FLASH-BASED PHYSICAL SIMULATION IN DEAF EDUCATION

DYNAMIC MEDIA VS. STATIC MEDIA

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A Master’s Project Proposal

Presented to

Information Design and Technology

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ABSTRACT

The main purpose of this project was to develop a Flash based physical simulation to examine if simulations benefit deaf students and to identify the benefits to deaf students after using it. It was also done to determine if deaf students benefited more from the simulation when used in a teacher-centered class or more when used in a student-centered class.

The study suggests that deaf students benefit from simulations and that the benefit is they make learning abstract concepts easier for deaf students to understand when they are coherent, engaging, welcoming, serve the students’ purpose for using them, and are responsive to the students’ needs and ways he/she does things. The findings also indicate the benefits deaf students gain from using simulations depends on how the teacher uses it in class. This study found that the most appropriate and beneficial use of simulations for deaf students is using them in a teacher-centered class to supplement instruction taught directly by the teacher and not in a student-centered class by student self-instruction.

A Flash-based physical simulation was created using information about photosynthesis but with dynamic images, video, and animations simulating the parts of photosynthesis, the process of photosynthesis, and the importance of photosynthesis. The principles of Human-Centered Design Theory were used as a guide to analyze the simulation. Research was further calculated by comparing scores on written tests given to students in the teacher-centered classroom and student-centered classroom as well as surveys, and interviews to further discuss the simulation and reaction students had to it.
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I. INTRODUCTION

Recently, technology is becoming increasingly popular with new developments, faster Internet connections, affordable pricing, and greater availability to the public.

“The rapid growth in the types of available technological tools, paired with the decline in the price of these resources, captivated schools and parents alike, who wanted to prepare their children for a society where learning and employment were increasingly dependent on digital access and expertise,” (Staples, Pugach, & Himes, 2005, p.285).

It is also true in the educational community in school districts that presently use technology to motivate, instruct, and support students’ education, especially for students learning theoretical concepts. (Linn & Hsi 2000) believe that many researchers in educational technology advocate the importance of integrating technologies into science teaching and learning. Extensive use of technology in classrooms has the potential to support students’ exploration of scientific ideas (de Jong & van Joolingen, 1998).

Although with new technology, there is skepticism by those who question its functionality because of who uses it.

Wu & Huang (2007) point out, when technology is used in a teacher-centered approach that emphasizes direct guidance, lectures, and demonstrations of teaching materials, it is sometimes more effective than a student-centered approach that allows students to do self-paced learning and freely interact with the technological tools.

A study that reinforces this idea was done by (R. D. Hannafin & Sullivan 1996) which examined the effects of assigning high school students to a computer-delivered geometry program that either matched or did not match their preferred amount of instruction as measured by a preprogram questionnaire. The case findings showed that students under a learner-controlled environment performed more poorly on cognitive tasks than on teacher-directed or program-controlled situations. However, little is understood about
how students who are deaf interact with simulations in class settings with different instructional approaches. Thus, the purpose of this master’s project is to create a physical simulation for middle school students who are deaf and examine the benefits deaf students have after using it and to identify what they are.
II. BACKGROUND

As an instructor of the deaf, it is very difficult to teach deaf and hard of hearing students in the same manner most hearing students are taught strictly with direct instruction. It is equally difficult to teach deaf and hard of hearing students the same information in the same timeframe that their hearing peers are taught due to their lower levels of literacy.

Berent (2009) attributes this to the deaf population’s hearing loss that restricts the intake of linguistic information through the auditory channel and inhibits the development of the spoken language to the point where deaf children typically have significant deficiencies in the target language and enter adolescence and adulthood without having acquired proficiency in the language of the larger community.

Sadker & Sadker (2000) defines direct instruction as a model of teaching in which new information is followed by student practice and teacher feedback.

Gary D. Borich the author of “Effective Teaching Methods” identifies the teacher’s role in direct instruction “is to pass facts, rules, and action sequences in the most direct way possible. This usually takes the form of lecture recitation with explanations, examples, and opportunities for practice and feedback.”

In this method, the teacher has all control, does not have to assume that students will develop insights on their own, can control what will be learned, and who will learn it. Most importantly, the curriculum can be covered, so the teacher can say that he/she has taught the material. However, direct instruction is a teaching method that works best for students who have verbal “intelligence” students with the ability to analyze information and solve problems using language-based reasoning; students who can hear and speak. Verbal intelligence is one of the eight multiple intelligences first addressed by Howard Gardner, professor of Cognition and Education at the Harvard Graduate School of Education. Dr. Gardner is well known for his Theory of Multiple Intelligences, which
refuses to accept that there is only a single intelligence that can be accessed by standard psychometric instruments. Gardner (1993) believes there exists a multitude of intelligences, quite independent of each other, and that each intelligence, has its own strengths and constraints. For students who are deaf and hard of hearing, learning only by this method of instruction is not 100 percent affective. Unfortunately, teachers and even student teachers often mistake direct instruction as the only way to teach.

That is why I propose exploring the use of physical simulations in deaf education that promote interactive instruction, student motivation, and student engagement to identify the benefits they have on student learning while assisting instructors of the deaf with new ways to teach. Simulations are immersive learning environments that recreate a real world situation, event, or environment (Bulger, Mayer, Almeroth, & Blau, 2008). Simulations are becoming an increasingly popular method of teaching as computers in the classroom become an educational staple followed by Promethean and SMART Boards also used to run them. Because of this, we as educators need to tap into this powerful medium if we are to afford our students success in their comprehension, retaining of knowledge, and successful completion of school program.

My project will serve to examine the benefits deaf students have using a physical simulation to bridge information introduced and taught with direct instruction traditionally in a teacher-centered class as well as examine the benefits deaf students have using a physical simulation to construct information on their own in a student-centered class while still reinforcing the lesson’s goals and objectives.
III. RESEARCH QUESTIONS

Central Question

The central question this study will seek to answer is “Do simulations benefit deaf students and which components of simulations are beneficial?” The objectives of this project will be to build a Flash based physical simulation and to study which elements of it are beneficial to middle school students who are deaf learning photosynthesis in both a teacher-centered class and in a student-centered class. This simulation will be built and evaluated upon the principles of Human Centered Design (HCD) Theory. It will also be used to the students’ initial views of the physical simulation and their ideas after using it. The conclusion and findings of this thesis project could serve to further other studies that evaluate how simulations can be used in deaf education. It may also serve as a positive example for instructors of the deaf to use when looking to integrate technology in deaf education.

Sub Research Questions

1. Do deaf students do better on exams after taught with static media or with dynamic media in a teacher-centered classroom?

2. Do deaf students do better on exams using simulations in a teacher-centered classroom or in a student-centered classroom?

3. Do deaf students benefit more from using the simulation in a teacher-centered classroom or in a student-centered classroom?
IV. REVIEW OF RELATED LITERATURE

Several scholarly journal articles regarding deafness, static vs. dynamic media, and simulations were reviewed.

Deaf Culture:

Deaf Defined

The word deaf can be defined in three ways: a medical disability, an audiological experience, and as a self-identification. Mobus (2010) describes being deaf as a medical view in which someone is deficient in the sense of hearing.

According to Paddy Ladd, the author of “Understanding Deaf Culture” the word deaf spelled with a lowercase d refers to “those for whom deafness is primarily an audiological experience. It is mainly used to describe those who lost some or all of their hearing in early or late life, and who do not usually wish to have contact with signing Deaf communities, preferring to try and retain their membership of the majority society in which they were socialized” (Ladd, xviii).

In contrast with the word deaf being an audiological experience or disability, the deaf and hard of hearing people recognize the word Deaf as a culture with their own native language and views being deaf not a disability or an audiological experience.

“People who identify themselves as Deaf (note the capital “D”) belong to a proud and distinctive culture group known as the Deaf culture. Through their collective efforts to meet their own needs, Deaf people have organized a network of social, religious, athletic, dramatic, scholarly and literary organizations serving local, national and international memberships,” (www.wfd.org).

A main part of Deaf culture is sign language used for communication with expression and comprehension. The elements of sign language are hand shape, hand movement, hand location, palm orientation, facial expression, and eye contact (Lewis & Henderson 1997). Because of their three-dimensional/visual mode, different information can be sent simultaneously; persons, things, or situations, can be connected by markings in the space in front of the signer’s body (Mobus 2010). However, (Wang 2010) believes that because
deaf individuals use a different language and have a different culture than hearing individuals, the way they construct reality is different from the way hearing students do so. This then would imply it is more challenging to teach students of the deaf abstract concepts solely from lectures and static images that are used customarily when teaching hearing peers.

**Deaf Students’ Literacy**

Students who are deaf and hard of hearing read at much lower levels than their hearing peers, and their vocabulary is much smaller.

Regardles of whether they speak or sign, the median reading level of deaf students indicates sub par achievement. Approximately 10% of deaf students read beyond an eighth grade level (Traxler, 2000).

Reasons for this are the deaf and hard of hearing students’ weaknesses in sub skills required for reading. Paul (2003) noted the difficulties they have with two types of skills, which he divided along the lines of text and reader-based skills. Text based skills include word identification, vocabulary, syntax, and figurative language. Reader-based skills include working memory, metacognition, and prior knowledge. These skills are essential to literacy learning and literacy is the strongest predictor for success in education of deaf children (Barker 2003). Another reason for the low literacy rate in deaf students is that many of the concepts in abstract courses taught in school such as math and science are finger spelled as the teacher introduces them or is seen by the student as meaningless print when introduced in written form in a textbook. (Mussleman 2000) points out that deaf people communicate words that are part of their vocabulary but for which no specific sign exists, with finger spelling, signing only the letters that make up the word. This makes it even more difficult for deaf and hard of hearing students to understand the
meaning of written and spoken language. Even when there are American Sign Language (ASL) signs for vocabulary, there may only be a few or just one for a word that has many synonyms. This contributes to deaf students’ small vocabulary and even their inability to differentiate past, present, and future tenses when writing. Luckner & Cooke (2010) report delayed acquisition of vocabulary knowledge, smaller lexicons, slower rates while acquiring new words, and narrower range of contexts that result in word learning contribute to the deaf students’ low literacy. All of these contributing factors lead to low-test scores, poor reading and writing skills, lack of student motivation, failure to learn, and even quitting school. Therefore, it is more likely that students who have hearing loss and face these challenges in their education will do much worse than their hearing peers if they continue to be taught with traditional methods of instruction via lectures and static images.

As mentioned earlier, deaf and hard of hearing people tend to have their own culture, their own language, and their own way of constructing reality that is different from the hearing mainstream. Bocher & Bocher (2009) point out “Since deaf learners rely heavily on visual and printed input to acquire spoken language and literacy skills, it is important for teachers to take advantage of every opportunity to facilitate their students’ visual processing of linguistic information. That is why research is still needed to examine positive uses of technology to teach deaf and hard of hearing students’ subject matter and literacy.

**Static Media vs. Dynamic Media**

With more professions requiring greater knowledge of technology, more emphasis is being made to integrate technology in school curriculum. “These technology-mediated
practices are viewed as essential for students in the 21st century to develop, and there has been an international push for educators to address these needs in their classroom,” (Kitson, Fletcher, & Kearney, 2007, p.29). Positive results that support such practices are those found in an explorative study done by Rachel Karchmer. Karchmer (2001) showed that incorporating technology within literacy instruction increased students’ ability to collaborate, communicate, acquire and sift through information, and solve problems. There is strong empirical evidence that people learn better with text and visualizations than with text alone (Anglin, Vaez & Cunningham 2004). Since we know that deaf and hard of hearing students are visual learners from (Bocher & Bocher 2009), it is important to review past research done on the subject of static media vs. dynamic media when used to learn with to administer our own study of the topic. Static media is defined as texts or images while dynamic media are animations or simulations.

In accordance with Scholtz and Lowe (2008) dynamic visualizations such as animations or videos are depictions that change continuously over time and represent continuous flow of motion where as static visualizations do not show any continuous movement, but specific states taken from such a flow of motion. (Holzinger, Kickmeier-Rust, & Alfred 2008) see dynamic media as “an increasingly important factor in educating the so called twitch speed generation.” Presnsky (2001) developed the term twitch speed generation to reference the under 30 generation that are capable of processing information faster than the generations before it. Because this generation is massively immersed with technology such as computers, E-readers, smart phones, Internet, and more, the debate over which media is best to teach them with, static or dynamic is ongoing and the results of studies have been mixed. Arguments for static media have been made by (Mayer, Hegarty, Mayer, & Cambell (2005) who conducted four experiments that compared learning from a computerized animated display to
learning from a series of still visuals presented in print media.

“Animation may be entertaining, but these experiments offer no reason to conclude that animation inherently provides more educational value than static diagrams. Instead, a well designed series of still frames can be as good or better than animation” (p. 264).

Possible reason why static media is more beneficial to students is shared by (Clark & Mayer 2008).

“The amount of visual and auditory information that a learner must absorb in an animated lesson exceeds working memory capacity to select, organize, and integrate, the critical information” (p. 8).

Other researchers who see static media comparable to dynamic media are Kul, Scheiter, Gerjets, & Gemballa (2011) who examined the differences between static and dynamic visualizations in their study of 75 students assigned to learn the physical principles of fish locomotion using a text only, a text with dynamic visualizations, or a text with static visualizations. Their study’s outcome showed that no significant differences were observable between the two medias concerning any of the learning outcomes measured: factual knowledge, pictorial recall, and transfer. This was true also when observing the two medias to evaluate students’ cognitive load, perceived difficulty and mental effort when learning about principles of fish movement. (Lin, Chen, & Dwyer 2006) also evaluated the effects of static and dynamic media using them in a study that facilitated immediate and delayed achievement in English as a foreign language classroom. They discovered that when dynamic media was used to present complicated information and learning tasks, static media was as effective as dynamic media. However, when dynamic media was used with instructional objectives to produce lower level learning outcomes involving factual and declarative knowledge it was superior to static media. Other ways dynamic media has been found to be superior to static media is when it is used to direct
learners’ attention to important elements as well as incorporating pause and replay functionality for better learning results. Offering students more chances to watch an animation can lead to higher performances on exams evaluating vocabulary and fact retention all equated to practice using dynamic media. Although dynamic media is becoming more popular to teach with, researchers still caution educators before using them. According to (Holzinger, Kickmeir-Rust, & Albert 2008) for dynamic media to be successful in facilitating learning in comparison to static media, they must be able to do three things: accommodate learner’s experience, expertise, and prior knowledge.

“Therefore, material containing dynamic media must avoid information, animations, and elements, which are not necessary to comprehend a concept,” (Holzinger, Kickmeir-Rust, & Albert p. 288).

**Simulations:**

**Simulations Defined**

Defining simulations can be problematic, given the many perspectives of its users and the differences between the types of simulations that are used today: physical, interactive, procedural, and situational. To avoid confusion, it is important to clearly define the term and its usage within this thesis project. A typical dictionary definition from “The Oxford English Dictionary” describes simulation as:

"The technique of imitating the behavior of some situation or system (Economic, Mechanical etc.) by means of an analogous model, situation, or apparatus, either to gain information more conveniently or to train personnel."

(Bulger, Mayer, Almeroth, & Blau, 2008) define simulation as an immersive learning environment that recreates a real world situation, event, or environment. Thompson, Simonson, and Hargrave (1996) concur with their definition of simulation, which is a
representation or model of an event, object, or phenomenon. When simulations are used in education users can learn through interaction and a new type of simulation is defined as an educational simulation. This simulation can “facilitate learning through immersion, engagement, and adaptive surroundings that ultimately provide guidance and constructive feedback to the learner” (Hartly 2006 p. 53). Allessi & Trollip (2001) believe simulations can “Help learners build their own mental models of the phenomena or procedures and provide them opportunities to explore, practice, test, and improve those models safely and efficiently,” (p. 214). On the flip side to this statement, doubters have seen simulations and technology in general as distractions to learners and time wasted that could be used in other ways to benefit learning.

(Guerrero, Walker, & Dugdale, 2004) summarized teachers’ attitudes toward the use of technology in classrooms as “apprehensive” and that the majority of teachers interviewed indicated that they had not observed any software that really helped learning and using software did not save time in teaching or evaluation.

However, like any dynamic media that is used in education, for simulations to be effective, it needs to be designed with content and users in mind and be implemented correctly.

**Types of Simulations**

Simulations generally fall under four groups: physical, interactive, procedural, and situational. The authors Stephen M. Allessi and Stanley R. Trollip (2001) of the “Multimedia for Learning Methods and Development” define these simulations as the following:

“In physical simulations a physical object or phenomenon is represented on the screen, giving the user an opportunity to learn about it. Many examples are in the physical and biological sciences (gravity, optics, chemical bonding, photosynthesis, weather) in engineering (internal combustion engines, transmission of electricity through power lines, computer logic circuits), and in

For this thesis project, a physical simulation will be used to evaluate the benefits deaf students have after using it.

“Interactive simulations...are quite similar to physical simulations in which they teach about something. The primary difference is the manner in which learners interact with the simulation. Instead of continuously manipulating the simulation as it unfolds in either real or manipulated time, the learner runs the simulation over and over, selecting values for various parameters at the beginning of each run, observing the phenomena occur with intervention, interpreting the results, and then running it all over again with new parameters,” (Allesis & Trollip 2001, p.217).

Because (Alessi & Trollip 2001) point out a disadvantage of simulations is that they are the most challenging of all the multi-media methodologies to design and develop and due to time constraints, I will not be creating the interactive simulation for this thesis project.

“The purpose of procedural simulations is to teach a sequence of actions to accomplish some goal. Examples include flying a plane, performing a titration, or diagnosing equipment malfunctions,” (Stephen M. Allessi and Stanley R. Trollip (2001) p.221). “Situational simulations deal with the behaviors and attitudes of people or organizations in different situations, rather than with skilled performance,” (Allesis & Trollip 2001 (2001) p. 224).

As stated in the central question of this thesis project, I will be concerned with evaluating the students’ performance via exam of knowledge learned about the phenomena of photosynthesis and not the sequence of actions for students to physically create photosynthesis nor examining the students view of people in different situations who study photosynthesis so using a procedural or situational simulation will not be utilized.

**Simulations Connect Education to the Real World**

Mentioned often by researchers is that simulations can “allow students to explore complex interactions among dynamic variables that model real-life situations,” (Park, Lee, & Kim 2009 p. 649). De Jong & van Joolingen (1998) in a study discovered that
complex objects and phenomena assessable on desktop computers could be modeled.

“The computer instead of the student can assume responsibility of processing the underlying mathematics in order to let the student begin exploring a complex system by focusing on conceptual understanding,” (Rieber, Tzeng, & Tribble, 2004 p. 307). Simulations can facilitate scenarios similar to those in real life and can even serve the student’s learning more. “The benefit of doing … experiments with a simulation is that the user can complete many more trials with less effort than could be done in a laboratory with real objects,” (Alessi & Trollip, 2001 p. 220). Another way simulations connect education to the real world is offering safe environments for students to learn in and chances to fail. Simulations are valuable education tools in situations where learning in the real environment without sufficient training could be dangerous (Hartley, 2006, p. 54). (Alessi & Trollip, 2001 p. 231) point out that simulations maybe used as tests and give the example of a student learning to fly. If he/she crashes in the simulation then more practice is needed and if the student does not, he/she is perhaps is ready to fly a real airplane. “People do not truly learn until they practice and fail in a safe environment… Simulations help learners try and fail a task in a safe environment” (Hartley, 2006, p. 53). Allowing for students to fail in a controlled safe environment simulation, instructors can evaluate students understanding of material covered in class to prepare students for the real exam.

**Simulations Motivate & Engage**

(Keller & Suzuki, 1988) equate the motivational element found in simulations is relevance.

“Most learners consider simulations more relevant to their learning than lectures, books, or other passive methods, because they are engaging in the activity rather than just reading and hearing about it,” (Alessi & Trollip, 2001 p. 229).
Bonk and Zhang (2006) point out that the use of “interactivity, visualization, collaboration, captivation, and technology sophistication motivate learners and promote effective learning” (p. 251). This is true when comparing simulations with lectures and textbooks and dynamic media vs. static media. In a study done by Lay & Smarick (2006) using a simulation to access college student’s comprehension and motivation to learning American politics, they found that students gain more understanding and are more confident in their knowledge of politics than their peers who were taught by lecture and textbook. In a study done by (Dede, Clarke, Ketelhut, Nelson & Bowman, 2005) evaluating secondary students motivation and engagement using a simulation to learn biological content and complex inquiry skills discovered that students were highly engaged, their class attendance improved, disruptive behavior in the class decreased and students did better than students receiving traditional methods of instruction. Simulations can be associated with student’s control, a component of Malone’s Theory of motivation. (Allessi & Trollip 2001) state “Malone’s Theory of motivation suggests learners are more motivated when they have a sense of being in control,” (p.246). Also (Alessi & Trollip, 2001) constitute simulations more motivational than textbooks and lectures in that, “Learners find them interesting because they are participating in events rather than reading about them,” (p.245). (Hennessy 2006) conurs stating “learners can make the decision to do something first, and then see what happens, rather than just getting spoon fed.” (p. 712).

**Simulations Build Visual Models**

Many concepts are easier to learn when it they are taught with a clear visual model than one without and described only. (Rieber, Tzeng & Tribble 2004) points out that
Computer simulations are more feasible for promoting adaptive learning in students when traditional instruction cannot provide easily observable objects. Simulations have the advantage of helping a learner by making concepts visual (Hennessy et al., 2006, p. 709).

“Because of their ability to present dynamic information and to visualize complex concepts, simulations are among those types of computer applications that educators view as especially promising for the learning of complex scenarios, problem-solving tasks, and the study of phenomena that are not visible to the human eye,” (Lee, Plass, & Homer, 2006, p. 902).

Sometimes simulation is the only way of providing certain types of instruction. In a history course, for example, it is impossible for learners to actually witness events in the past. However, simulation can create an impression of what happened and provide role-playing of historical figures. Similarly, in an economics course, simulation may be the best way for learners to recreate and analyze the events of the Great Depression,” (Allessi & Trollip, 2001, p. 227).

**Simulations Promote Constructive Learning**

Simulations connect education to the real world, motivate and engage, build visual models and promote constructive learning. The constructive approach to learning focuses on knowledge that is actively built by the learner (Biggs, 1999). Therefore, under constructivism, learning cannot be a mere accumulation of facts but an interactive process of creating meaning out of knowledge (Davis, 2011). One way for learners to do this is with simulations. Simulations support constructivist learning by guiding the learner to use existing knowledge to gain new knowledge (Hennessy 2006,). “Not only can simulations improve the quality of learning but, when blend with real world technology used in the workplace, it can equip students with employable skills,” (Davis 2011, p. 4).
V. METHODOLOGY

The research methodology used to evaluate this project was qualitative inquiry. According to the author John W. Creswell of “Qualitative Inquiry And Research Design Choosing Among Five Traditions” says that Qualitative Inquiry is a

“Process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem. The researcher builds a complex, holistic picture, analyzes, words, reports detailed views of informants, and conducts the study in a natural setting,” (p. 15).

Qualitative inquiry research can be done using one of the five traditions: biography, a phenomenology, a grounded theory of study, an ethnography, and a case study. Because of time constraints and the small number of participants, this project was evaluated with a case study, one of the five traditions of qualitative inquiry. Robert K Yin, the author of “Case Study Research” defines case study as a method that “Allows investigators to retain the holistic and meaningful characteristics of real-life events—such as individual life cycles, small group behavior, organizational and managerial processes, neighborhood change, school performance, international relations, and maturation of industries,” (p. 4). “This method of research can be used to contribute to our knowledge of an individual, group, organizational, social, political, and related phenomena,” (Yin, 2009 p.4). The general structure of a case study reported by (Creswell, 1998, p. 65) includes four dimensions for qualitative research: focus, discipline origin, data collection, data analysis, and narrative form.

In this thesis project the focus was first to examine the benefits deaf students have using simulations to learn. The second was to develop a comparison analysis of which class benefited more from using the simulation, the teacher-centered class or the student-centered class. Third, to develop a comparison analysis of the benefits of dynamic media
(simulation) over static media used to teach students who are deaf. The discipline origin will be students from two eighth grade science classes. The data collection and data analysis is from student performance exams, surveys, interviews, and field notes from class observations. All the research done in this project thesis did not require the Institutional Review Board approval because it was exempted from the Federal Policy for the Protection of Human Subjects, under Section 49 CFR Part 690, Section 101, Subpart B. The narrative form is a summary of the findings from students using the simulation in both the teacher-centered class and in the student-centered class. This is then followed up by the limitations to this project, and conclusion and further research that can be done in the future.
V. PROJECT DESIGN

Background

Currently, at a school for the deaf in New York State, which will be referred to as the “Target School”, students in middle school science classes are taught photosynthesis by direct instruction with lecture, textbooks, graphic organizers, and overhead transparencies. This instruction is passive and its structure can be rigid enough to hinder the creativity of the teacher because of state requirements to cover an entire subject’s curriculum designated by the New York State Education Department (NYSED) in a 40-week school year while incorporating state education standards. Because content needed to be taught is extensive, and factoring class time lost for school functions, half days, superintendent conferences, student absences, etc., teachers must pay close attention to how many class periods they schedule to teach a lesson or unit. This sometimes leaves little time to improvise and a step-by-step procedure is used. According to (Slavin 2000), the procedure usually starts with an introduction, followed by the rationale for the instruction, then by the instruction itself. The procedure ends with a summary and then followed by an assessment, usually homework or a quiz.

At the Target School, the instructor routinely begins the lesson by asking the students what he/she knows about photosynthesis to introduce the topic. The instructor then reads from the textbook and lectures about the parts needed for photosynthesis, the process of photosynthesis, key vocabulary terms related to photosynthesis, and why photosynthesis is important to green plants and too animals and human beings. Materials used to teach photosynthesis are overhead transparency sheets that show students static images of the parts that make up photosynthesis: sunlight, water, and carbon dioxide. These parts are
defined and described how they work to create food and oxygen in green plants. To
demonstrate the process of photosynthesis, the instructor places the transparencies with
each part on top of one another. This then is followed by teaching students the
photosynthesis formula \( \text{CO}_2 + \text{H}_2\text{O} + \text{Light Energy} = \text{Sugar} + \text{O}_2 \). Reinforcement of the
lesson is summarized the next day with graphic organizers that the students fill in as the
instructor reviews the material. Students then are either given questions to answer for
homework to assess their comprehension or a quiz. So it is up to the instructor to direct
the learning and students to memorize the information written down. As stated earlier,
this maybe difficult for deaf and hard of hearing students to do in a short amount of time
with vocabulary that is unfamiliar and many times without ASL signs. Student
motivation is another factor. Watching someone sign for an extended amounts of time
can lead to information overload and fatigue due to increased concentration of the eyes as
oppose to being able to multitask when one can hear.

This project consisted of the creation of a Flash-based physical simulation used to
teach students the importance of photosynthesis; the parts needed for photosynthesis,
vocabulary related to photosynthesis, the process of photosynthesis, and the
photosynthesis formula in both a teacher-centered class and in a student-centered class.
The two classes were used to make a comparison between the differences in how students
used the simulation and to identify the advantages deaf students had using the simulation
in a teacher-centered class and in a student-centered class.

In this project, the study looked at whether or not students were more engaged using
the physical simulation to learn photosynthesis and its underlying principles. Because
many deaf students tend to be visual learners, animations simulating the process of
photosynthesis, parts of photosynthesis, and vocabulary associated with photosynthesis would serve them better. The study also looked at whether or not students who had control of their learning by using the buttons: play, stop, previous, next etc. within the simulation would be more motivated due to the fact many deaf students tend to be kinesthetic learners.

**Visual Layout**

Present-day simulations are created from a wide array of software programs. Some of the popular applications are 20-Sim, Automod, Matlab, Simba, Flash, and Intrax. For this project, Flash because I was familiar with it, and I have had experience using it in the Information Design & Technology (IDT) program to present information.

According to Wikipedia, Flash is a multimedia platform used to add animation, video, and interactivity to web pages. It supports bidirectional streaming of audio and video, and it can capture user input via mouse, keyboard, microphone, and camera. Flash content may be displayed on various computer systems and devices, using Adobe Flash Player, which is available free of charge for common web browsers, some mobile phones and a few other electronic devices (using Flash Lite), ([http://en.wikipedia.org/wiki/Adobe_flash](http://en.wikipedia.org/wiki/Adobe_flash)).

**Human-Centered Design (HCD) Theory**

By using Flash, the photosynthesis simulation could be hosted on the Internet at [http://www.baranmammothdesignstudio.com](http://www.baranmammothdesignstudio.com) for students with access to computers and Internet access to use after they had used it in class. This offered students more chances to use the simulation outside of school and more time to learn photosynthesis if they needed it. The second decision made to this project was to create the simulation based upon effective elements of design. In “Information Design” written by Robert Jacobson, Mike Cooley an engineer who holds a Ph.D. in computer-aided design and contributor to the book advocates information should be designed with linguistic, cultural, and
geographical diversity using nine characteristics of Human-Centered Systems. “Human-Centered Systems rejects the notion of the ‘one best way’ and the ‘sameness’ of scientific ideas and suggest instead forms of science and technology that would be culturally specific,” (Cooley p. 64). The nine characteristics of Human-Centered Design are coherence, inclusiveness, malleability, engagement, ownership, responsiveness, purpose, panoramic, and transcendence. These characteristics are said to add interactivity to a system and provide exciting context that can make it more interesting to users. The project can be broken down into those nine elements.

**Coherence**

Coherence deals with not obscuring information from the user but instead clarifying it so that the user is not confused or is able to find his/her way around a design (Cooley p.68). The physical simulation utilizes coherence by factoring in the learner attribute that students are familiar with using Websites on the Internet either in school or at home. The simulation is similar in appearance to a Website and is intended to make the transition from direct instruction to constructivist learning more manageable with students having some familiarity. The layout is a liquid one that is used by web developers to fit information on any screen size it’s viewed on. The physical simulation consists of the following sections: Contents section (HOME), Welcome section, Opening Question section, Vocabulary section, Photosynthesis & Its Parts section, Photosynthesis Process section, Lesson Summary section, Practice Questions section, and Resources Section. Throughout the simulation, each page has a gray-white gradient background to read and see information clearly and places importance on the design of information rather than on the aesthetics of the design. Colors used for text are black with the exception of green to
emphasize the term photosynthesis used by green plants and blue for when links change and in the Practice Question section. The color red is not used in consideration that students that are colorblind may have difficulty in differentiating between the colors green and red. An example of the principle of coherence is incorporated in the Contents section (HOME) shown in Figure 1.

Figure 1 – Screen shot of the Contents section of the simulation. This screen shot shows that the simulation utilizes coherence factoring in the learner attribute that students are familiar with using Websites to find his/her way around the simulation.

Inclusiveness & Malleability

Inclusiveness refers to the design being inviting making the user want to use it (Cooley p. 68). To incorporate inclusiveness, the simulation has a welcome page that features an inviting message to the students introducing the simulation. This is followed with clear learning objectives that explain the educational purpose of the simulation along with the activity to follow to familiarize them with what to expect. As per Cooley (p.68) malleability is providing the possibility to mold the situation to suit, to pick-and-mix and
sculpt the environment to suit one’s own instrumental needs, aesthetic tastes and craft traditions. To integrate this characteristic of design, each page of the simulation has clear navigational buttons (HOME, PREVIOUS, and NEXT) to move sequentially or nonlinearly within the simulation. Inclusiveness & malleability is incorporated in the Welcome section shown in Figure 2.

Figure 2 - Screen shot of the Welcome section of the simulation. This screen shot shows that the simulation utilizes inclusiveness by featuring an inviting message to the students introducing the simulation. The screen shot also shows that the simulation utilizes malleability offering students clear navigational buttons to move sequentially or nonlinearly within the simulation.

Welcome to the Photosynthesis Simulation

Objectives
Hello and welcome to this physical simulation on photosynthesis. It is designed to help you learn the meaning of photosynthesis, the parts of photosynthesis, the process of photosynthesis, the photosynthesis formula, and why photosynthesis is important to green plants and living organisms.

Navigation
To move through the simulation, please use the buttons: HOME, PREVIOUS, and NEXT near the bottom of each page. To control animations and video, please use the play, stop, and repeat buttons.

Additional Information
There are also rollovers, additional information for you that appears when your mouse rolls over a word or image. When you have completed the simulation, please check out the links in the resources page. Just click on a link to connect to the referenced site. To view this simulation again, the website address is at http://www.baranmammothdesignstudio.com

Engagement

Engagement references users’ sense of feeling involved, being able to participate in the process and being emotionally connected (Cooley p. 68). To include engagement within the pages that makeup the thesis project, instructional supports, animation, video, and instant feedback is included to make using it relevant to users, a characteristic of engagement as mentioned earlier in the reviewed literature section. User involvement is
important and one example of it within the simulation is in the Opening Question section. The Opening Question section is created and used to establish the scenario for the lesson. It is a textual opening asking students if he/she knows that organisms (living things) are dependent on green plants and trees. Students can choose either yes or no and will be given instant feedback using a rollover. A rollover is a button created to provide interactivity between the user and the page itself. If the student chooses yes, he or she will see a statement that says “That Is Correct” followed by the assertion “Green plants and trees do provide organisms with food and oxygen that they make on their own through the process of photosynthesis.” If the student chooses no, he or she will see a statement that says “That Is Incorrect” followed by the assertion “Green plants and trees do provide organisms with food and oxygen that they make on their own through the process of photosynthesis.” Engagement is incorporated into the simulation in the Opening Question section shown in Figure 3.

Figure 3 – Screen shot of the Open Question section of the simulation. This screen shot shows that the simulation utilizes engagement by incorporating buttons for users to control the simulation and to participate and feel involved while using it.
Ownership

According to Mike Cooley (p. 68), ownership is when a user feels that he/she has a sense of belonging and companionship. To incorporate this element of Human-Centered Design Theory in the project, the simulation offers a customizable option in using it by using clear navigational buttons to move sequentially or nonlinearly within the simulation. Even after the instructor has pointed out the linear way to maneuver through the simulation to parallel the order that the direct instruction was taught the day prior, the user has the option to do everything their way and not view the simulation linearly. Offering more than one choice on sections of the simulation such as controlling a video or controlling an animation or having the directions signed via video as oppose to reading them offers the user another avenue for taking ownership of the design by allowing them to choose how they learn. Ownership has been incorporated throughout the simulation and one example is shown in Figure 4.

Figure 4 – Screen shot of the Photosynthesis Parts section of the simulation. This screen shot shows that the simulation utilizes ownership by offering users customizable options to control it from clear navigational buttons to move sequentially or nonlinearly within the simulation to buttons used to play and stop the video and animation.
Responsiveness

Responsiveness is when the system responds to the user’s needs and ways of doing things (Cooley p. 68). In the project, when a user wants to see how the process of photosynthesis occurs and clicks on action buttons to start, stop, and replay, the simulation responds to the user’s needs and displays that content. If the user wants to see only one part of photosynthesis simulated, the simulation will respond to that too by simulating only that selected part. Responsiveness is incorporated in many sections of the simulation. On example is in the Photosynthesis Process section shown in Figure 5.

Figure 5 – Screen shot of the Photosynthesis Process section of the simulation. This screen shot shows that the simulation utilizes responsiveness when a user wants clicks on the action buttons to Start and Stop, the simulation responds to the user’s needs and displays that content. If the user wants to see only one part of photosynthesis simulated, the simulation will respond to that too by simulating only that selected part.

Other sections that the element of responsiveness is demonstrated are in the
Vocabulary subsections and Practice Question section. The Vocabulary section lists vocabulary terms related to photosynthesis. Each Vocabulary subsection is accompanied with a definition that is written, an image of the term, a short video of the teacher signing the written definition, and the term is simulated. This was done for the following definitions: photosynthesis, organism, producers, consumers, light energy, carbon dioxide, water, chlorophyll, chloroplast, roots, and leaves. Responsiveness can be found in the Practice Question section in which students are given instant feedback when he or she answers a question by choosing an answer provided. The simulation responds differently based upon which answer the student chooses. Example of the Vocabulary subsection demonstrates responsiveness shown in Figure 6, and in Figure 7 shows an example of the Practice Questions section in which responsiveness has been incorporated into the simulation.

Figure 6 - Screen shot of the Vocabulary subsection “Chloroplast” of the simulation. This screen shot shows that the simulation utilizes responsiveness when a user wants clicks on the action buttons to Start and Stop, the simulation responds to the user’s needs and displays that content.
Purpose

Purpose references the characteristic of Human-Centered Design Theory in which the system is capable of responding to the purpose the user has in mind and then encouraging him or her to go beyond it (Cooley p. 70). The purpose of the simulation will be for the user to use the simulation to learn about photosynthesis. Including a Practice Questions section that students can use to gauge his/her learning has incorporated the element of purpose. Students have an opportunity after using the simulation to answer multiple-choice questions and receive instant feedback if they have answered correctly or incorrectly to assess their learning and to review for the quiz later. Purpose has been incorporated throughout the simulation and in this project is meant to be used to teach students who need to learn photosynthesis in the 8\textsuperscript{th} grade science class. An example how
purpose has been incorporated into the simulation is in the Practice Questions section shown in Figure 8.

Figure 8 - Screen shot of the Practice Questions section of the simulation. This screen shot shows that the simulation utilizes purpose by offering students questions to review material taught in class for the purpose of learning photosynthesis and assessing his/her comprehension of the material taught.

Panoramic & Transcendence

Panoramic refers to encouraging users to acquire boundary knowledge to take what they are doing in the understanding of a wider context. Transcendence references how the user should be engaged, enticed, and provoked to go beyond the immediate task, (Cooley p. 70). Both of these characteristics have been taken in account with the placement of the Resources section for encouraging students to visit other sites on photosynthesis for more knowledge of the subject. These sites have been listed for students to visit them outside
of school or in class if they finish the simulation early. Panoramic and transcendence has been incorporated in the Resources section shown in Figure 9.

**Figure 9 - Screen shot of the Resources section of the simulation.** This screen shot shows that the simulation utilizes panoramic by offering students links to Websites on photosynthesis to encourage students to acquire more knowledge and understanding of the subject. The screen shot also shows that the simulation utilizes transcendence by offering the same links on photosynthesis to entice students to go beyond just using the simulation to learn photosynthesis.
VI. PROJECT IMPLEMENTATION:

The field-testing of the simulation was conducted in four days with two deaf middle school science classes. Because of time constraints and small class sizes that are typical in schools for the deaf, this case study was done on a very basic level. For the purpose of privacy, both the instructor and students’ names remain anonymous in this thesis project and are referenced as “Teacher” or “Student” followed by a number to distinguish one student from another. The same anonymity was given to the school the project was conducted in using the pseudo name “Target School”. Of the two science classes in the study, one class was assigned as the teacher-centered class and the other as the student-centered class. In the teacher-centered class the teacher directed the instruction and taught and in the student-centered class, students used the simulation to learn on their own and the teacher served more as a manager of class time.

Teacher-Centered Class

The first group consisted of three deaf middle school students taught in a teacher-centered class at 10:15 in the morning, which I will refer as Students 1, Student 2, and Student 3. On Day 1, the students were given a pre-test to assess his/her knowledge of photosynthesis prior to instruction. The teacher took about 15 minutes and signed each question and answer until she read and signed the last question. The teacher then collected the exams and asked students if he/she knew or had seen the word photosynthesis signed. Student 1, Student 2 and Student 3 did not know the meaning of the word, however, Student 3 remembered the word signed to her once before by a different teacher a year ago. The teacher then asked the students to take out their textbooks and look at some of the static images of vocabulary related to photosynthesis.
The teacher had each student take turns signing (reading aloud) a section in the textbook and would explain to him or her what he or she had read, meant. This continued for most of the period along with her writing key terms and definitions on the whiteboard that students copied onto graphic organizers for them to study for a quiz the next day. Occasionally, the teacher would reference a model of a plant cell to show where chloroplasts were located, which is the place where photosynthesis occurs in plants and to explain the term chlorophyll. Students in the class taught without the simulation exhibited signs of fatigue and anxiety; two yawned openly and a third got up twice to get water from the sink in the classroom. The students appeared as though the students had been tired or bored from the lecture or from concentrating to hard when watching the teacher sign. To redirect this behavior the teacher had Student 1 and Student 3 sign (read aloud) another paragraph from the textbook each time they would show signs of tiredness or boredom. Students were taught the process of photosynthesis using overhead transparencies with the necessary parts: light energy, water, and carbon dioxide printed on them and placed on top of one another. The lesson ended with students copying the photosynthesis formula as written on the whiteboard onto his/her graphic organizer.

On Day 2, the students were given a quiz on the material taught on Day 1 using questions from the pre-test but in different order. This quiz was also signed to the students. Students were then introduced to the Flash-based physical simulation created for this thesis project. The instructor used the simulation to teach her lesson on photosynthesis and first did so linearly, starting at the Contents section where she then used the “NEXT” button on each section to navigate through the simulation until the class reached the practice questions section. The teacher had each student take turns
controlling the simulation while she explained the information on each section. Unlike Day 1, Student 1 and Student 3 show signs of excitement when using the simulation and did not yawn, get water, or appear bored. Student 2 was more excited too. In fact, the three students appeared more motivated to learn with the simulation than when taught without it. An example of this was when they watched the videos of the teacher sign the information in all the sections of the simulation; they appeared interested and never lost eye contact. However, when the students watched the teacher sign the same information on photosynthesis in real life the previous day, they showed signs of being tired and would look down or get out their seat and miss parts of the lesson.

One important observation made during this project while the teacher and the students used the simulation together was that the teacher had not only used the simulation to teach photosynthesis but had also used it to teach students how to study with it. In the Practice Questions section, students each took turns controlling the simulation to answer questions. Some of the questions relating to the vocabulary were difficult for the students to answer at first. The teacher demonstrated to the students to click the “HOME” button to navigate back to the contents section then to select the Vocabulary section, then the vocabulary term was listed as one of the answer choices. Students then could watch the video and see the term simulated to review the information taught in class. The teacher also showed the students how to return to the Practice Questions section to answer the question they were stumped on. This was done when students wanted to answer the question correctly the first time and when they answered them wrong and needed to review why the answer they chose was incorrect.
Near the end of class, the instructor had the students each choose a different URL Web address to supplement her lesson and offer the students transcendence. Transcendence refers to how the user should be engaged, enticed, and provoked to go beyond the immediate task, (Cooley p. 70). On separate computers running the simulation, students were asked to click on a different link and explore the Website. This exposed the students to other sources on photosynthesis that they might like in addition to the simulation used in class. On Day 3, students took a post quiz with the same questions administered on Day 2. This too was signed for them. The students then filled out a survey with questions created using principles of Human-Centered Design Theory as a guide to discover what the students liked and remembered from the simulation to assess the benefits it had on deaf students after they used it. On Day 4, one student was interviewed to further discuss both the simulation and his/her reaction to it.

**Student-Centered Class**

The second group consisted of two deaf middle school students taught in a student-centered class at 11:00 in the morning, which will be referred to as Student 4 and Student 5. On Day 1, the students were given the same pre-test given to Student 1, Student 2, and Student 3 to assess his/her knowledge of photosynthesis prior to instruction. The teacher took about 15 minutes and signed each question and answer until she read and signed the last question. The teacher then collected the exams and asked students if he/she knew or had seen the word photosynthesis signed. Student 4 could not remember and Student 5 had signed he learned about it in another class last year. Students then were told by the teacher they would use a simulation to learn photosynthesis, and she explained what a simulation was. The teacher then asked the two students to sit at one of two computers
with the simulation running, which were on opposite sides of the classroom. The two students started to argue with one another of who would get to use the computer connected to the projector by the whiteboard. This bickering lasted for seven minutes. Student 4 won the argument and remained by the whiteboard while Student 5 used the computer near the window.

The simulation was used very differently from how the simulation was used in the teacher-centered classroom. Student 4 began to complain and yell that she did not have to use the simulation and that the teacher was being lazy having Student 4 teach herself. Student 4 even complained that photosynthesis was not even related to material taught in the 8th grade science class. The teacher redirected Student 4’s behavior by showing her this year’s 8th grade science exam that Student 4 took a week ago, and the teacher pointed to the questions on photosynthesis that Student 4 answered wrong. Student 4 calmed down and proceeded to try the simulation. As the class period went on, Student 4 appeared to be using the simulation to learn by first watching the videos of the teacher signing the information in each section and viewing the vocabulary terms simulated. She even used the simulation linearly starting at the beginning and moving through each section in order. However, after Student 4 completed the Vocabulary subsections, she returned back to the Welcome section. She began to play with the video controls to manipulate the teacher in the video to repeat the word “Hello” which would constantly be played very loud through the auditory system in the classroom placed for hard of hearing students. She continued to do this to get the attention of the teacher and to annoy her. Student 4 continued to laugh and play this phrase over and over. The teacher tried to redirect Student 4’s behavior and the student quit using the simulation entirely. She did
not reach the Summary section used to review information on photosynthesis, did not attempt the Practice Questions to prepare for the next day’s quiz, and did not bother trying the links in the Resource section.

Student 5’s behavior and usage of the simulation was better than Student 4’s but he too did not take it seriously and did not complete the entire simulation. Student 5 was went through the simulation very quickly, only clicking the “NEXT” button without regard for reading the information, playing the signed video, or viewing the information simulated. It was as if he was trying to preview the simulation in its entirety and quickly first before playing any video or animations. Student 5 then moved through the simulation nonlinearly and later returned to the Welcome section. This was the only video signed that he chose to watch. While viewing the video, he began to laugh and wave back at the teacher almost taunting her because she was on video. He then skipped most of the simulation and chose only to use the Vocabulary subsections and the Practice Questions. He too did not attempt to view the Summary section nor the Resource section with links to different websites for additional information on photosynthesis. He stopped using the simulation before the class period was over.

On Day 2, the students took a post quiz with the same questions administered on Day 1 but in different order. The teacher signed this quiz too. The students then filled out a survey with questions created using principles of Human-Centered Design Theory as a guide to discover what the students liked and remembered from the simulation to assess the benefits it had on deaf students after they used it. On Day 3, one student was interviewed to further discuss both the simulation and his/her reaction to it.
VII. DATA & FINDINGS

Static Media vs. Dynamic Media

After collecting the data from observations, pre-tests and post-tests, surveys, and interviews, qualitative responses were developed and then organized into figures and tables and were reviewed. From these responses, themes were identified from the results of this project that are mentioned in the Conclusion & Further Research section of this paper.

Looking first at the grades from the exams given to the students in the teacher-centered class, it is clear that the simulation benefited the three deaf students. There is a gradual increase between the pre-test, post-test after learning with static media (lecture and textbooks), and from the post-test after learning with dynamic media (simulation). Figure 10 below clearly shows this. Figure 10 also shows that students in the teacher-centered class benefited more from using dynamic media (simulation) over static media (lecture and textbooks). However, between the two methods of instruction, dynamic media proved to be more beneficial by a small percentage.

Figure 10 - Teacher-Centered Class Exam Data
This graph shows the scores from exams given to students in the teacher-centered class. Students scored highest when after using the simulation. The graph also shows students scored higher after using the simulation than after being taught with static media.
When compared to students from the student-centered class who were given only a pre-test and post-test after learning with dynamic media (simulation) the similar trend occurred. The students in the student-centered class also did better using the simulation. Figure 11 below shows this.

**Figure 11 - Student-Centered Class Exam Data**

This graph shows the scores from exams given to students in the student-centered class. Students scored higher after using the simulation than on the pre-test.

![Exam Scores From The Student-Centered Class](image)

In both tables, the scores with the exception of Student 5 appear low. The findings might be because of Student 1, Student 2, Student 3, and Student 4’s low reading level and delay in cognitive development, which is a common characteristic of the deaf population. Students who are deaf and hard of hearing read at much lower levels than their hearing peers, and their vocabulary is much smaller.

Regardless of whether they speak or sign, the median reading level of deaf students indicates sub par achievement. Approximately 10% of deaf students read beyond an eighth grade level (Traxler, 2000).

According to (Parasnis, Samar, & Berent, 2001) “Many deaf students appear to exhibit weaknesses in attention and immature social behaviors. These behaviors may be a result of the impact of the hearing loss and communication struggles on social-emotional
development,” (p. 260). Another characteristic of the deaf population that might be reflected in the exam scores is that deaf students often have an additional disability that hinders their learning (Guardino, 2008). Students who participated in this study had additional disabilities other than deafness which included Asperger Syndrome, minor Cerebral Palsy, Attention Deficit Hyperactivity Disorder (ADHD), and Oppositional Defiance Disorder (ODD) all made record in each student’s Individual Education Program (IEP). An IEP is assigned to all special education students by law who at the target school are classified because of their deafness.

When examining the post-tests to compare the mean scores of the two classes, the results showed the simulation was more beneficial to deaf students in a student-centered class than in a teacher-centered class. Figure 12 below shows this.

Figure 12 - Comparison of Post Exam Data After Simulation
This graph shows the scores from exams given to students in the teacher-centered class and student-centered class. Students in the student-centered class scored higher after using the simulation than students in the teacher-centered class.
Evaluation of Student Comprehension

Now having determined that deaf students benefit from using simulations to learn, it was important to identify questions students answered incorrectly to both improve upon the simulation and advise the teacher which areas her lesson on photosynthesis needed reviewing or made more clear for the students. Table 1 below shows the break down of questions answered correctly and incorrectly and the section in the simulation where information was in referenced to the question.

Table 1 - Comparison of Post Exam Questions
This table shows which questions were answered correctly and incorrectly on the post exam after using the simulation by students in the teacher-centered class (TCC) and student-centered class (SCC). The results are varied except for questions 1, 2, 5 & 10, which students answered correctly and questions 9 and 14, which all students answered incorrectly. Incorrect answers are bolded.

<table>
<thead>
<tr>
<th>Question</th>
<th>(TCC) Student 1 Answer</th>
<th>(TCC) Student 2 Answer</th>
<th>(TCC) Student 3 Answer</th>
<th>(SCC) Student 4 Answer</th>
<th>(SCC) Student 5 Answer</th>
<th>Simulation Section(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>Parts of Photosynthesis</td>
</tr>
<tr>
<td>2</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>Vocabulary</td>
</tr>
<tr>
<td>3</td>
<td>correct</td>
<td>incorrect</td>
<td>correct</td>
<td>incorrect</td>
<td>correct</td>
<td>Vocabulary</td>
</tr>
<tr>
<td>4</td>
<td>correct</td>
<td>incorrect</td>
<td>correct</td>
<td>incorrect</td>
<td>correct</td>
<td>Opening Question</td>
</tr>
<tr>
<td>5</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>Vocabulary</td>
</tr>
<tr>
<td>6</td>
<td>correct</td>
<td>incorrect</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>Parts of Photosynthesis</td>
</tr>
<tr>
<td>7</td>
<td>incorrect</td>
<td>incorrect</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>Vocabulary</td>
</tr>
<tr>
<td>8</td>
<td>correct</td>
<td>correct</td>
<td>incorrect</td>
<td>incorrect</td>
<td>incorrect</td>
<td>Vocabulary</td>
</tr>
<tr>
<td>9</td>
<td>incorrect</td>
<td>incorrect</td>
<td>incorrect</td>
<td>incorrect</td>
<td>incorrect</td>
<td>Vocabulary</td>
</tr>
<tr>
<td>10</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>Vocabulary/Process of Photosynthesis</td>
</tr>
<tr>
<td>11</td>
<td>incorrect</td>
<td>correct</td>
<td>incorrect</td>
<td>incorrect</td>
<td>correct</td>
<td>Vocabulary</td>
</tr>
<tr>
<td>12</td>
<td>correct</td>
<td>incorrect</td>
<td>correct</td>
<td>correct</td>
<td>correct</td>
<td>Vocabulary/Process of Photosynthesis</td>
</tr>
<tr>
<td>13</td>
<td>correct</td>
<td>incorrect</td>
<td>correct</td>
<td>incorrect</td>
<td>correct</td>
<td>Process of Photosynthesis</td>
</tr>
<tr>
<td>14</td>
<td>incorrect</td>
<td>incorrect</td>
<td>incorrect</td>
<td>incorrect</td>
<td>incorrect</td>
<td>Vocabulary</td>
</tr>
<tr>
<td>15</td>
<td>incorrect</td>
<td>incorrect</td>
<td>incorrect</td>
<td>correct</td>
<td>correct</td>
<td>Vocabulary</td>
</tr>
</tbody>
</table>
From the incorrect answers bolded, all the students need more review for questions 9 and 14 referenced in the Vocabulary section of the simulation. Question 9 asked, “What word means organisms that make their own food?” The answer is producers. The term was simulated with trees, flowers, and plants growing but may have served students better having shown fruit growing on plants and trees. Question 14 asked, “What word means gas produced by animals when they breathe out waste air?” The answer is carbon dioxide. The term was simulated with animals breathing out carbon dioxide while near a lake. This simulated term might have served students better having shown animals both breathing in oxygen and breathing out carbon dioxide to differentiate the two. All the students had chosen the incorrect answer, oxygen. Other questions that more than one student answered incorrectly were questions: 3, 4, 7, 8, 11, 13, and 15. These questions were in reference to the Opening Question, Vocabulary, and Process of Photosynthesis sections. These sections will need to be reevaluated and changed for future use.

**Students’ Responses To Simulation**

In addition to tests, a survey was given to all the students to establish what deaf students like, what they responded to, and how well they comprehended information presented in a simulation. The survey questions varied by students rating specific aspects of the simulation: visual design, signed videos, simulated animations, content, navigation, and the overall simulation. Below in Figure 13 are results from the survey based upon students’ ratings of the specific aspects of the simulation mentioned above on a scale of 1-5.
The ratings show that the majority feeling of using the simulation to learn photosynthesis in both classes was positive. The visual design, the videos of the teacher signing the lesson, and the simulated animations were favored more in the teacher-centered class than in the student-centered class. Looking at the students responses to content, navigation, and understanding of the information, in both classes they are the same with the rating or 4/5. Future improvement to the simulation may need to be made in those areas and improvement to the simulated animations, which was given a rating of 3.5/5 by students in the student-centered class. More in depth questions about what students could recall after using the simulation, how he/she used components of the simulation and the number of times he/she used certain components of the simulation were also asked in the survey.

In summary, students in both classes were asked to rate the simulation’s visual design, the signed videos, the simulated animations, the content taught, their ease when using the navigation within the simulation, their understanding of photosynthesis after using the simulation, and their overall impression of the simulation. Students used a scale of 1-5, 5 being great and 1 being poor to rate each aspect of the simulation. Students in the
teacher-centered class rated the following aspects of the simulation in order of highest to lowest: signed videos 5/5, simulated animations 5/5, visual design 4.7/5, overall use of simulation 4/5, content 4/5 navigation 4/5, and understanding 4/5. Students in the student-centered class rated the following aspects of the simulation in order of highest to lowest: visual design 4/5, signed videos 4/5, content 4/5, navigation 4/5, understanding 4/5, overall use of the simulation 4/5, and simulated animations 3.5/5.

Table 2 - Students’ Survey Responses to the Simulation

This table shows the survey results based upon students’ ratings of which aspects helped them use the simulation and remember content taught in class using a scale of 1-5. 5 = Very helpful, 4/5 = Helpful, 3/5 = somewhat helpful, 2/5 = Not very helpful, and 1 = Not helpful. The table also shows responses students chose from the survey to answer questions in relation to how students used the simulation.

<table>
<thead>
<tr>
<th>Question #</th>
<th>Student 1 Response</th>
<th>Student 2 Response</th>
<th>Student 3 Response</th>
<th>Student 4 Response</th>
<th>Student 5 Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2/5 Not very helpful</td>
<td>4/5 Helpful</td>
<td>4/5 Helpful</td>
<td>3/5 Somewhat helpful</td>
<td>2/5 Not very helpful</td>
</tr>
<tr>
<td>4</td>
<td>1/5 Not helpful</td>
<td>3/5 rating Somewhat helpful</td>
<td>2/5 rating Not Very Helpful</td>
<td>2/5 Not very helpful</td>
<td>1/5 Not helpful</td>
</tr>
<tr>
<td>5</td>
<td>“I have never used simulations before.”</td>
<td>“I have never used simulations before.”</td>
<td>“I have never used simulations before.”</td>
<td>“I have never used simulations before.”</td>
<td>“I have never used simulations before.”</td>
</tr>
<tr>
<td>6</td>
<td>“The information made sense but was not in an order that was easy to follow.”</td>
<td>“The information made sense but was not in an order that was easy to follow.”</td>
<td>“The information made sense but was not in an order that was easy to follow.”</td>
<td>“The information made sense but was not in an order that was easy to follow.”</td>
<td>“The information made sense but was not in an order that was easy to follow.”</td>
</tr>
<tr>
<td>7</td>
<td>“The background color made the text, pictures, video, and animations easy to see and read.”</td>
<td>“The background color made the text, pictures, video, and animations easy to see and read.”</td>
<td>“The background color made the text, pictures, video, and animations easy to see and read.”</td>
<td>“The background color made the text, pictures, video, and animations easy to see and read.”</td>
<td>“The background color made the text, pictures, video, and animations easy to see and read.”</td>
</tr>
<tr>
<td>8</td>
<td>“It was easy to see and made sense.”</td>
<td>“It was easy to see and made sense.”</td>
<td>“It was easy to see and made sense.”</td>
<td>“It was easy to see and made sense.”</td>
<td>“It was easy to see and made sense.”</td>
</tr>
<tr>
<td>10</td>
<td>“I started at the first section (home page) and went to each section of the simulation in order clicking next on each page.”</td>
<td>“I started at the first section (home page) and went to each section of the simulation in order clicking next on each page.”</td>
<td>“I started at the first section (home page) and went to each section of the simulation in order clicking next on each page.”</td>
<td>“I started at the first section (home page) and clicked next to go in order but later changed my mind and returned to the homepage to not go in order.”</td>
<td>“I started at the first section (homepage) and clicked next to go in order but later changed my mind and returned to the homepage to not go in order.”</td>
</tr>
<tr>
<td>11</td>
<td>“I read the information and watched the information signed in the video.”</td>
<td>“I watched the information signed in the video.”</td>
<td>“I read the information and watched the information signed in the video.”</td>
<td>“I read the information.”</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>“I played the signed video then the animation.”</td>
<td>“I played the signed video then the animation.”</td>
<td>“I played the animation than the signed video.”</td>
<td>“I played the animation than the signed video.”</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>“I played each animation all the way through.”</td>
<td>“I played each animation all the way through.”</td>
<td>“I played each animation all the way through.”</td>
<td>“I played each animation all the way through.”</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>“I played the animations twice.”</td>
<td>“I played the animations more than 2 times.”</td>
<td>“I played the animations twice.”</td>
<td>“I played the animations once.”</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>“I played the signed videos once.”</td>
<td>“I played the signed videos once.”</td>
<td>“I played the signed videos once.”</td>
<td>“I played the signed videos once.”</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>“Water, environment, and plants.”</td>
<td>“I remember some.”</td>
<td>“Carbon dioxide, light energy, and water.”</td>
<td>No response</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>No response</td>
<td>No response</td>
<td>“Food, home, and air.”</td>
<td>“Food”</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>1/5 Not helpful</td>
<td>1/5 Not helpful</td>
<td>3/5 Somewhat helpful</td>
<td>1/5 Not helpful</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>“Cows, plants, and rain.”</td>
<td>“Plants, people, and animals.”</td>
<td>“Plants, trees, and sun.”</td>
<td>“Plants, sun, and rain.”</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>5/5 Very helpful</td>
<td>5/5 Very helpful</td>
<td>4/5 Helpful</td>
<td>3/5 Somewhat helpful</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>4/5 Helpful</td>
<td>4/5 Helpful</td>
<td>4/5 Helpful</td>
<td>3/5 Somewhat helpful</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>5/5 Very helpful</td>
<td>4/5 Helpful</td>
<td>4/5 Helpful</td>
<td>3/5 Somewhat helpful</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Light energy, water, leaves, roots, and consumers</td>
<td>Photosynthesis, water, organism, leaves, roots, producers, and consumers</td>
<td>Photosynthesis, light energy, water, chloroplast, organism, leaves, roots, producers, and consumers</td>
<td>Photosynthesis, light energy, water, leaves, roots, and consumers</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>4/5 Helpful</td>
<td>4/5 Helpful</td>
<td>4/5 Helpful</td>
<td>1/5 Not helpful</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>3/5 Somewhat helpful</td>
<td>3/5 Somewhat helpful</td>
<td>4/5 Helpful</td>
<td>1/5 Not helpful</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>5/5 Very helpful</td>
<td>5/5 Very helpful</td>
<td>5/5 Very helpful</td>
<td>1/5 Not helpful</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>“Words need to be bigger.”</td>
<td>No response</td>
<td>“Needs to have bigger words.”</td>
<td>No response</td>
<td></td>
</tr>
</tbody>
</table>

Reviewing the responses from Table 2, deaf students may need more time to construct meaning, simpler language to remember vocabulary, larger text for easier reading, and more practice using the simulation. Paul (2003) noted deaf students have difficulty with
text and reader-based skills. Text based skills include word identification, vocabulary, syntax, and figurative language. Reader-based skills include working memory, metacognition, and prior knowledge. These skills are essential to literacy learning and literacy is the strongest predictor of success in education of deaf children (Barker 2003). Reviewing the table in more depth, this study found that students were in agreement for questions 5, 6, 7, 8, 9, 13, and 15. The responses to the rest of the questions were mixed. Students agreed that the information made sense in the simulation but was not in an order that was easy to follow. This issue dealt with the principle of coherence; can the user make sense of the design and find his/her way through it? Prior to creating the simulation and after speaking with the teacher, it had been predicted that students using this simulation would have familiarity because it was designed to look very similar to a website, and students have some familiarity using websites to do research information in other classes as well as surf the Web outside of school. Another factor that may have contributed to this response was that all the students had never used a simulation and some were nervous before using it. It is important to work more to improving the integration of the principle of coherence the next time the simulation is to be used or for future research.

Similar responses recorded in the survey from students were that the visual design itself made seeing and reading information easier. All the students were able to find information from sections within the simulation relating to photosynthesis and it made sense to them. Every student played at least one video and simulated animation all the way through. One thing to note that did not seem as valuable as other components in the simulation was the word photosynthesis highlighted in green. Most students’ response
was that it did not really help them remember the word photosynthesis. That was surprising since highlighting words is a technique to identify main ideas and for identifying organizational patterns. Photosynthesis was purposefully highlighted in green for that reason.

Differences between student responses had been how they had used the simulation either linearly throughout, nonlinearly throughout, or linearly first and then nonlinearly. Because the teacher directed the instruction in the teacher-centered class, students used it linearly for the most part where in the student-centered class students used it more nonlinearly. The number of times students played the simulated animations was different. Students in the teacher-centered class were more excited to watch and play them that the number of times simulated animations were played were higher than when played in the student-centered class. There was even a difference in the correct information students recalled from the simulation when asked fill in the blank questions. Student 3 and Student 5 seemed to recall the most from the simulation out of the five students who used it. Another difference was that when the simulation was used in a teacher-centered class the students valued the simulated animations more than when they were used in the student-centered class. Students in the student-centered class gave low ratings for the animations aiding them in remembering vocabulary and the parts needed for photosynthesis. The opposite was true in the teacher-centered class.

Another set of questions were asked to one student from each class in interviews of 30 minutes to identify which principles of Human-Centered Design Theory were beneficial to deaf students after using the simulation. Below in Table 3 are some of the responses.
<table>
<thead>
<tr>
<th>HCD Principle</th>
<th>Sample Positive</th>
<th>Sample Neutral</th>
<th>Sample Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coherence - the user has understanding</td>
<td>No Response</td>
<td>“The information made sense but was not in an order that was easy to follow.”</td>
<td>“I would have liked the links at the top of the simulation rather than at the bottom.”</td>
</tr>
<tr>
<td>Malleability - the user has choices</td>
<td>“I liked that the simulation had a video in each section of the teacher signing I did not have to read the text.”</td>
<td>No Response</td>
<td>“I did not like having the video and text together. It made everything look crowded. I would prefer the text only next time.”</td>
</tr>
<tr>
<td>Inclusiveness - the simulation is inviting to the user</td>
<td>“The welcome section where the teacher signed the directions made me less nervous of trying to use the program. Seeing her sign the meanings of the words was a relief”</td>
<td>“I wasn’t nervous and did not need to have the directions signed. I was able to use the simulation on my own.”</td>
<td>No Response</td>
</tr>
<tr>
<td>Engagement – sense of feeling involved</td>
<td>“I like being able to play the cartoons more than once. I felt like I was in control.”</td>
<td>No Response</td>
<td>No Response</td>
</tr>
<tr>
<td>Ownership – the user has control</td>
<td>“I liked being able to skip sections using the buttons at the bottom of the page.”</td>
<td>No Response</td>
<td>“I did not like the buttons on the vocabulary section. I would click on a vocabulary word and when I wanted to go back to the main vocabulary section I could not by clicking the ‘previous’ button but had to go back to the contents page then click the vocabulary link. It was frustrating.”</td>
</tr>
<tr>
<td>Responsiveness - the simulation responds to the user</td>
<td>“I really liked the practice questions and it being multiple choice. I also liked that the program told me if I was right or wrong after I chose an answer.”</td>
<td>No Response</td>
<td>No Response</td>
</tr>
<tr>
<td>Purpose – the simulation serves the user’s reason for using it</td>
<td>“This simulation helped me learn the parts of photosynthesis and its process.”</td>
<td>“I already knew what photosynthesis was but the cartoons helped me remember some of the vocabulary.”</td>
<td>No Response</td>
</tr>
<tr>
<td>Panoramic - the simulation encourages the user to acquire additional knowledge</td>
<td>I liked one of the links in the resource section that we visited in class. It had different pictures.”</td>
<td>No response</td>
<td>“I saw the links but I did not click on any of them. I really didn’t care to try them. I felt the simulation was enough.”</td>
</tr>
<tr>
<td>Transcendence - the simulation entices and encourages the user</td>
<td>I liked one of the links in the resource section that we visited in class. It had different pictures.”</td>
<td>No Response</td>
<td>“I saw the links but I did not click on any of them. I really didn’t care to try them. I felt the simulation was enough.”</td>
</tr>
</tbody>
</table>
Looking at Table 3, most of the comments were positive about the simulation. Principles of Human-Centered Design Theory that did not have negative responses and were identified beneficial to deaf students learning with this project’s simulation but maybe subject to further study were inclusiveness, engagement, responsiveness, and purpose. Inclusiveness incorporated in the design benefited students when they used the Welcome section in which the teacher invited her students to the simulation and explained the objectives and directions in a warm and encouraging manner. These techniques appeared to have a positive effect; students appeared more relaxed. The second principle of HCD to benefit deaf students was engagement, which was incorporated in all of the simulation by providing students opportunities to control it with different buttons. The third principle of HCD that benefited deaf students using this simulation was responsiveness, especially students who used the Practice Questions section to review and were given instant feedback when they selected an answer to a question. The fourth principle of HCD that benefited deaf students was purpose. Students responded by stating that the simulation helped them understand and remember the parts of photosynthesis and the process of photosynthesis.
IX. CONCLUSIONS & FURTHER RESEARCH

After reviewing the data from the tests, the field notes, the responses from the surveys, and interviews, the overwhelming reaction to the simulation has been positive. Some of the themes that have surfaced have been that deaf students may benefit from using simulations to learn in school and that teaching deaf students with only static media (lectures & textbooks) may not be the best option. Another theme from this project is that deaf students may benefit from simulations when they are welcomed and invited to use them, are able to find their way around them, feel involved using them, are able to make simulations respond instantly and consistently while controlling them, and if simulations serve the students’ purpose for using them. Other themes discovered from this project were how students used the simulation, how many times they viewed different parts of the simulation, and even the difference in behavior and enthusiasm students showed when the simulation was used in a teacher-centered class and in a student-centered class.

In the teacher-centered class the simulation was used the same since the teacher directed the instruction. Students used the simulation linearly, watched each video of the teacher signing and simulated animation, tried the questions, and visited the links from the Resource section until the class period ended and even for five minutes after. At various points in the class, students watch the simulated animations more than once and did so enthusiastically. When the students reached the Practice Questions section, the teacher taught the students to use the simulation to study with. She showed them how to navigate nonlinearly through the simulation using the “HOME” button to connect to the Contents section, then demonstrated where to locate the information to the question, and how to return back to the Practice Questions section to answer the question. The students
then each followed her example whenever they were unsure of the answer to the question they had chosen. It should be noted that Student 1 in the teacher-centered class responded the next day by stating she had tried the simulation outside of school at the Website address provided to her by the teacher. She mostly used it to watch the simulated animations. This was encouraging because the simulation was seen by Student 1 valuable enough to use on her own outside of class. If not for nothing, the students were exposed to the information multiple times, and every student can benefit from that, deaf or hearing.

In the student-centered class the opposite occurred. Both students did not take using the simulation seriously and even used it to distract and annoy the teacher. Student 4 complained at first and refused to use it. She then agreed to try it after the teacher redirected her. Student 4 and Student 5 viewed the simulation differently too. Student 4 and Student 5 had used it nonlinearly for the most part. Student 4 and Student 5 played the simulated animations only once. However, at the beginning of using the simulation, Student 5 did go through it linearly but did so with no regard for understanding it and did so within seconds. Student 5 used only the sections: Welcome, Vocabulary, Process of Photosynthesis, and Practice Questions. Student 4 had used only the sections: Welcome, Opening Question, Vocabulary and then quit after being redirected by the teacher a second time due to her bad behavior. Neither student used the full class period to learn with the simulation nor tried the Summary or Resource sections. Neither student tried it online outside of school but did say they liked it the next day.

The goal for this project was to help deaf students learn the concept of photosynthesis with the creation of a Flash-based physical simulation. It was to identify whether
simulations benefit deaf students and to identify the benefits to deaf students based upon principles of Human-Centered Design Theory. After this project, the conclusion that can be made is that simulations may benefit deaf students learning in schools and that the principles of Human-Centered Design that may benefit them are when coherence, inclusiveness, engagement, responsiveness, and purpose are incorporated into the design of the simulation. However, the data does not truly reflect which class simulations benefit deaf students more. From the post exams between the teacher-centered class and the student-centered class, it appears simulations are more beneficial to deaf students in a student-centered class in which they control their learning and construct meaning on their own. To the contrary, the study found that the teacher-centered class that used the simulation was more beneficial to deaf students. Students were more engaged, motivated, and had used the simulation in its entirety. The teacher’s lesson was more powerful with the dynamic visuals and the simulated animations were more effective when the teacher explained what was occurring and why, directly after they were shown. What was also discovered after the study was that the teacher-centered class was taught before the student-centered class who used the simulation the period before lunch. For future studies, it might be better to have had the teacher-centered class before lunch and the student-centered class at 10:15 to keep all the students focused. It may even be better to have had the simulation tested in both classes earlier in the morning or later in the afternoon. Student’s behavior in the student-centered class might have been directly related to being hungry or being unable to focus because of needing medication, which they receive at lunch. It too might have been the anticipation to leave for lunch or uneasiness to work independently the period before it. Other factors that may have
contributed to this finding is that, “Many deaf students appear to exhibit weaknesses in attention and immature social behaviors. These behaviors may be a result of the impact of the hearing loss and communication struggles on social-emotional development,” (Parasnis, Samar, & Berent, 2001 p. 260). Students in the student-centered class may have been struggling emotionally at the time or the teacher-centered class might have been more mature. Another characteristic of the deaf population that might be reflected in the misbehavior of students in the student-centered class is the additional disability of Attention Deficit Hyperactivity Disorder (ADHD) Student 4 is diagnosed with and Oppositional Defiance Disorder (ODD) Student 5 is diagnosed with based upon their IEP. Many students with hearing loss have an additional disability that hinders their learning (Guardino, 2008).

Limitations to this project have been time constraints and delays in implementing the simulation due to student absences, field trips, and half-day schedules with shorten class periods. The simulation itself was not bought but created for this study with specific content from the New York State Education Department (NYSED) 8th grade science curriculum in the program Flash and with direct input from the science teacher who taught the five deaf students in this study. Because it was created in Flash, more options to make the simulation engaging, responsive, and assessable were possible. However, Flash is a demanding program to use that is case sensitive and prone to problems when coding and required many long hours and days to build and tweak. The low number of students tested using the simulation has also limited these findings. In spite of all this, no system problems or possible problems accessing the simulation via Internet occurred when the students used the simulation. This was avoided by placing the simulation on a
CD and then directly on the computers’ hard drive. This eliminated slow bandwidth speeds when playing videos and connection problems when using links to navigate through the simulation. Even with the small tested population of middle school students who attend the target school, there were still trends between both classes. All the students generally liked the simulation, the simulated animations, and the interaction they had with it. After using the simulation, students did better on questions relating to the process of photosynthesis and the parts needed for photosynthesis. Students continued to struggle with vocabulary terms but it’s expected from deaf students because they need constant exposure to material taught and extended time to comprehend it. These students at the target school are not self-learners and are not motivated to learn independently. They need constant reinforcement from the teacher.

With that said, this study looked specifically at the deaf population for the purpose of evaluating the benefits Flash-based physical simulations have teaching deaf students abstract concepts and vocabulary. This study expected to find that simulations benefit deaf students because they tend to be visual learners as Bocher & Bocher (2009) point out, “Since deaf learners rely heavily on visual and printed input to acquire spoken language and literacy skills, it is important for teachers to take advantage of every opportunity to facilitate their students’ visual processing of linguistic information.” This study found that Flash-based physical simulations might benefit deaf students when used in a teacher-centered class under the direction of the teacher. It can also be noted that the simulation was useful for teaching the abstract concept, process of photosynthesis because it was more visual than textual and students were able to view it multiple times. However, the simulation may not be a strong indicator of student comprehension of
subject vocabulary since many students answered questions incorrectly that they had answered correctly in pretests and in post exams given after they were taught with static media. Although, scores on post exams after using the simulation were slightly better than exams given prior to using the simulation. In order for deaf students to comprehend subject vocabulary consistently it may have to be taught many times and much repetition is needed whether static or dynamic media is to be used.

It was believed that simulations would be helpful to deaf students individual needs: such as instruction that is step by step in nature, consistent, engaging, and with specific objectives. Because deaf students have delayed acquisition of vocabulary knowledge and lexicons, acquire new words and narrower range of contexts at slower rates than their hearing peers (Luckner & Cooke 2010) simulations used independently would offer them additional time to learn abstract concepts like photosynthesis. This study found that the majority of students did not independently use the simulation outside of class and when used independently in class, it was not taken seriously. This finding is concurrent to a similar study done by (R. D. Hannafin & Sullivan 1996) which examined the effects of assigning hearing high school students to a computer-delivered geometry program that either matched or did not match their preferred amount of instruction as measured by a preprogram questionnaire. The case findings showed that students under a learner-controlled environment performed more poorly on cognitive tasks than on teacher-directed or program-controlled situations. As stated earlier in this paper, this project’s particular finding maybe from the students’ additional disabilities, immaturity, weakness in attention, delayed emotional development, or the time of day the study was implemented.
Further study of this topic is needed to be done with more deaf students and may need to be done in many deaf schools to form a better conclusion. The research studied in this project was with deaf middle school students. But this study can be taken further if done with deaf students in various grade levels and even with hard of hearing students. A comparison study between deaf and hearing students using the same simulation may also be done to identify the benefits simulations have on both deaf and hearing students that use them and the differences between them. This could lead to more awareness of simulations in the education community and its increased use in schools. Changes that can be made to the simulation can include shortening and simplifying for it to be more focused to the individual needs of the deaf. It may need to be created on a different platform to offer teachers a less challenging program to learn and create simulations with as well as be more familiar and coherent to deaf students. Using simulations as an instructional methodology can be advantageous in deaf education as long as it is created with good principles of design and is teacher guided.
REFERENCES


APPENDIX A: PRE-TEST

Name
Pre-Test

Directions: Please read the question carefully and circle one of the four choices to answer the question.

1. What is the name of the process used by plants to make their own food?
   a. Respiration
   b. Photosynthesis
   c. Consumers
   d. Carbon Dioxide

2. What part or parts are used in photosynthesis?
   a. Carbon Dioxide
   b. Water
   c. Light Energy
   d. All the Above

3. Why are green plants and trees important to organisms?
   a. Green plants and trees make oxygen for organisms.
   b. Green plants and trees make food for organisms?
   c. Green plants and trees are used as shelter (home) for organisms.
   d. All the Above.

4. Which word means living thing?
   a. Carbon Dioxide
   b. Producers
   c. Organism
   d. Light Energy

5. What word means organisms that make their own food?
   a. Producers
   b. Photosynthesis
   c. Consumers
   d. Carbon Dioxide
6. What word means liquid that plants’ roots collect from rain?
   a. Carbon Dioxide
   b. Producers
   c. Water
   d. Consumers

7. What word means energy from the sun?
   a. Light Energy
   b. Photosynthesis
   c. Consumers
   d. Carbon Dioxide

8. What word means gas produced by animals when they breathe out waste air?
   a. Oxygen
   b. Light Energy
   c. Water
   d. Carbon Dioxide

9. What word means organisms that obtain energy by eating other animals, food, or plants?
   a. Organisms
   b. Producers
   c. Consumers
   d. Carbon Dioxide

10. What word means where photosynthesis takes place in the plant?
    a. Roots
    b. Chloroplast
    c. Leaves
    d. Chlorophyll
11. What word means where water enters the plant?
   a. Roots
   b. Chloroplast
   c. Leaves
   d. Chlorophyll

12. What word means where carbon dioxide enters the plant?
   a. Roots
   b. Chloroplast
   c. Leaves
   d. Chlorophyll

13. What word means green pigment color in plants?
   a. Roots
   b. Chloroplast
   c. Carbon Dioxide
   d. Chlorophyll

14. The word photosynthesis comes from which country?
   a. England (English)
   b. France (French)
   c. Japan (Japanese)
   d. Greece (Greek)

15. What is the formula for photosynthesis?
   a. Carbon Dioxide + Sugar + Water = Water + Light Energy
      \[ \text{CO}_2 + \text{O}_2 + \text{H}_2\text{O} = \text{C}_6\text{H}_12\text{O}_6 + \text{Light Energy} \]
   b. Carbon Dioxide + Water + Oxygen = Sugar + Light Energy
      \[ \text{CO}_2 + \text{H}_2\text{O} + \text{O}_2 = \text{C}_6\text{H}_12\text{O}_6 + \text{Light Energy} \]
   c. Carbon Dioxide + Water + Light Energy = Sugar + Oxygen
      \[ \text{CO}_2 + \text{H}_2\text{O} + \text{Light Energy} = \text{C}_6\text{H}_12\text{O}_6 + \text{O}_2 \]
   d. Carbon Dioxide + Light Energy = Sugar + Oxygen + Water
      \[ \text{CO}_2 + \text{Light Energy} = \text{C}_6\text{H}_12\text{O}_6 + \text{O}_2 + \text{H}_2\text{O} \]
APPENDIX B: POST-TEST/WITH STATIC MEDIA

Name
Post-Test After Traditional Instruction (Lecture/Static Images)

Directions: Please read the question carefully and circle one of the four choices to answer the question.

1. What part or parts are used in photosynthesis?
   
   a. Carbon Dioxide
   b. Water
   c. Light Energy
   d. All the Above

2. What word means energy from the sun?
   
   a. Light Energy
   b. Photosynthesis
   c. Consumers
   d. Carbon Dioxide

3. What word means organisms that obtain energy by eating other animals, food, or plants?
   
   a. Organisms
   b. Producers
   c. Consumers
   d. Carbon Dioxide

4. Why are green plants and trees important to organisms?
   
   a. Green plants and trees make oxygen for organisms.
   b. Green plants and trees make food for organisms?
   c. Green plants and trees are used as shelter (home) for organisms.
   d. All the Above.

5. What word means liquid that plants’ roots collect from rain?
   
   a. Carbon Dioxide
   b. Producers
   c. Water
   d. Consumers
6. The word photosynthesis comes from which country?
   a. England (English)
   b. France (French)
   c. Japan (Japanese)
   d. Greece (Greek)

7. Which word means living thing?
   a. Carbon Dioxide
   b. Producers
   c. Organism
   d. Light Energy

8. What is the name of the process used by plants to make their own food?
   a. Respiration
   b. Photosynthesis
   c. Consumers
   d. Carbon Dioxide

9. What word means organisms that make their own food?
   a. Producers
   b. Photosynthesis
   c. Consumers
   d. Carbon Dioxide

10. What word means where water enters the plant?
    a. Roots
    b. Chloroplast
    c. Leaves
    d. Chlorophyll
11. What word means green pigment color in plants?
   a. Roots
   b. Chloroplast
   c. Carbon Dioxide
   d. Chlorophyll

12. What word means where carbon dioxide enters the plant?
   a. Roots
   b. Chloroplast
   c. Leaves
   d. Chlorophyll

13. What is the formula for photosynthesis?
   a. Carbon Dioxide + Sugar + Water = Water + Light Energy
      \[ \text{CO}_2 + \text{C}_6\text{H}_12\text{O}_6 + \text{H}_2\text{O} = \text{H}_2\text{O} + \text{Light Energy} \]
   b. Carbon Dioxide + Water + Oxygen = Sugar + Light Energy
      \[ \text{CO}_2 + \text{H}_2\text{O} + \text{O}_2 = \text{C}_6\text{H}_12\text{O}_6 + \text{Light Energy} \]
   c. Carbon Dioxide + Water + Light Energy = Sugar + Oxygen
      \[ \text{CO}_2 + \text{H}_2\text{O} + \text{Light Energy} = \text{C}_6\text{H}_12\text{O}_6 + \text{O}_2 \]
   d. Carbon Dioxide + Light Energy = Sugar + Oxygen + Water
      \[ \text{CO}_2 + \text{Light Energy} = \text{C}_6\text{H}_12\text{O}_6 + \text{O}_2 + \text{H}_2\text{O} \]

14. What word means gas produced by animals when they breathe out waste air?
   a. Oxygen
   b. Light Energy
   c. Water
   d. Carbon Dioxide

15. What word means where photosynthesis takes place in the plant?
   a. Roots
   b. Chloroplast
   c. Leaves
   d. Chlorophyll

APPENDIX C: POST-TEST/WITH DYNAMIC MEDIA
APPENDIX C: POST-TEST/WITH DYNAMIC MEDIA

Name
Post-Test After Simulation

Directions: Please read the question carefully and circle one of the four choices to answer the question.

1. What part or parts are used in photosynthesis?
   a. Carbon Dioxide
   b. Water
   c. Light Energy
   d. All the Above

2. What word means energy from the sun?
   a. Light Energy
   b. Photosynthesis
   c. Consumers
   d. Carbon Dioxide

3. What word means organisms that obtain energy by eating other animals, food, or plants?
   a. Organisms
   b. Producers
   c. Consumers
   d. Carbon Dioxide

4. Why are green plants and trees important to organisms?
   a. Green plants and trees make oxygen for organisms.
   b. Green plants and trees make food for organisms?
   c. Green plants and trees are used as shelter (home) for organisms.
   d. All the Above.

5. What word means liquid that plants’ roots collect from rain?
   a. Carbon Dioxide
   b. Producers
   c. Water
   d. Consumers
6. The word photosynthesis comes from which country?
   a. England (English)
   b. France (French)
   c. Japan (Japanese)
   d. Greece (Greek)

7. Which word means living thing?
   a. Carbon Dioxide
   b. Producers
   c. Organism
   d. Light Energy

8. What is the name of the process used by plants to make their own food?
   a. Respiration
   b. Photosynthesis
   c. Consumers
   d. Carbon Dioxide

9. What word means organisms that make their own food?
   a. Producers
   b. Photosynthesis
   c. Consumers
   d. Carbon Dioxide

10. What word means where water enters the plant?
    a. Roots
    b. Chloroplast
    c. Leaves
    d. Chlorophyll
11. What word means green pigment color in plants?

a. Roots  
b. Chloroplast  
c. Carbon Dioxide  
d. Chlorophyll

12. What word means where carbon dioxide enters the plant?

a. Roots  
b. Chloroplast  
c. Leaves  
d. Chlorophyll

13. What is the formula for photosynthesis?

a. Carbon Dioxide + Sugar + Water = Water + Light Energy  
   \[ CO_2 + C_6H_{12}O_6 + H_2O = H_2O + \text{Light Energy} \]

b. Carbon Dioxide + Water + Oxygen = Sugar + Light Energy  
   \[ CO_2 + H_2O + O_2 = C_6H_{12}O_6 + \text{Light Energy} \]

c. Carbon Dioxide + Water + Light Energy = Sugar + Oxygen  
   \[ CO_2 + H_2O + \text{Light Energy} = C_6H_{12}O_6 + O_2 \]

d. Carbon Dioxide + Light Energy = Sugar + Oxygen + Water  
   \[ CO_2 + \text{Light Energy} = C_6H_{12}O_6 + O_2 + H_2O \]

14. What word means gas produced by animals when they breathe out waste air?

a. Oxygen  
b. Light Energy  
c. Water  
d. Carbon Dioxide

15. What word means where photosynthesis takes place in the plant?

a. Roots  
b. Chloroplast  
c. Leaves  
d. Chlorophyll
APPENDIX D: SURVEY QUESTIONS

Survey Questions

1. On a scale of 1-5, 5 being great and 1 being poor, rate the following characteristics of the simulation?
   - Visual Design (how it looked) 1 2 3 4 5
   - Videos of teacher signing information 1 2 3 4 5
   - Simulated Animations 1 2 3 4 5
   - Information/Content 1 2 3 4 5
   - Home, Previous, Next Links 1 2 3 4 5

2. On a scale of 1-5, 5 being great and 1 being poor, how would you rate the overall simulation? 1 2 3 4 5

Why?____________________________________________________________________
________________________________________________________________________

3. On a scale of 1-5, 5 being very nervous and 1 being not nervous, rate how nervous you were to use the simulation before using the simulation? 1 2 3 4 5

4. On a scale of 1-5, 5 being very nervous and 1 being not nervous, rate how nervous you were to use the simulation after reading or watching the teacher in the video sign the directions and then welcomed you to using the simulation in the welcome section? 1 2 3 4 5

5. Aside from using this simulation in science class, have you used a simulation before?
   __ I have never used simulations before
   __ I have used simulations before (If you have, when and in what class?)
   __________________________________________________________________
6. How would you describe how the information in the simulation was presented?
__The information made sense and was in an order that was easy to follow
__The information made sense but was not in an order that was easy to follow
__The information did not make sense and was not in an order that was easy to follow

7. How would you describe the background color in each section of the simulation?
__made the text, pictures, video, and animations easy to see and read
__made the text, pictures, video, and animations difficult to see and read
__made some parts easy to see and read and other parts difficult to see and read

8. How would you describe the signed parts in the simulation?
__Easy to see and made sense
__Difficult to see but made sense
__Difficult to see and did not make sense

9. Were you able to find information from the following sections: welcome, opening question, vocabulary, parts of photosynthesis, process of photosynthesis, summary, practice questions, and resources?
__Yes
__No
If you said no, which sections did you not find information on?

10. How would you describe how you used the simulation?
__Started at the first section (homepage) and went to each section of the simulation in order by clicking next on each page
__Started at the first section (homepage) and clicked on different sections of the simulation but did not go in order
__Started at the first section (homepage) and clicked next to go in order but later changed your mind and returned to the homepage to not go in order
11. How would you describe how you viewed the information in the simulation?

__Read the information
__Watched the information signed in the video
__Read the information and watched the information signed in the video

12. Which statement best describes sequence of how you viewed the videos and simulated animations of the simulation?

__Played the signed video then the animation
__Played the animation then the signed video
__Played both the signed video and animation at the same time

13. Which statement best describes how you played the animations?

__Played each animation all the way through
__Played each animation part way through

14. Which statement best describes how many times you played the animation?

__Once
__Twice
__More than two times

15. Which statement best describes how many times you played the signed video?

__Once
__Twice
__More than two times

16. Can you recall the 3 things needed for photosynthesis that was shown in the photosynthesis parts page of the simulation?

________________________________________________________________________
17. In the Opening Question section, can you recall three things organisms need from green plants to live?

18. The word photosynthesis was highlighted in green throughout the simulation. On a scale of 1-5, 5 being great and 1 being poor, rate how it helped you remember the word photosynthesis?
   1   2   3   4   5

19. What are three images you recall from the photosynthesis process section?
   ______________________________________
   ______________________________________
   ______________________________________

20. On a scale of 1-5, 5 being great and 1 being poor, how would you rate the animation of cows eating grass and the hawk eating the mouse in helping you to remember that consumers eat plants and other animals?
   1   2   3   4   5

21. On a scale of 1-5, 5 being great and 1 being poor, how would you rate the animation of light energy, carbon dioxide and water entering the chloroplast in helping you remember the 3 parts needed for photosynthesis?
   1   2   3   4   5

22. On a scale of 1-5, 5 being great and 1 being poor, how would you rate the animation of the plant absorbing light energy, rain, and carbon dioxide from the squirrel in helping you remember the 3 parts needed for photosynthesis?
   1   2   3   4   5
23. Which animations helped you remember the vocabulary for this lesson? Check all that apply.
__Photosynthesis
__Light Energy
__Carbon Dioxide
__Water
__Chlorophyll
__Chloroplast
__Organism
__Leaves
__Roots
__Producers
__Consumers

24. In the photosynthesis formula section, which part helped you remember the photosynthesis formula? Check all that apply.
__Words written out (Carbon Dioxide + Water + Light Energy = Sugar + Oxygen)
__Animation of Carbon Dioxide + Water + Light Energy = Sugar + Oxygen
__The actual formula CO2 + H2O + Light Energy = C6H12O6 +O2

25. On a scale of 1-5, 5 being great and 1 being poor, in the summary section, rate how you it helped you remember the photosynthesis parts, the definition of photosynthesis, photosynthesis formula, photosynthesis vocabulary terms, and reasons why green plants are important to organisms?
1                2                3              4              5

26. On a scale of 1-5, 5 being great and 1 being poor, how would you rate how helpful the links in the resource section were?
1                2                3              4              5
27. On a scale of 1-5, 5 being great and 1 being poor, in the practice questions section, rate how you felt about finding instantly if you answered right or wrong? 1 2 3 4 5

28. What would you add to the simulation to improve it and make it more meaningful to others?
APPENDIX E: INTERVIEW QUESTIONS

You will be asked answer the following questions based upon your experience using the Flash-based physical simulation to learn photosynthesis. Please be as descriptive as possible when answering the questions but also keep in mind you have the right to decline a question that makes you feel uncomfortable. Tank you for your participation.

QUESTIONS

1. After using the simulation, how would you describe how the information, video, simulated animations, and text were presented?

2. Were you nervous before using the simulation?

3. Did seeing your teacher welcome you to the simulation in the welcome section make you feel invited and less nervous about using the simulation?

4. Did having the choice to watch the video of your teacher sign the information of the information printed for you to read make a difference to you using the simulation?

5. What did you like most about the simulation that made you feel like you were part of it and that made it hands-on for you?

6. Did you feel that you were in control of the simulation and how so?

7. Did the simulation respond to you when you pressed different button. What sections especially did it respond to you?

8. Did this simulation help you learn about photosynthesis? How specifically did it?

9. Did the links in the resources section interest you? Why or why not?