to the freezing point of the pure water. You can use this property to calculate the molar mass of an unknown. In this assignment, you will dissolve a sample of NaCl in water, measure the freezing point depression for the solution, and then calculate the molar mass for NaCl as if it were an unknown.

1. Start *Virtual ChemLab* and select *Freezing Point Depression* from the list of assignments (4-7). The lab will open in the Calorimetry laboratory with a beaker containing 45.00 g of ice (record the mass of ice in the data table) and a coffee cup calorimeter on the lab bench. A sample of sodium chloride (NaCl) will also be on the balance.

2. Click on the *Lab Book* to open it. Record the mass of the sodium chloride in the data table. If it is too small to read, click on the *Balance* area to zoom in, record the mass, and then return to the laboratory.

3. 100 mL of water is already in the calorimeter. Use the density of water at 25°C (0.998 g/mL) to determine the mass from the volume and record it in the data table. Make certain the stirrer is ***On*** (you should be able to see the shaft rotating).

4. Click the thermometer window to bring it to the front and click ***Save*** to begin recording data in the lab book. Allow 20-30 seconds to obtain a baseline temperature of the water.

5. Drag the beaker of ice until it snaps into place above the calorimeter and then pour the ice into the calorimeter. Click the thermometer and graph windows to bring them to the front again and observe the change in temperature in the graph window until it reaches zero. Record this a the initial temperature of the ice-water mixture.

6. Drag the weigh paper from the balance to the calorimeter and then pour it into the calorimeter. Observe the change in temperature until it reaches a stable minimum and click ***Stop*** in the temperature window. A blue data link will appear in the lab book. Click

the blue data link and record the *lowest* temperature after adding the salt in the data table as the final temperature. (Remember that the water may have begun to warm back up.)

Data Table

mass NaCl _____ (g)

volume of water _____ (ml)

mass water _____ (g)

mass ice _____ (g)

mass water + ice _____ (g)

initial temperature _____ (^{o}C)

final (minimum) temperature _____ (^{o}C)

ΔT(temperature change) _____ (^{o}C)

Calculations

Freezing point depression can be calculated using the equation $\Delta T = K_f$ x m x i , where ΔT is the change in freezing point, i is the number of ions in the solution per mole of dissolved NaCl (i = 2), m is the molality of the solution, and *Kf* is the molal freezing point constant for water which is 1.86°C/m.

Calculate molality using the equation:

molality (m) = $\Delta T / (K_f \, x \, i)$

m = _____

Since molality equals moles of solute per Kg solvent and moles equals mass divided by molar mass:

m = (mass in grams of solute / MM solute) / Kg solvent

Calculate the molar mass of solute (NaCl) using the following equation:

MM solute (NaCl) = mass solute in g / (molality x Kg of solvent)

MM (NaCl) = _____

Percent error = [[Experimental MM- Theoretical MM (59.5 g/mol)] / Theoretical MM] x 100

APPENDIX F

Molar Mass Determination by Freezing Point Depression (TRADITIONAL)

If you dissolve a substance such as ordinary table salt (NaCl) in water, the freezing point of the water will decrease relative to the freezing point of the pure water. You can use this property to calculate the molar mass of an unknown. In this assignment, you will dissolve a sample of NaCl in water, measure the freezing point depression for the solution, and then calculate the molar mass for NaCl as if it were an unknown.

1. Add 100 mL of water to the coffee cup calorimeter. Use the density of water at 25°C (0.998 g/mL) to determine the mass from the volume and record it in the data table.

2. Weigh approximately 20 grams of sodium chloride. Record the mass of the sodium chloride in the data table.

3. Weigh approximately 45.00 g of ice Record the mass of ice in the data table.

4. Add ice to water in calorimeter. Wait until the temperature reaches a minimum level. Record this temperature as the initial temperature.

5. Add salt to the ice-water mixture and observe the temperature until it reaches a new minimum. Record this as the final temperature of the ice-water mixture.

Data Table

mass NaCl _____ (g)

volume of water _____ (ml)

mass water _____ (g)

mass ice _____ (g)

mass water + ice _____ (g)

initial temperature _____ (^{o}C)

final (minimum) temperature _____ (^{o}C)

ΔT(temperature change) _____ (^{o}C)

Calculations

Freezing point depression can be calculated using the equation $\Delta T = K_f$ x m x i , where ΔT is the change in freezing point, i is the number of ions in the solution per mole of dissolved NaCl (i = 2), $m$is the molality of the solution, and Kf is the molal freezing point constant for water which is

1.86°C/m.

Calculate molality using the equation:

molality (m) = $\Delta T / (K_f x i)$

m = _____

Since molality equals moles of solute per Kg solvent and moles equals mass divided by molar mass:

m = (mass in grams of solute / MM solute) / Kg solvent

Calculate the molar mass of solute (NaCl) using the following equation:

MM solute (NaCl) = mass solute in g / (molality x Kg of solvent)

MM (NaCl) = _____

Percent error = [[Experimental MM- Theoretical MM (59.5 g/mol)] / Theoretical MM] x 100

APPENDIX G

Heat of Reaction: NaOH(aq) + HCl(aq) (VIRTUAL)

Energy is either absorbed or released for all chemical reactions, and we call this energy the enthalpy of reaction (ΔHrxn). If the enthalpy of reaction is positive, then we say that the energy was absorbed or that the reaction was *endothermic.* If the enthalpy of reaction is negative, then we say that energy was released or that the reaction was *exothermic*. Most chemical reactions are exothermic. In this problem, you will measure the amount of heat released when aqueous solutions of NaOH and HCl are mixed and react to form water and then you will calculate the heat of reaction.

NaOH(aq) + HCl(aq) = H2O(l) + NaCl(aq)

1. Start *Virtual ChemLab* and select *Heat of Reaction: NaOH + HCl (3.10)* from the list of assignments.

2. Click the *Lab Book* to open it. In the thermometer window click ***Save*** to begin recording data. Allow 20-30 seconds to obtain a baseline temperature of the water.

3. Pour the first beaker containing 100 mL of 1.000 M HCl into the calorimeter and then pour the second beaker containing 100 mL of 1.000 M NaOH into the calorimeter.

4. Observe the change in temperature until it reaches a maximum and then record data for an additional 20-30 seconds. Click ***Stop*** in the temperature window.

5. A blue data link will appear in the lab book. Click the blue data link and record the temperature before adding the NaOH and the *highest* temperature after adding the NaOH in the data table. (Remember that the water will begin to cool down after reaching the equilibrium temperature.)

6. *Is the observed reaction endothermic or exothermic? What will be the sign of* ΔH*rxn?*

7. *Calculate the change in temperature,* ΔT. Record your results in the results table on the following page.

8. *Calculate the mass of the reaction mixture in the calorimeter.* (To do this, first determine the total volume of the solution based on the assumption that the volumes are additive and that the density of the solution is the same as that of pure water, 1.0 g/mL.) Record your results in the results table.

9. *Calculate the total heat released in the reaction, assuming that the specific heat capacity of the*

solution is the same as that of pure water, 4.184 J/K □g. Record the result in the results table.

Remember: heat of reaction = $m \times C \times \Delta T$

Initial temperature (°C) _____

Final temperature (°C) _____

10. *Calculate the number of moles of NaOH used in the reaction by multiplying the volume of NaOH times the molarity (1.000 mol/L).* Record the results in the results table.

11. *Calculate ΔHrxn, in kJ/mol, of NaOH for the reaction and record the results in the results table.* Make sure the sign of ΔHrxn is correct.

Results Table

Mass of Reaction Mixture	ΔT	Total Heat Released	Moles of NaOH	ΔRxn/mol

APPENDIX H

Heat of Reaction: NaOH(aq) + HCl(aq) (TRADITIONAL)

Energy is either absorbed or released for all chemical reactions, and we call this energy the enthalpy of reaction (ΔHrxn). If the enthalpy of reaction is positive, then we say that the energy was absorbed or that the reaction was *endothermic.* If the enthalpy of reaction is negative, then we say that energy was released or that the reaction was *exothermic*. Most chemical reactions are exothermic. In this problem, you will measure the amount of heat released when aqueous solutions of NaOH and HCl are mixed and react to form water and then you will calculate the heat of reaction.

NaOH(aq) + HCl(aq) = H2O(l) + NaCl(aq)

1. Pour 100 mL of 1.000 M HCl into a beaker. Insert a thermometer and record the temperature of the acid.

2. Pour 100 ml of 1.000 M NaOH into a beaker. Insert a thermometer and record the temperature of the base.

3. If the temperatures are different, allow the beakers to stand next to each other until the temperatures are the same.

4. Pour both the acid and base simultaneously into a Styrofoam calorimeter. Cover with a lid and observe the change in temperature until it reaches a maximum and then record the final temperature.

5. *Is the observed reaction endothermic or exothermic? What will be the sign of* ΔH*rxn?*

6. *Calculate the change in temperature,* ΔT. Record your results in the results table on the following page.

7. *Calculate the mass of the reaction mixture in the calorimeter.* (To do this, first determine the total volume of the solution based on the assumption that the volumes are additive and that the density of the solution is the same as that of pure water, 1.0 g/mL.) Record your results in the results table.

8. *Calculate the total heat released in the reaction, assuming that the specific heat capacity of the solution is the same as that of pure water, 4.184 J/K* □*g.* Record the result in the results table.

Remember: heat of reaction = $m \times C \times \Delta T$

Initial temperature (°C) _____

Final temperature (°C) _____

9. *Calculate the number of moles of NaOH used in the reaction by multiplying the volume of NaOH times the molarity (1.000 mol/L).* Record the results in the results table.

10. *Calculate ΔHrxn, in kJ/mol, of NaOH for the reaction and record the results in the results table.* Make sure the sign of ΔHrxn is correct.

11. Repeat two more times.

12. Average the results.

Results Table

Mass of Reaction Mixture	ΔT	Total Heat Released	Moles of NaOH	ΔRxn/mol

APPENDIX I

Acid-Base Titration: Unknown HCl (Virtual)

Introduction

Titrations provide a method of quantitatively measuring the concentration of an unknown solution. In an acid-base titration, this is done by delivering a titrant of known concentration into an analyte of known volume. In this assignment, you will titrate a 0.2564 M solution of NaOH into 25 mL of an unknown concentration of HCl and calculate the concentration of the HCl solution.

Procedure

1. Start *Virtual ChemLab*. Click on **Notebook** to open it. Click on *Enter Laboratory*. Click on *Titrations Laboratory*. Click in the *Stockroom*. Click on *Clipboard*. Select *Strong Acid Strong Base Unknown* from the list of assignments. Click on *Return to Lab*.

2. a. Click the *Lab Book* to open it.

b. Move the *Lab* window to the upper right side of the screen.

c. Click "X" on the *Conductivity Meter* window to close it.

d. Drag the *Buret Zoom View* window to the lower right corner of the screen. The buret is filled with 0.2564 M NaOH. The beaker has 25.00 mL of unknown HCl.

e. Drag the *Lab Book* window to the upper left corner of the screen. The pH meter is turned on and has been calibrated.

f. Drag the *pH Meter* window to the lower center of the screen below the *BEAKERS* drawer. The indicator is bromocresol green.

g. Drag the *Plot* window to the lower left corner of the screen.

3. Perform the titration.

a. Click the ***Save*** button in the *Buret Zoom View* window so the titration data can be saved. The horizontal position of the orange handle is off for the stopcock.

b. Open the stopcock by pulling down on the orange handle. The vertical position delivers solution the fastest with three intermediate rates in between. Each time you click on the handle the liquid moves out faster.

c. Turn the stopcock to second position. **WARNING – Watch the curve carefully.**

d. When the blue line in the graph window (the pH curve) begins to turn up, double-click the stopcock to turn it off.

e. Move the stopcock down one position to add volume drop by drop.

4. a. To determine the volume at the equivalence point stop the titration (close the stopcock) when a color change occurs, and then click the ***Stop*** button in the *Buret Zoom View*.

b. A blue data link will appear in the lab book. Click the blue data link to open the *Data View* window. Scroll down to the last data entry and record the volume at the equivalence point. Average the volume immediately before and after the steep pH change.

5. **(Optional)** Click ***Select All*** button to copy and paste the data to a spreadsheet program.

6. Record your unknown sample number.

7. Record the volume of 0.2564 M NaOH was required by the titration to reach the equivalence point

8. Calculate the molarity of the HCl using 25.00 mL of HCl solution and the volume and the molarity of the 0.2564 M NaOH from your titration. $M_AV_A=M_BV_B$

9. Repeat procedure with two other unknowns.

a. Double click on the bottle of acid.
b. Go to the stock room.
c. Double click on the acid bottle again.
d. Click on the clipboard and then click on the Strong acid Strong base link. A new acid bottle will appear.
e. Return to the lab to conduct the next titration.

Data Sheet

Trial 1

Volume of acid used _____ ml

Volume of base used _____ml

Molarity of the base used _____M

Unknown number _____

Molarity of unknown _____M

Calculations:

Trial 2

Volume of acid used _____ ml

Volume of base used _____ml

Molarity of the base used _____M

Unknown number _____

Molarity of unknown _____M

Calculations:

Trial 3

Volume of acid used _____ ml

Volume of base used _____ml

Molarity of the base used _____M

Unknown number _____

Molarity of unknown _____M

Calculations:

APPENDIX J

Acid-Base Titration: Unknown HCl (Traditional)

Introduction

Titrations provide a method of quantitatively measuring the concentration of an unknown solution. In an acid-base titration, this is done by delivering a titrant of known concentration into an analyte of known volume. In this assignment, you will titrate a 0.10 M solution of NaOH into 20 mL of an unknown concentration of HCl and calculate the concentration of the HCl solution.

Procedure

1. Fill a buret with 0.10 M NaOH a little past the top line. Allow a small amount of NaOH to drain into a clean beaker to fill the tip of the buret. Make sure all air is gone from the tip before starting the titration. Record the initial volume of NaOH in the buret.

2. Accurately measure 20-ml of HCl of unknown concentration in an Erlenmeyer flask. Record the volume of HCl.

3. Perform the titration.

a. Slowly open the stopcock. The vertical position delivers solution the fastest.

c. Swirl the flask as the NaOH is added.

d. When the pink color starts to appear in the flask, slow down the addition of NaOH. **Watch the color change carefully, a sheet of white paper under the flask helps notice the color change.**

e. Continue to add NaOH until the pink color persists but avoid getting a dark pink or purple. This is the equivalence point of the titration.

6. Record your unknown sample number.

7. Record the volume of 0.10 M NaOH was required by the titration to reach the equivalence point.

8. Calculate the molarity of the HCl using the volume in mL of HCl solution and the volume in ml and the molarity of the 0.10 M NaOH from your titration. $M_AV_A=M_BV_B$

9. Repeat procedure with two other unknowns.

Data Sheet

Trial 1

Volume of acid used _____ ml

Volume of base used _____ml

Molarity of the base used _____M

Unknown number _____

Molarity of unknown _____M

Calculations:

Trial 2

Volume of acid used _____ ml

Volume of base used _____ml

Molarity of the base used _____M

Unknown number _____

Molarity of unknown _____M

Calculations:

Trial 3

Volume of acid used _____ ml

Volume of base used _____ml

Molarity of the base used _____M

Unknown number _____

Molarity of unknown _____M

Calculations: