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Implementing a Virtual Reality Paradigm in Human Anatomy/Physiology College Curricula

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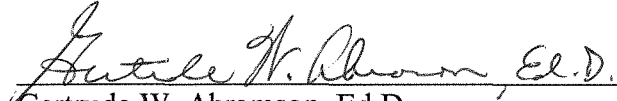
by

Helen St. Aubin

A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy

School of Computer and Information Sciences

Nova Southeastern University

2000

We hereby certify that this dissertation, submitted by Helen St. Aubin, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirements for the degree of Doctor of Philosophy.

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An Abstract of a Dissertation Submitted to Nova Southeastern University
in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

Implementing a Virtual Reality Paradigm
in Human Anatomy/Physiology
College Curricula

by
Helen St. Aubin

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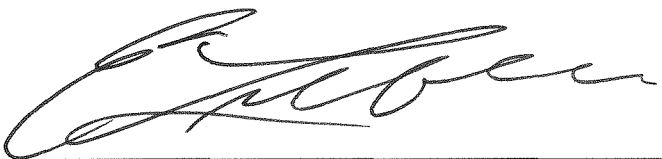Modes of instruction in the college course called Human Anatomy/Physiology are changing. Due to ethical concerns and the ever-increasing source of new physiological data, there is a need for enhancements to assist the instructor and student. The computer science of virtual reality (VR) provides a method to electronically educate, train, prototype, test and evaluate new enhancements to the college curricula.

This study detailed the modeling and simulation of a skeletal human hand with degrees of freedom of movement, which provided the students with a physiological representation of some of the movements of the hand. The primary objectives of the study were to assess the use of the VR simulation by college students and to assess the potential learning outcomes of students in their use of the VR simulation. The simulation was implemented into classes of Human Anatomy/Physiology as an adjunct enhancement for the students' use. The expectation centered on the constructivist theory that students develop an analytic outlook to the various articulations of the human skeleton.

Positive results were shown based on the answers to the questionnaire, summary and post-test taken by the students, after their use of the VR simulation. The results supported the constructivist theory that critical thinking took place. The results showed that the virtual reality simulation enhanced the learning ability of the students.

The recommendations of the study include future experimentation to be done on increasing the number of VR simulations, incorporating the VR simulations into undergraduate courses, testing the outcomes, and following the progression of students into graduate programs that are using VR simulations. Faculty and administration are advised to consider implementing the paradigm of VR simulations in undergraduate courses of Human Anatomy/Physiology.

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I am forever grateful to my husband, John, for his continuous encouragement, understanding, patience, kindness and insistence that I finish my long awaited goal of my doctorate degree.

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Chapter I

Introduction

Virtual reality (VR), telepresence, interactive computer aided instruction, holographic visualization: This is the language of the new generation of medicine. Using the new computer science of virtual reality (VR) we can electronically educate, train, prototype, test and evaluate. Among all these information technologies, VR holds out the greatest promise for surgical education and training. There has been much publicity about this infant science, virtual reality. Most is pure speculation; however within lies a powerful kernel of truth that spawns nascent medical and scientific applications (Satava, 1996, p.100).

The world of cost constrained healthcare is here. The high dollar technologies, especially those of virtual reality and telepresence, will not survive unless they can be linked to solid improvements in quality of care, better service to patients, and cost reductions in the operating room. These outcomes are primarily the results of the education of the medical student. The need to provide high quality, cost-effective training programs throughout the surgical community has been identified as an educational priority by many teaching institutions (McGovern, 1997).

Virtual reality simulation offers potential for improving medical care through education, training, instrumentation design, surgery planning and surgical support. The

virtual reality simulation environment is becoming a testbed for design and evaluation procedures and instruments.

The virtual reality simulation environment is a major change in the paradigm of medical education, and the motivation of the student to utilize a virtual reality simulation for education may prove to be a medical school cost savings. Further considerations are also in the planning stages for virtual reality simulations in the science courses in the undergraduate programs in high schools, colleges and universities. The early 90's saw plans being formulated, the mid 90's saw some development of virtual reality simulations, but also the realization of many barriers to the actual use of the simulations. The last years of the 1990's and on into the 2000's may see the need to have virtual reality simulations in all levels of science education. Once again, in the changing paradigm of educational enhancements, wanting virtual reality simulations and actually implementing them are two diverse objectives.

Hoffman and Vu (1997) believe that virtual reality is gaining recognition for its enormous educational potential based upon the intuitive manner in which users can control and interact with virtual objects and events. They further state that the high visual nature of virtual reality and its ability to provide interactions not possible in the real world make it a compelling and motivating learning environment.

Statement of the Problem

The statement of the problem is twofold. Although achievements in virtual reality simulations are in the early stages, some simulations are currently in use in some medical school programs. An early concern has arisen relative to the implementations of the

simulations. Those students, who are introduced to the simulations in medical school, usually have not had any prior training or background in virtual reality simulations. Simulations must show that they are teaching skills that are relevant to real task performance (Smith, Wan, Taffinder, Read, Emery & Darzi, 1999).

A second issue in medical science education is the on-going change in the Human Anatomy/Physiology courses in college curricula. Students planning a career in most medical fields are required to take a course called Human Anatomy/Physiology. The undergraduate course is two semesters long and covers the human anatomy and physiology in reference to the cellular level, histological (tissue) level, and the systems of the body (integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic-immune, respiratory, digestive, urinary, and reproductive). Prerequisites are usually a general biology course and chemistry. Brinkley and Rosse (1997) believe that since anatomy is fundamental to all health professions, an anatomy knowledge base should be widely reusable for organizing and managing biomedical information. As the knowledge base evolves, it will facilitate the organization and analysis of images.

Cliff and Wright (1996) point to the fact that Human Anatomy/Physiology is a foundational course for advanced topics that put emphasis on problem solving, and it is necessary to help students to develop necessary synthetic, analytic, and diagnostic thinking skills. Past teaching practices in the course would rely heavily on the students memorizing vast amounts of data without the cognitive ability to reason the need for all the data and how it applies to the human body.

Changes in the college curricula are being researched, developed and implemented, but new paradigms need to be researched to enhance the present methods

of instruction. These paradigms, that may include virtual reality simulations, will enable students to continue into the medical school environment with an introductory background in virtual reality applications in the study of human anatomy/physiology.

Compounding the need for new paradigms is the need for implementation of physiological material in the anatomical course (Cliff & Wright, 1996). Although the course is referenced as Human Anatomy/Physiology, usually it is very slanted to the study of anatomy. In teaching the course for nine years, this instructor has encountered fellow instructors who are divided on the subject. Some believe in teaching anatomy, primarily, and believing that the students will encounter the physiological functioning when they go into their respective studies, after the students complete the first two years of undergraduate courses. An example would be the students learning the physiology of muscle action when they go into nursing, physical therapy, orthopedic rehabilitation, radiology, respiratory therapy, or other specialized areas.

Other instructors teach only some of the human anatomy and some physiology with the excuse of there not being enough time to cover every system, so they emphasize what is most important. Who makes the judgement of what is most important? Nevertheless, there are a few instructors who prefer to concentrate on physiology and believe that the teaching assistants will cover the anatomy in the lab. Perhaps if there were virtual reality simulations of the anatomical and physiological functions of the human body, instructors would have more time with their students, and students could reinforce their learning by re-doing the virtual reality simulation on their own time, not in class time.

Rosse (1995) points out that the purpose of anatomy education is to develop the skills for anatomical reasoning, which is a requirement for performing a number of clinical tasks. Further, he believes the emphasis in anatomy training seems to be on the presentation of large amounts of factual information about the spatial domain of anatomy. Symbolic information continues to be presented at a superficial level, mainly in the form of lists of terms. Rosse states that there is a great deal of interest in virtual reality simulations that would provide a sense of presence in the user interactions comparable to that of cadaver dissection. He continues to put forth his philosophy that a basic requirement for anatomy study is 3-D, spatial models of the human body, with interactive manipulation, thus providing the physiological representations.

Instead of testing factual recall on textbook memorization, the inference functions built into the symbolic virtual reality model make it possible to develop assessment measures that can evaluate whether the student is applying some productive reasoning strategies in problem solving. This constructivist type of exercise can provide a better foundation for the assessment of diagnostic reasoning and a very different modality of instruction and testing. Further, with the challenges of attracting more students into the college environment, new innovative methods are being pursued.

Goals

The goals of this dissertation were the creation and implementation of a virtual reality simulation of the human skeletal hand with some degrees of freedom movement in the fingers and thumb. More specifically, the movement was of the individual phalanges of each of the four fingers (fingers are also called digits with three phalanges for each

finger) and the thumb (or pollex has two phalanges). Each finger has three phalanges: distal (the end of the finger), middle, and proximal. The thumb has no middle phalanx. (Phalanx is the singular term for phalanges.) There was no movement of the metacarpals (palm of the hand) or the wrist bones (carpals). The VR simulation was a non-immersive stereoscopic screen display and it was placed on a split-screen, on a desktop personal computer. The split screen contained the 3-D real-time VR simulation on one half the screen (right half) and a multi-media 2-D presentation on the other half of the screen (left half). A split-screen is a feature of the Windows environment on a personal computer (Windows 95 or later version). To view the 2-D multi-media presentation (that was placed on the left half of the screen) that was prepared by James Crimando, Ph.D., access the following web site Uniform Resource Locator (URL)

http://www.gwc.maricopa.edu/class/bio201/hand/anhand.htm

The VR simulation was implemented in two modes of an educational application in the Human Anatomy/Physiology college curricula. It was for on-site classes in community colleges (2-year) and colleges (4-year) and in a distance learning web-based Anatomy/Physiology course offered by a community college (2-year). Although the emphasis of this study was for use in the community college environment, the virtual reality simulation can also be used in the university environment, because the course Human Anatomy/Physiology has the same requirements in either the college or university. Standards have made it possible for the course credit to be transferred from the college to the university.

In a non-immersive VR system, according to Roblyer, Edwards and Havriluk (1997), the user interacts with a 3-D environment by manipulating conventional computer

peripherals such as a keyboard and mouse. The range of movement allowed by the software combined with the speed and accuracy for updating an image also contribute to the naturalness of navigation. The VR simulation in this research was non-immersive and the students used the keyboard and mouse for the manipulation of the VR simulation. The decision to develop a non-immersive VR simulation was based solely on cost. The community colleges and college, in this study, have computers available but do not have the funds for any peripheral devices that would be necessary for an immersive VR simulation. In this study, a non-immersive VR simulation was better received because of the low cost of just using a computer, keyboard and mouse.

An immersive VR simulation would have required more sophisticated equipment such as head-mounted displays (HMDs), data gloves and other peripheral enhancements, that are not usually found in college labs. The VR simulation was a test and if deemed successful, then there could be the possibility of enhancing the simulation to be a potential immersive simulation. The possibilities of developing additional immersive VR simulations could take place, but at present it probably would be more conducive to develop more non-immersive VR simulations of the human body (such as the foot, ankle, knee, wrist, elbow and shoulder).

The virtual reality simulation of the human skeletal hand provided the students with a physiological representation of some of the movements of the hand. At present in classes on site, students have no representation of the movement; all they have is the text material describing in short detail the physiological movements of the hand (i. e. flexion, extension, abduction, adduction and opposition – Marieb, 1998). The cadaver that is now available in most of the community college labs, that basically has replaced cat dissection

(due to ethical reasons and cost), is already dissected (by a professional) and the students view the cadaver as the instructor does a "show and tell". Students generally do not handle the cadaver, again because of cost. The college needs to preserve the cadaver for as long as possible because of its initial cost. One point of reference, however, is that the cadaver hand is rigid; no finger or thumb flexion and extension are available.

The plastic skeleton models available to students in the lab also have rigid hands that are held in place by wires, thus permitting no finger and thumb flexion and extension. Furthermore, some of the community colleges have discontinued cat dissection and also do not use a cadaver. So the only items present are the plastic skeletons and plastic models of the arm and hand which are covered in the muscles and are rigid, with no spaces between the fingers and thumb for viewing the individual fingers. The study of the hand is usually a memorization of the bones of the hand. The test is usually a lab practical test that asks for the identification of the different bones of the skeletal hand. Likewise, when the students study the muscular system, many times the muscles of the hand are not on the required list of memorization. With some of the textbooks used in Anatomy/Physiology classes there may be one or two CDs (compact disks) packaged with the textbook. These CDs contain 2-D graphics and text and some of them may have some animation, but nothing that is student interactive, such as would be available with a 3-D real-time VR simulation.

In the Anatomy/Physiology courses that are being taught on the Internet in a web-based environment, the students access the community college web page, go to the class site and on that web page are the lessons. The lessons contain typed lecture material, hot links to many other web sites on material for the subject, self-quizzes, puzzles, and the

use of seven CDs that are classified as anatomy and physiology. There is no textbook, only seven CDs specifically for the Anatomy/Physiology course on the Internet. There is a way that the students download a file that enables them to run slide shows of the Anatomy CD (one of the seven CDs previously mentioned). This action gives the students a split screen with one side all text and the other side a graphic 2-D multi-media view of the human. There is no interaction other than viewing the material on the screen.

In this research the students viewed a multi-media, 2-D presentation of the anatomy of the human skeletal hand on the left side of the split screen, and by using the mouse, they were able to move the 3-D real-time VR simulation of the skeletal hand on the right side of the split screen. They were able to move the hand, using the mouse, by rotating it left to right, right to left, and basically moving the hand wherever in the split-screen area (using the x, y, and z axis). By clicking with the mouse, on the phalanges of the fingers and the thumb, the students could see the various movements of the fingers and the thumb. They saw flexion and extension movements of the hand. (At the time abduction and adduction of the fingers and thumb were not included because of the amount of computer memory and speed necessary for real-time simulation. Also, the special action of the thumb called opposition was not available, as opposition uses the motion of the metacarpal bone. No movement of the metacarpals was available in the VR simulation.) The multi-media 2-D presentation and the VR simulation were not combined, but were accessible to the students on the split screen. The students used the mouse as a point and click in the multi-media 2-D presentation and used the mouse to point, click and maneuver in the VR simulation.

The VR simulation was another computer enhancement to the courses that utilize rigid cadavers and rigid plastic skeletal models. In testing the use of the VR simulation, a questionnaire was administered to the college students. In testing, Cliff and Wright (1996), recommend a short focused scenario combined with 10-15 directed questions. This provides sufficient depth of analysis without requiring excessive time or effort by the students. The questions required a balance of fact recall, logical explanation, and synthetic analysis. Cliff and Wright believe that the student then develops a synthetic or analytic outlook to the problem instead of merely reinforcing his or her talent for fact recall.

The goals of this research involved the modeling, simulation, and implementation of an anatomical and physiological virtual reality simulation. The intent was to develop an enhancement for use in the changing paradigm in the course called Human Anatomy/Physiology in the college curricula. The VR simulation is reusable and can be placed in a split screen environment with a 2-D multimedia program for use in the study of anatomy and physiology of the human skeletal hand. Further intent was to provide the VR reusable simulation coupled directly with knowledge of the underlying physiology, or what is referred to as functional anatomy. Functional anatomy should link the anatomical and physiological behavior of the body through fundamental causal principles that are content rich.

Hoffman and Vu (1997) realize that VR-based anatomy programs will allow users to investigate structures in ways not possible in the real world. VR-based systems have the potential to make broad-based training experiences available to students at all levels, without the risks and ethical concerns associated with using animal and human subjects.

VR-based anatomy programs also enhance the students' learning of physiology, which will better prepare them for their future studies relating to the movement of the human anatomical structure.

The students who volunteered to use the VR simulation in this study had not completed BIO201 – Human Anatomy/Physiology. They had completed their study of the skeleton and articulations (but had not studied the muscles, which comes after the study of articulations). The VR simulation, the questionnaire and post-test were used as an enhancement to what they learned. From the results of the questionnaire and post-test, a determination was made as to whether the VR simulation would be an enhancement to the course and would be beneficial to be incorporated into the future classes of BIO201.

Objectives

In preparing for the assessment use of the VR simulation, the investigator:

1. Modeled and simulated a virtual reality simulation of the human skeletal hand with some of the degrees of freedom movement of the hand (excluding the palm or metacarpal bones and the wrist or carpal bones.)

2. Imported the 3-D real-time VR simulation into a split-screen application, with a 2-D multimedia application, in a non-immersive, computer application for college student use as an enhancement in Human Anatomy/Physiology classes

3. Designed and implemented the VR simulation for on-site college courses and distance learning, web-based Human Anatomy/Physiology courses.

The primary objectives of this study were:

1. To assess the use of the VR simulation by college students

2. To assess the potential learning outcomes of students in their use of the VR simulation.

Hypotheses Generated by the Objectives

The purpose of this study was to ascertain levels of effective use and learning outcomes in the use of a non-immersive virtual reality simulation by college students in the study of Human Anatomy/Physiology. Another reason for the study was to investigate the desire for further VR simulations by the college students.

Hypotheses for consideration based on the objectives were:

1. A virtual reality simulation will help college students master some of the physiological movements of the human hand.

The students need to understand physiological movements as they go further in their studies into a selected career such as in physical therapy, orthopedic rehabilitation, occupational rehabilitation and many other fields of study. Presently, students learn the physiological movements primarily from their textbook descriptions and demonstrations by the instructor. In using a VR simulation they can view a 3-D dimensional model that has the dimensions of height, width and depth which gives the rounded view of a fully sculpted skeletal hand. The VR simulation gave another quality whereby students were able to interact with the simulation and move it and experience seeing physiological movements unique to the hand. Students were able to view the VR simulation multiple times and that could reinforce learning the physiology of the hand.

In addition, multiple use of the VR simulation can be a learning tool used early in their education in undergraduate courses. This learning can be carried into graduate

courses and the use of more powerful VR simulations. The use of VR simulations should be started early on in education, in this case, in the undergraduate level. This early introduction could enhance the learning curve in the students' advanced courses when the students would be more comfortable with the VR simulation technology, based on their undergraduate experience with VR simulations.

2. Students who develop an in-depth understanding of the physiology of the hand through a virtual reality simulation will want similar experiences for each of the other parts of the body studied.

Once students have been introduced to a VR simulation of the unique physiological movements of the hand, questions can be raised as to the hand being a model for the study of synovial joint movement. Then a comparison with the other various joints, the types of movement or degrees of freedom of movement of the various joints, and the limitations of some of the joints can be considered. These raise the issues of VR simulations of the many and diverse joints in the human body. At present the physiological study of all the joints and the unique movements of said joints is through the study of the textbook and a demonstration by the instructor.

A VR simulation permits the students to review the movement of the hand multiple times. The VR simulation enables the student to develop a constructivist view of the movements of the hand by posing questions to themselves relative to the movement of the hand and eventually to the specific movements of all the articulations in the body.

3. Students who encounter a VR simulation for the first time during their professional courses (orthopedic rehabilitation, occupational rehabilitation, medical school, physical

therapy and others) need repeated practice with the technology before they become VR competent.

Since the understanding and use of a VR simulation is a different kind of learning experience, and if students have not experienced VR simulations in their undergraduate courses, it will require time in their graduate courses to become VR competent. This time impinges on limited time schedules and classroom time is at a premium during their graduate courses of study. This could distract from the true nature of the VR simulation to act as an enhancement to the quick learning of a procedure in graduate school.

Relevance and Significance

Educational Use

Weiss (1996) makes some general statements concerning virtual reality that give some semblance of understanding to why virtual reality can be used in education. She believes that VR does not have to be totally realistic in order to be useful – or fun. A virtual environment needs only to be realistic enough so that the people who use VR feel they have learned something or done something they could not ordinarily learn or do. She states that VR is not one single technology, it is several. Further, absolute realism is not what VR is all about. VR is not the same as actual reality. She believes it never will be, either.

When creating simulated environments, a critical question becomes the tradeoff between preserving physical fidelity to the environment versus preserving only cognitive fidelity according to Collins (1996). He further states that the benefit of stressing cognitive simulation is that it makes it possible to focus on salient aspects of the situation,

so the student does not get lost in complexity. Also, cognitive simulations are much cheaper to build. In this research, the virtual reality simulation was not an exact replica of the skeletal hand. It was a representation so the students would look more at the motion rather than the salient features of the hand structure.

Gagne, Briggs, and Wager (1992) present another view. They look at the instructional design efforts, which must meet intellectually convincing standards of quality, and such standards need to be based on scientific research and theory in the field of human learning. At this time there is very limited research on the use of virtual reality simulations in the college undergraduate environment.

Andleigh and Thakrar (1996) point out that virtual reality is a very qualitative interactive experience where the participant should feel the immersion of the interaction. Human-computer interaction is more intense in virtual reality than in any other human interaction with a computer. They believe that prompt feedback, from the computer to the participant's action, is required. Virtual reality systems require the hardware to produce rapid coordinated changes in visual effects, sound effects, and sensory perceptions, while at the same time accepting multimedia input from a variety of devices tracking the movements and actions of the human participant. The user of a virtual reality simulation needs to feel comfortable using the simulation, or the learning process will be negated out of frustration. Any barrier to the use of the virtual reality simulation will restrict the learning that may be a benefit from such usage.

Collins (1996) puts forth an issue on virtual reality in education. The issue is the constructivist view of education, which argues that the goal of education is to help students construct their own understandings. The constructivist view leads to an

emphasis on learning rather than teaching, and on facilitative environments rather than instructional goals. Dede, Salzman and Loftin (1996) believe that virtual reality has the potential to complement existing approaches to science instruction and learners can gain direct experiential intuitions about how the natural world operates.

Simulations in Anatomy and Physiology

A considerable amount of effort has been aimed towards developing real-time deformable objects for surgical simulation, but very little work has been aimed towards including physiology within the models. Most training aids separate physiological and anatomical aspects of living systems. A simulation that links the structural and functional aspects of the human body, should allow the user to develop a better understanding of the intrinsic link between anatomy and physiology (Avis, Briggs, Kleinermann, Hose, Brown & Edwards, 1999).

Kaufman and Bell (1997) concur on the issue that VR will revolutionize the learning of human anatomy. Students will be able to visualize organs and tissues in a perspective never before available. Further, students will be able to view and manipulate anatomical structures; one method being the rotation of objects in space.

Cliff and Wright (1996) list some issues to consider in evaluating simulations:

- Did it make it easier to learn anatomy and physiology?
- Did it help to deepen or solidify the students' understanding of anatomy and physiology?
- Did it make them appreciate the relevance of learning anatomy and physiology?

- Did it make them curious to learn more advanced concepts of anatomy and physiology?

- Was it a useful way to learn anatomy and physiology?

Virtual reality offers the promise of interactive, natural control of visualization processes, greatly enhancing the scientific value of the data produced by medical imaging systems. Due to the computational and real time update requirements of virtual reality interfaces, however, the complexity of polygonal surfaces that can be displayed is limited according to Cameron, Manduca and Robb (1996). They further state that to sustain the illusion, a VR interface needs to be able to generate smoothly animated images. They believe that to do this, the system must be able to sustain a display update rate of at least 30 frames per second (100 frames per second would be of much finer quality), and must respond to the user's commands in near real time. Due to the limitations of computer hardware, these requirements limit the possible complexity of the displayed images. They conclude that to be successful, a VR system requires a method for transforming volumetric data into useful geometric (polygonal) models, models that both sufficiently capture object detail and can be displayed and manipulated in real time.

These points are reiterated throughout the literature. The need for smoothly animated images displayed in real-time that can be manipulated by the user places major constraints on the use of virtual reality simulations on PC desktop computers and also for use in web-based classes. These constraints are compounded by the limited bandwidth that is available for transmission on the Internet. Also there is the constraint on the limited number of packets for transmission that some Internet Service Providers have set. This investigator encountered such a limitation in transmission of a VR file via the

Internet within a six-mile radius using the Internet Service Provider (ISP) MSN.com. Many virtual reality simulations are very large files and may exceed the packet limit. In addition to many other constraints, implementing a large virtual reality simulation via the Internet still is not totally a workable action. This was one of the considerations in limiting the physiological movements of the hand in this research.

The investigator created and implemented a non-immersive virtual reality simulation into a Human Anatomy/Physiology college course as an enhancement to learning some of the physiological movements of the human skeletal hand. In a literature review of the use of virtual reality simulations, it appears that many studies look at the use of VR technology in medical simulations, and different educational venues. There is the look at the many limitations in the development and use of virtual reality applications, and the look at the benefits of simulations to the priority of cost containment in the medical arena. Concerns are raised on computer hardware limitations, the cost of software and hardware, and the possibilities of the use of virtual reality simulations in Internet web-based classes. Further concern is starting to surface relative to the human-computer interaction with VR simulations. The concept of virtual reality simulations, as developing new tools in a changing paradigm of educating college students, has many advocates and many adversaries.

Barriers and Issues

Creating a virtual reality simulation has many constraints relative to the software and hardware. Using a virtual reality simulation in a classroom setting has constraints in introducing students to computer use and simulation use. Changing the paradigm of

learning anatomy/physiology, from the previous lab use of cats for dissection, cadavers, and rigid plastic models, to the present day use of cadavers, rigid plastic models, 2-D multi-media and 3-D real-time VR simulation computer applications, will need many classroom changes.

Previous methods of instruction in classes of anatomy/physiology involved the use of cats for dissection. This practice is being discontinued and some colleges are using human cadavers instead of cats. This is a constraint as usually there is only one cadaver for the college (due to cost) and, therefore, the students only do a "look and observe". The instructor does a demonstration and the students, sometimes as many as twenty-four per class, just observe. With the use of cadavers there also still is used the plastic skeletons, both articulated (the fully attached, wired, skeleton) and the disarticulated, separate bones of the human skeleton. In addition to the cadaver and plastic models, some colleges are using 2-D multimedia computer programs on CDs that are now being bundled with most Anatomy/Physiology textbooks. These CDs have graphic displays and text material. There is no interactive movement of the graphics by the students as would be the case in a VR simulation.

To add to the CDs accompanying the text, some instructors have developed 2-D multi-media displays, but again without any movement. This gives the students no physiological concept of movement as in the case of the fingers of the hand. The only source of information on the movement of the hand is usually a short description of the intrinsic muscles of the hand and the fine movements of the fingers (usually about one-half page of text). This tends to give the impression that the skeletal system is a static system rather than a dynamic system. Also, those classes being taught as Internet, web-

based applications use only CDs with text and graphics, but no animation. A VR simulation can change this paradigm of education and permit interaction by the students to enable them to view movement in the skeletal hand such as flexion and extension.

Issues were the availability of the state-of-the-art computer hardware and software, students being computer literate, and the students' use of the Internet application. Further issues were the levels of expertise of the instructors administering the simulation in their respective classes.

According to Salzman, Dede and Loftin (1995), VR supports true learning by doing, offers multi-sensory communication, and motivates users, but they also state that VR has several technological limitations and the interface design challenges may impede users' learning. They stress the importance of looking at the usability, learning techniques, and to guide the learning process by advancing from the very basics of instruction to the more advanced activities.

Satava (1996) lists five requirements for creating virtual reality simulations in order to produce a sense of realism. He lists them as:

1.) visual realism or fidelity,

2.) interactivity between objects,

3.) physical properties of objects,

4.) physiologic properties of objects, and

5.) sensory input.

He states that to date, the VR simulations have been able to incorporate the first three requirements while the latter two have not been actively implemented into VR

simulations. One of the problems is that each of the requirements requires its own large amount of computing power.

Virtual reality environments are taking users a bit farther along the range from "looking at" to "being in" according to Shneiderman (1998). Virtual environment users should be able to select actions rapidly by pointing or gesturing, with incremental and reversible control, and display feedback should occur immediately to convey the sense of causality. Shneiderman believes that in desktop virtual reality environments the most appealing systems should have an enjoyable user interface that offers a natural representation of the task objects and actions – direct manipulation. Actions should be rapid, incremental, and reversible, and should be performed with physical actions instead of complex syntactic forms. The results of the operations should be visible immediately. He states that poor design, slow implementation, or inadequate functionality can undermine acceptance. The initial introduction of a VR simulation in the classroom setting should be one of simplicity in use and understanding.

This study required the cooperation of instructors and their classes of Human Anatomy/Physiology students. It involved interaction, which is intrinsic to successful, effective instructional practice and individual discovery. When multimedia applications are developed, significant emphasis must be placed on the ways in which the specified users can access, manipulate, and navigate through the content material (Sims, 1995).

Limitations

Limitations included the need for state-of-the-art computer hardware and software programs for the development of the simulation and the implementation of the VR

simulation in both on-site classrooms and distance learning, web-based classes. Limitations were evident in the use, understanding, and implementation of a virtual reality simulation application by the students. First and foremost was the need to be computer literate. Another limitation from student to student was the coordination of sensual perceptions.

Avis et al. (1999) discuss some structural modeling challenges. Modeling deformable objects has been a challenging area of computer science. The main challenge in the structural modeling is in achieving real time performance in a model that incorporates the complex material characteristics. Also, physiological modeling presents more challenges than structural modeling, due to the fact that, often only indirect measures of physiological processes exist.

Hodgins (1998) addresses another limitation in that simulations use the laws of physics to generate motion of figures and other objects. Real-time simulations allow interactivity, an important feature for virtual environments. Computer models of the human body consist of rigid body parts connected by rotary points that are assigned one, two or three degrees of freedom with respect to the x, y, z coordinate axes and the criteria for assessing the quality of simulated human motion depend on the application. Virtual environments require motion with sufficient variety, expressiveness and realism to create a feeling of immersion for the user. It is imperative to construct limited motion well, then progress into more detailed motion in reference to the movement of the human body, which is a very complex system of motions and articulations.

Another limitation is covered by Mandel (1997) in that developers of simulation programs should not get too involved in usability tests, because they usually are very

knowledgeable about how the product works, and it would be easy for them to cue the test participants. A developer should serve in a support role, rather than as the actual test monitor who works directly with the test participants.

Assumptions

College students have the mental and sensual abilities to be able to use a 3-D real-time virtual reality simulation. College students have the understanding and ability to use computer hardware.

Definitions

Anatomy/Physiology (A/P) Terms

(Note: all the following A/P terms are referenced from Marieb, 1998.)

Abduction – in relation to the fingers is to splay them laterally, but to abduct the thumb is to point it anteriorly.

Adduction – is to draw the fingers back so they are touching each other, and adduction in the thumb is to point the thumb posteriorly.

Anatomy – in human studies, anatomy is the study of the structure of the body.

Articulation – in human studies, articulation is the joint or juncture of two or more bones.

Extension – in this research of the movements of the fingers of the hand, extension is the movement that increases the angle of a joint, for example, the straightening of the bent finger.

Flexion – in this research of the movements of the fingers of the hand, flexion is the movement that decreases the angle of the joint, for example, bending the finger from a straight to an angled position.

Opposition – in this research opposition refers to the movement of the thumb – moving the thumb toward the little finger. This action enables the person to grip objects in the palm of the hand. Thumb movements are different from the movements of the other fingers, because the thumb lies at a right angle to the rest of the hand. The thumb flexes by bending medially along the palm, not anteriorly, as do the other fingers. The thumb extends by pointing laterally (as in hitchhiking), not posteriorly, as do the other fingers. The action of opposition of the thumb also entails the movement of the two phalanges and the metacarpal bone, which articulates with the carpal bones.

Physiology – in human studies, physiology is the study of the function of the body.

Synovial joint – a freely movable joint which exhibits a joint cavity.

Computer Terms

(Note: all the following computer terms are referenced from Pimentel and Teixeira (1995).)

2-D – two-dimension is a display that creates a flat image with only height and breadth (width) such as looking at television displays.

3-D – three-dimension refers to the visual display that exhibits breadth, height, and thickness or depth.

Immersion – as generally applied to virtual reality, is when one or more of a user's sensors (eyes and ears, generally) are isolated from the surrounding environment and fed

only information coming from the computer. Again, consensus on what is immersion is vague, but immersion usually includes more than looking at the screen of a PC computer and using the computer mouse for manipulation. Immersion usually involves HMDs (head-mounted display equipment), data gloves, or many other types of peripherals.

Non-immersion – generally taken, means immersion by looking at a PC screen, and using the mouse for manipulation of the VR simulation. The user has the freedom to look away from the VR simulation.

Simulation – is a complexity of issues in virtual reality – it provides for the motion (animation), but in addition to motion there are many other qualities of simulation that evolve the virtual environment into a realistic, moveable object in an interactive scene. To create the simulation a software program, called a simulation manager, organizes and manages the resources and devices available to the VR application to create the VR world.

Virtual Reality – is a term that varies from author to author and discipline to discipline (and what is defined in a biological sense is different in a psychological sense). The word virtual refers to the essence or effect of something, not the fact. The authors believe that to have a virtual reality system, there should be three characteristics: response to user actions, real-time 3-D graphics, and a sense of immersion. Usually, these characteristics are achieved using visually coupled displays and powerful graphics hardware.

Educational Terms

Constructivist theory – students learn by taking in information from their environment and they construct their own meaning from the experience as opposed to having someone tell them the information (Sprague and Dede, 1999).

Paradigm – is an outstandingly clear or typical example or archetype. New interface technologies sometimes enable major steps forward, or paradigm shifts in the evolution of user interfaces (Mandel, 1997).

Summary

This study provided an opportunity for changes in the teaching and learning of human anatomy/physiology by establishing a need for the use of virtual reality simulations as an enhancement to the traditional human anatomy/physiology laboratory techniques. These techniques have been the use of rigid plastic models of the hand, the rigid hand of a cadaver and a multi-media 2-D computer program.

The VR simulation allowed the students to construct their individual view of some of the physiological movements of the hand. This enhanced their learning in an environment that has many modalities to strengthen the students' learning of both anatomy and physiology, a change from present day methodologies being used in the class. According to Salis and Pantelidis (1997) the exploration and manipulation of an object in a virtual environment recalls the theory of constructivism. They further state that visualization and navigation tools have great pedagogical potential, because the student selects the strategies for discovering the characteristics of an object.

Furness, Winn and Yu (1998) believe that what is learned persists if it is practiced, and this is true of cognitive as well as of psychomotor learning. VR simulations are ideal for permitting students to repeat activities with or without variations, for as long as it may take them to master the concepts. Manipulation and direct experience of things that cannot be manipulated and experienced in the real

environment are probably some of the most useful attributes of virtual environments for education. They concur that virtual environments motivate students to learn.

In changing the paradigm of anatomy/physiology study, the possibility of progressive education (where educators are mentors and facilitators, who aim to promote the individual learning techniques and personal development) is made possible by a virtual reality simulation. Holmes (1999) states that preventing regimentation in education may be a goal of progressive educators, who focus on developing the individual learner. He further believes that progressive educators seek different methods to help individual learners develop. They may do this by providing the learners with a variety of experiences.

Chapter II

Review of the Literature

Introduction

Since the purpose of this study was to determine levels of effective use and learning outcomes in the use of a non-immersive virtual reality simulation by college students in the study of Human Anatomy/Physiology, there were a number of areas to be reviewed. First was the college course in Human Anatomy/Physiology. Many issues concern the study of physiology in said course, and the rapidly increasing volume of information on physiology, and the confusion as to how to apply the information into the course of study. Next was the use of virtual reality simulations in the teaching of college courses and in the graduate levels of instruction. When is the time to incorporate a VR simulation into a student's education? Changes in modes of instruction may lead to changes in student interaction and learning such as the concepts of constructivism and collaboration. Further issues related to the implementation of a virtual reality simulation, both in an on-site class environment and via Internet web-based distance learning classes. Also reviewed were the complexities of issues of developing the VR simulation and implementing it in the classroom environment and on the Internet.

Key words in the search of literature were virtual reality, virtual reality simulations, virtual reality education, physiology, physiology education, virtual reality physiology, computer simulations in physiology, and constructivism. University based library research was supplemented by Internet searches.

Historical Overview

A simulation is a powerful technique that may teach about some aspect of the world by imitating or replicating it according to Alessi and Trollip (1991). They categorized simulations as those that teach about something and those that teach how to do something. Further, the users of the simulations learn from the simulations by manipulating some aspect of the world they are working with. These concepts from 1991 are the mainstay concepts today in 2000 for virtual reality simulations.

Vince (1999) referred to Ivan Sutherland, who back in 1965, published a paper that described how one day in the future, the computer would provide a window into virtual worlds. Sutherland built a head-mounted display (HMD) in 1968. This was not the first introduction to virtual reality, but was one of the more significant ones. According to Vince, the 1960s and 1970s were not periods renowned for low-cost, fast computers and consequently VR remained somewhat dormant. The 1980s saw the development of real-time computer graphics becoming a reality, and VR became a commercial reality. Initially it was a costly venture. The 1990s saw the relaxing of earlier rigid views about what comprised a VR system (especially in the realms of immersive versus non-immersive simulations) and a wider definition for VR became accepted. Vince noted that virtual reality offered something new – it allowed the users to reach out and move objects about, as if they existed. Virtual reality seemed to suggest a reality that was believable, and yet does not physically exist.

The 1980s and 1990s saw changes being made in the teaching of the sciences in the college and university levels. Personal computers with software applications were

slowly being introduced into the laboratories as new modalities of enhancing the learner's environment.

Senger (1996) observed that students in Human Anatomy/Physiology classes were limited to viewing, in a laboratory session, a single cadaver prepared in advance. This placed students in a primarily passive role, by their observing the anatomical detail that someone else had worked to expose. That passive role was disadvantageous and formed an obstacle to internalizing the anatomical information presented. He also stated that learning is best reinforced when the learner is an active participant and is required to build upon existing knowledge in order to discover new information. The cycle of reinforcing and expanding knowledge through reuse and adaptation should be the foundation of all good pedagogy.

The struggle continued in the teaching of Human Anatomy/Physiology over the concepts of what to teach in both the anatomy and physiology – a debate that continues today. Some consensus has been made on the need for new paradigms to be developed to enhance the learners' abilities, utilizing computer applications.

Sefton (1998) wrote that the discipline of physiology is a challenge to teach, because it has ill-defined boundaries and no agreed sequence for learning. She maintained that computer-based educational strategies offer promise but do not provide easy solutions, especially when they are unaffordable in many parts of the world. Her studies have shown that computer technology can provide problem-based learning which encourages the process of reasoning, provides a context for learning, and enhances the students' abilities to recall and to use knowledge, and it also represents an effective means of ensuring that learning is student-centered and independent. The study by

Sefton has shown that problem-based learning puts the key emphasis on self-direction, teamwork, reasoning and the application of integrated knowledge, thereby laying the foundations for life-long learning.

Constructivist Theories and Virtual Reality Research in Education

The constructivist theory is when students learn by taking in information from their environment and constructing their own meaning from the experience as opposed to the students having someone tell them the information. In using this constructivist concept in a curriculum the role of the educator changes to a facilitator and more control is turned over to the students and the different modes of technology. The modes of technology have expanded into the use of virtual reality simulations where activities are problem-based rather than drill-and-practice. Questions are designed to challenge students to look beyond the apparent, and to delve into issues deeper to form their own understanding (Sprague & Dede, 1999).

Carroll (1998) observed that it is not physically possible to teach all that is known about physiology and suggested that students will be better served by focusing on core concepts. It is an essential role of the educator to identify appropriate content. Now the various modes of technology will permit the student to circumvent the instructor to access the information base directly. This will be essentially true in the use of VR simulations. Computer simulation technology allows students to apply their understanding to a new situation, and allowing the students to make predictions of outcomes before running the simulations facilitates the learning process.

Research has shown (Winn, 1997) that students can learn from both immersive and desktop VR and from environments created and presented using technologies that are between the two extremes. Constructivist theories of learning give two assumptions that are relevant. The first is students construct their own understanding of what they are studying. They achieve this by interacting with their learning environments, using the knowledge and skills that they already have, to experiment and make sense of new experiences. These activities are often iterative. The second characteristic is that knowledge construction is collaborative.

Hsu, Bailey and DiCarlo (1999) worked with a "dry laboratory" using the "virtual rat" to help students understand the hormonal regulation of gastrointestinal functions. The students were given an experimental design that required identifying unknown agents on the basis of measurements obtained from the virtual rats. For the students to correctly identify the unknown agents, they had to use the knowledge gained from the background material in order to interpret the changes seen in the virtual rat. In this study the students were provided an opportunity to analyze and interpret laboratory data without the complications associated with using live animals. This is another positive reason to use VR simulations. Ethically speaking, the use of living animals is becoming unacceptable in undergraduate college courses.

Richardson (1997) found that computer laboratory VR simulation instruction enhanced learning outcomes in medical physiology despite student perceptions to the contrary. Of note is the fact that the students' connotation of "effective" dealt with "time" effectiveness as opposed to learning effectiveness.

Youngblut (1998) stated that students enjoy working with virtual worlds and the experiences can be highly motivating. In practical terms, desktop VR is more suitable for widespread use than immersive VR technology. Desktop VR is a mature technology. It is affordable because a basic level of technology can be achieved on most existing personal computers at either no cost or some minimal software cost. VR's ability to facilitate constructivist learning activities is the key issue, and it can provide alternative forms of learning that can support different types of learners. She reported a striking improvement in student motivation in their use of VR. She presented a number of questions pertaining to VR simulations in education:

1. Does learning in a virtual world provide something valuable that is not otherwise available?

2. How does the effectiveness of immersive and/or non-immersive virtual worlds compare?

3. How well does VR technology support collaborative learning?

4. Is collaboration educationally effective?

5. Is VR-supported learning cost effective?

6. For what type of educational objectives or materials is VR technology best suited? Where is it not suited?

7. Does the VR technology benefit only certain categories of students?

8. Do students find VR interfaces easy to work with?

9. Does the use of VR technology change the instructor's role in the classroom?

10. What are student and instructor reactions to the use of this technology?

11. Are the hardware platforms and minimum set of interface devices required affordable to most schools?

12. Are the needed software development tools commonly available?

13. Is the technology currently mature enough for practical use?

Cronin (1997) pointed out that contrary to popular conceptions, non-immersive desktop VR systems are by far the most common and inexpensive forms of VR there are. The main advantage of this form of VR is that it is relatively inexpensive. The high resolution of the screen provides good quality visualization of the graphical environment in contrast to the significantly lower quality performance of many HMDs. He further stated that the intersection of VR and education is of fundamental importance to the future development of both disciplines. The notion of building knowledge through experiencing reality is the cornerstone of the constructivist learning paradigm. The knowledge acquisition process in VR is one in which the student is constantly exploring and constructing reality for themselves.

Clarification of the concept of virtual reality is that virtual reality gives a participant the ability to interact in real time with a multi-perceptual, multi-dimensional, inclusive, potentially multi-participant environment; to change perspective at will, to make and implement decisions, to experience a "paradigm shift" in a wholly created system that exists only in the computer and the minds of the world designer and participants. Multimedia is a representation, whereas VR is a simulation, intended to fool the senses into believing that the participant is somewhere other than in his or her 'physical' body. Cyberspace is not a place; it is an experience. Instead of perception based on reality, VR is an alternate reality based on perception (Osberg, 1997)

For an effective curriculum, access to a wealth of information must be provided and there must be an exchange of information and formal learning between educators and students. An effective curriculum must integrate problem-solving and decision-making experiences with knowledge acquisition and reinforcement of learning outcomes that provide follow-up learning activities and feedback (Khonsari & Fabri, 1997).

Knowns and Unknowns

A computer simulation has many advantages over a static presentation and it has the ability to present a strong visual image that aids in learning. It is now possible to develop complete physiological simulations that can run on a wide variety of computers with an almost transparent ease of distribution (Dwyer et al., 1997).

Gupta et al. (1996) observed that medical knowledge has exploded over the last three decades and this has led to what some consider an actual information overload for the undergraduate medical curriculum. There is a growing need for a paradigm shift in medical education. They believe that multimedia is at the heart of the efficiency of learning, but unless an assessment tool is developed and the administrators of the institutions are able to reliably evaluate the proposed benefits of the methodology, they will not become properly implemented. Gupta et al. point out that faculty resistance is one of the most commonly cited reasons for the lack of wide-spread implementation of new technologies. Faculty members believe that they may be held liable for the outcome of proposed studies. Also, a majority of faculty members are resistant to technological advances which may require an increase in the time and effort that they must put forward even if only in the short term. Another issue that authors reference is student resistance.

Students can not afford to risk wasting time on unproven methods. There is not legitimate justification for compromising even one minute of conventional time to try out the latest VR simulation. Therefore, should new educational methods be used exclusively as an adjunct to traditional teaching?

Fenrich (1997) addressed some key issues on VR such as the use of a VR simulation provides a first-hand, personal experience of an event with minimal interference from real distractions, when the user interacts in a natural manner with the environment in real time. He also addressed the issue that VR can teach abstract ideas that educators cannot physically present, and the ability to manipulate abstract information in VR creates the potential to improve a student's understanding and memory of complex ideas. Fenrich also believed that a VR system can support learning by discovery and experimentation, with a variety of instructional approaches, including practice and feedback. Furthermore, an effective VR design focuses on the potential to educate and learn rather than on the capabilities of the hardware and software tools. One limitation that he mentioned is that runtime hardware required for smooth, natural motion exceeds the resources of most organizations.

The success of simulation and VR will depend on the ability to develop products, which meet the needs of customers: educators, physicians, students, and other scientists. The ability to mimic reality is not a requirement to create a simulation, which can provide students with an environment in which they will learn important skills, rather it is important to the user to feel as if they are interacting. An important element in the design of VR is the need to avoid incorporation of misinformation in the simulation (Meller et al., 1997).

Johnson et al. (1999) addressed some technical issues relative to VR. To improve the integration of simulation and visualization so adjustments can be made is called computational steering, which is the capacity to control all aspects of the computational science pipeline – the succession of steps required to solve computational science and engineering problems. When one interactively explores a simulation in time and space, the user steers it. Basically the user can rely on steering to assist in debugging and modifying the computational aspects of the application.

Singhal and Zyda (1999) addressed the need for faster processors, more powerful graphics hardware, and higher-capacity networks for supporting the development of networked virtual environments containing more detailed models of entity, appearance, and behavior. In looking at the use of VR simulations on the WWW (World Wide Web), they addressed some important issues of consideration:

> *Network latency* (network delay) is the amount of time required to transfer a bit of data from one point to another.

> *Network bandwidth* – the rate at which the network can deliver data to the destination host. Available bandwidth is determined by the type of wire used to transport data, and it is also limited by the hardware used to transmit the data.

> *Network reliability* – a measure of how much data is lost by the network during the journey from source to destination host. This data loss can be divided into categories:

>> *Data dropping* – data does not arrive at the destination host at all, because it has been discarded by the network, and

Data corruption – means that the content of the data packets has

been changed during transmission so that the arrive data

packet is basically useless to the destination host.

Update rate – the rate that allows one to move through a 3-D virtual world quite

nicely. This rate is presently at a minimum of 30 pictures (frames) per

second (fps), which is a world consisting of fewer than 3,333 polygons.

The solution for too many polygons is to *cull*, or throw away polygons,

using the processor to determine which polygons do not need to be drawn.

Alessi and Trollip (1991) focused on the need of fidelity, which refers to how

closely the simulation imitates reality. The realism of the simulation refers to the degree

to which a particular component appears like its real counterpart. This issue is very

important today, because the increased realism is not necessarily tied to increased

effectiveness.

Leavitt (1999) noted the barriers and technical limitations of bandwidth and

latency pertaining to VR simulations on the Internet (WWW) and on networked

environments. An item of concern is the many consumers who might want to view data-

intensive 3-D content and they still may have slower modems, which increase download

time. Latency problems will diminish when consumers obtain cable modems and access

to DSL (digital-subscriber-line technology).

Wiemer (1998) pointed out that results are showing that the various new

multimedia are powerful instruments for improving teaching and learning, but they

should not be expected to provide the sole basis for education. The applications still face

many problems regarding concepts, efficiency, and acceptance by students and staff. He

stresses that applications of the media can be advocated not on the basis of reduction of costs but only on the basis of an improvement of the quality of education. Further, sophisticated simulations are mostly of Anglo-American origin, but because of the language barrier, they are only of limited use for his students in Germany. At present the Internet is largely empty with regard to teaching materials for physiology.

Future Contributions to the VR Scenarios

Bell and Fogler (1995) concurred in their study that students learn best when a variety of teaching methods are used, and different students respond best to different methods. Computers are being used more as teaching tools, to give students a wider variety of learning experiences, but high-quality solutions are not yet affordable, and affordable solutions are not yet high-quality. They state that it is prudent to begin developing virtual reality education applications today, so educational institutions will be prepared for the advances in equipment software when they become available. The popularity of the new technology will drive prices down and quality up.

Bell and Fogler emphasized that virtual reality stands to add to the variety of educational delivery mechanisms and to address those areas where traditional methods are the weakest. One of the values of VR is its ability to give tangible, corporeal substance to otherwise abstract ideas and concepts. In looking at some other strengths and weaknesses of VR as an educational tool, they emphasize the ability to visualize situations and concepts, which could not be otherwise seen, student interest and enthusiasm. VR is designed to pull the user into the experience, and they believe that anything that can be done to get students more enthused and interested in the subject

matter is a good thing. VR is excellent for reaching the active, visual, inductive and global learners, who are not always served well through traditional methods.

Barker (1997) observed that her faculty believe that VR simulations offer an exciting opportunity to develop a realistic risk free teaching methodology to use for a commonly executed invasive procedure taught in nursing classes. When the VR simulation is incorporated into the curriculum, its effect will be carefully evaluated and results will provide valuable data for future simulation efforts. One objective of the evaluation process will be to determine whether the prototype simulation is realistic enough to be used for teaching the venipuncture procedure. She asks what do people want to know about the use of VR simulations versus traditional teaching methods? It is her belief that the ultimate teaching of invasive procedures in medical/nursing/allied health programs will be done with VR simulation. In order for VR simulations to move from the research and development laboratory to the teaching classroom on a large scale basis, four conditions must be met: faculty involvement, student cooperation, affordable equipment and administrative support.

The Internet is perceived to be a powerful medium for VR simulations, and there is a very good chance that it will develop into a major sector for future VR work. VR has matured very quickly and offers powerful solutions to some very difficult problems. VR is no longer a technology looking for an application, it is a solution to any problem that involves the real-time visualization of complex 3-D data (Vince, 1999).

Adding dynamic user interaction greatly enhanced the interest in 3-D modeling. VR is becoming another exciting extension of the WEB (Internet – WWW), and with the development of 3-D worlds and objects, and 3-D browsers in which to view them, Web-

based virtual reality is getting closer, and the public seems to be embracing the new technology enthusiastically. As with other forms of multimedia, the process of downloading files, installing and configuring plug-ins, and obtaining a special browser are time-consuming, and a fast and powerful computer system to achieve the full effect of a virtual world is needed. But with such capabilities, the results are very impressive. VR plug-ins quite often cause systems to hang, but over time, the technology will become more stable. VR on the Web is still in its infancy. The ability to interact with scenes and manipulate objects is becoming available, and users are very intrigued. Some people have referred to the realization of virtual reality on the WEB as the "Second Web" (Greenlaw & Hepp, 1999).

With the rapid growth of the Internet and the media-rich extensions of the WWW, new developments in the way instructors transfer knowledge to their students is now available. Changing lifestyles and demanding schedules are forcing students to use the benefits of academic instruction remotely and this demand for distance education is growing exponentially. With the availability of increasingly powerful communication information technologies, ways for enhancing traditional teaching and learning in both distance and conventional education using synchronous and asynchronous tools are available.

Online courses need to provide students with a combination of the best aspects of Internet services, multimedia, and effective teaching. To realize these objectives, the system being developed should be capable of providing a low-cost content-rich resource, which encourages the students to explore new avenues of learning. Since the IP (Internet Provider) network is the delivery medium, the content delivered may suffer from inherent

disadvantages of the network, namely, variable and unpredictable end to end latencies and the lack of any guaranteed quality of service. Educational and cognitive research has shown that the most effective learning environment involves interactive collaborative, "learning-by-doing" models, such as those offered in virtual reality simulations (Latchman, Salzmann, Gillet & Bouzedri, 1999).

Summary

Colleges and universities are entering an unprecedented time of change and challenge for teaching Human Anatomy/Physiology in the twenty-first century. Many new methods and ideas have surfaced, in traditional educational settings, but more so in the use of newer technologies. The opportunities are many but these opportunities will be enhanced with a sharing of ideas and active cooperation to enhance the professionalism of Human Anatomy/Physiology education.

One of the opportunities is the inclusion of virtual reality simulations into the curricula. What distinguishes VR from all preceding technologies is the sense of immediacy and control created by immersion. VR gives the feeling of "being there", or presence, that comes from a change in visual displays.

Flexibility is important for the mastery of skills. VR simulation users can practice hundreds of times, with many variations in the different scenarios. These scenarios can vary in scope, difficulty, and degree of assistance provided to the student. Students can even practice responding to abnormal or unexpected events in order to improve their ability to function appropriately under simulated conditions. Learning is a complex process. Many factors affect learning in the cognitive, affective, and psychomotor

domains. Some educators argue that the most important concept underlying any learning experience is motivation. Two other concepts to consider in the use of VR simulations are constructivism and collaboration.

Kaufman and Bell (1997) felt that computer-aided multimedia software will play an important role in conceptualization, visualization, and verbalization, but VR simulators will be required for physical practice, correction and reinforcement, and achievement of skill mastery. The relatively high development costs for VR require conducting a proper need assessment to assist in identifying key areas. The authors list five areas that need to be considered when developing VR simulators: 1) educational; 2) anatomy and physiology; 3) instructional design; 4) engineering; and 5) programming.

Although there are many complexities and issues in the implementation and use of VR simulations in Human Anatomy/Physiology college curricula, the learning potential is too great to avoid. With the implementation and use of VR simulations in the medical schools, the time is now to consider VR simulations in the undergraduate college curricula.

Chapter III

Methodology

Introduction

The literature review in Chapter II provides some insight into the complexities of adding enhancement material to a college course in Human Anatomy/Physiology. Further issues were raised on the concurrence of what should be covered in the content of the Human Anatomy/Physiology course.

In the preceding chapters the goals and objectives were explained and the works of others in related fields were presented. In this chapter, the methodology to accomplish those goals and objectives is detailed.

This research was a descriptive developmental study. It involved collecting data in order to test hypotheses (Gay, 1996). It involved the creation of a non-immersive 3-D real-time virtual reality simulation, the implementation of the VR simulation into college Human Anatomy/Physiology courses, the administration of a survey questionnaire and post-test and the analysis of the data gathered.

Following is the sequential list of the major steps.

1. Continued research on virtual reality simulations in use in the teaching of Human Anatomy/Physiology. Explored the educational use of various virtual reality simulations in different environments.

2. Created, by modeling and simulating, a non-immersive virtual reality simulation of a human skeletal hand with some degrees of freedom movement (not including the carpal bones of the wrist and the metacarpal bones of the palm of the hand).

3. Implemented the simulation into two modalities of use: on-site Human Anatomy/Physiology college courses and equivalent distance learning Internet web-based courses.

4. Developed a descriptive student information booklet.

5. Developed and pre-tested a questionnaire comprised of Likert scale and semantic differential scale questions (Gay, 1996).

6. Administered the student information booklet, student questionnaire and post-test to validate the usability and usefulness of the virtual reality project in small-group testing (Gagne, Briggs & Wager, 1992) in on-site classes only.

7. Analyzed the results of the student questionnaire and post-test.

8. Published the results as a dissertation.

The concept of VR simulations in an undergraduate course is a new concept. There is limited information on the implementation of a VR simulation in a Human Anatomy/Physiology course in the college curricula. Most of the proposed research in this dissertation was of an experimental nature.

Design

A descriptive developmental research method was used for investigating an educational void in the study of the physiological movements in the Human Anatomy/Physiology college curricula. Descriptive data are usually collected through a

question survey and the investigator must give careful thought to sample selection and data collection. A descriptive study requires the development of an instrument appropriate for obtaining the desired information. Since the development of the instrument was necessary, the instrument had to be tried out and revised before it was used in the actual study. According to Gay (1996), descriptive research can provide very valuable data, but it demands more than asking questions and reporting answers. It involves careful design and execution of each of the components of the research process.

Modeling –Tessellating – Culling – Rendering

The investigator created a model of polygons of the human skeletal hand by using a software program called MultiGen Creator (1998) that produces a realistic three-dimensional model in real-time application. MultiGen Creator includes an integrated set of powerful tools for building hierarchical visual databases in a "what you see is what you get" (WYSIWYG) environment. It has a comprehensive set of tools organized to focus on both creating and editing models and databases.

The model was rendered (developed) using MultiGen Creator on a Compaq DeskPro EP NT system. The Compaq is a dual environment system (both NT and Windows 98) with the following hardware specifications: Pentium II, 350 megahertz, 6.4 gigabyte hard drive, 64 megabytes RAM, Compaq color monitor – 19 inches, Intel Ethernet card and Fire GL1000 Pro 8 megabyte video card.

In creating the model the investigator tessellated (add more polygons) the model by adding polygons to give the rounded appearance of the long bones. Then she culled (cut out) the polygons from the inside of the bone geometry to reduce the number of polygons so that when she imported the file into the simulation software program, the

model would have the lowest possible number of polygons. This low number of polygons decreases the lag or latency time of the simulation.

Simulation

The investigator opened the file saved in MultiGen Creator into a real-time simulation software program called EON Studio 2.5 (1999), which is a powerful tool for creating three-dimensional, interactive, real-time simulations. Interaction with the simulation is through standard devices such as the mouse and keyboard. Building an EON simulation involved three main actions – adding and enhancing 3D graphic objects, defining behavioral properties for the objects, and specifying how the users will interact with them in the simulation. Objects were added to the simulation by importing them from the modeling program, and once in the EON's 3D environment, the objects were positioned, scaled, and assigned colors. To further enhance the realism of the simulation scene, two modes of lighting were added. The 3D object was assigned behavioral properties that are appropriate for its role in the simulation. The behavioral properties were the Boolean logic (if/then/else), developed for each movement of the phalanges of the fingers and thumb to provide a degree of freedom movement for each of the phalanges. This degree of freedom movement allowed the movement of flexion and extension of each phalange. The degree of freedom was placed in the modeling program of MultiGen Creator, but the logic of the movement was developed in the EON simulation program.

After creating the simulation in EON, she downloaded from the EON Internet web page, a copy of the EON Viewer. The viewer is a public domain file provided by the EONReality Company for users to download to their computers to view simulation files.

It had to be loaded on to the hard drives of any computers that the investigator used on site at the colleges. The file for EON Viewer is 5.4 megabytes, which is too large a file to be stored on a 3 ¼ floppy disk. The viewer runs in a Windows environment (Windows 95/98 or NT) and is best downloaded using Microsoft Internet Explorer (other Internet Service Providers may require the downloading of additional files).

The EON simulation software program (used for developing the VR simulation) is copy protected. When the software program was installed on a specific computer, the user sends an e-mail of the computer configurations to the EONReality Company. A specific FlexLM file was sent to the user's computer to be placed in a special Window's folder for access when the software program was used.

Reasons for Specific Design

The movement of the hand was limited to:

1. only the flexion and extension of the fingers and the thumb by clicking the left mouse button when the mouse arrow is placed on the phalange that is to be moved, and this movement goes in both directions – flexion, the bending action and then returning to extension, the straightening action if the left mouse button is clicked again,

2. movement of the whole hand from right to left and left to right on the screen, by clicking on the left mouse button, and dragging the mouse arrow across the screen,

3. movement of the hand to fade it back into the screen by pressing the left mouse button and moving the arrow on the screen (that associates with the movement of the mouse with the left button depressed) upward on the screen. The reverse action of moving the hand to the foreground of the screen requires the click of the left mouse button and the arrow on the screen to be pointed downward on the screen.

The movements of the hand were limited in order to reduce the size of the file, so that it could be placed on a 3 ¼ floppy (2HD) disk for transportability to the various colleges. Also reducing the size of the file enabled experimentation with the use of the file via the Internet for the web-based distance learning class. Consideration was given to using a Zip disk which would have permitted the development of a larger file, but none of the colleges in the test had computers with Zip drives.

Modes of Delivery

The investigator has been teaching the college course Human Anatomy/Physiology both on-site (in a college classroom laboratory) and on the Internet (on-line, distance learning, web-based classes). She looked at two modes of delivery of the VR simulation – one in the classroom and one on the Internet. Her testing was done only in the on-site classes.

On-site Classes

The on-site classes were at two places, a two-year community college and a 4-year college. She installed the EON Viewer on computers in the respective labs and had the file of the VR simulation on floppy disks. She set up the split screen with one half (left half) of the screen having a 2D multimedia program (developed by James Crimando, Ph.D.), which has a picture of the human skeletal hand that has a hot-link capability. The hot-link allows the student to click on, with the left mouse button, on any of the bones and the selected bone turns red and a short description appears in a dialogue box of the name of the bone. There is also a drawing of the skeletal bones of the hand that is hot-

linked at the same time that the picture of the hand is hot-linked. The 2D program can be viewed on the following web site URL:

http://www.gwc.maricopa.edu/class/bio201/hand/anhand.htm

The EON Viewer file was downloaded onto the hard drive of the computers and the VR simulation file was loaded from the floppy disk. The screen was reduced to one-half (right half) and this enabled the students to view the 2-D multimedia file on the left side of the screen and the 3-D real-time VR simulation of the hand on the right side of the screen. Interaction in both the 2-D multimedia program and the VR simulation was by using the mouse left button.

The investigator was available to assist the students (with any technical problems) when they used the VR simulation. Although the instructor of the class was in the classroom, the instructor did not have to assist the students. Since the purpose of the VR simulation was to be an enhancement to the materials available to the student for studying the human skeletal system, the students needed to interact with the VR simulation without instructor intervention.

Internet Web-based Classes

The investigator teaches a class of Human Anatomy/Physiology on the Internet, and she planned to experiment with the possibility of using the VR simulation in the class. However, there were technical constraints, which needed to be addressed. She had a faculty member and some students who wanted to experiment with using the VR simulation. The experimenters were not part of the testing population.

Implementation

Implementation of the VR simulation was at two colleges:

1. Gateway Community College, Phoenix, Arizona and

2. Central Arizona College, Apache Junction, Arizona.

Permissions for implementation and testing were obtained (permissions were addressed to the Science Division Chairperson and a faculty member at Gateway Community College, and the Science Division Chairperson and a faculty member at Central Arizona College – Appendix A). Two faculty members (who teach Human Anatomy/Physiology) from whom permission was received volunteered to do a validation of the VR simulation, booklet, questionnaire, and post-test. Permission to implement the VR simulation, questionnaire and post-test in the college classes was approved by NOVA Southeastern University's Institutional Review Board (IRB) prior to the implementation.

The implementation of the VR simulation was done in the first three weeks in March 2000. It was implemented in an undergraduate class called BIO201 Human Anatomy/Physiology. No names, or methods of identification of the individual students using the VR simulation and taking the questionnaire and post-test were revealed. The investigator addressed limitations, such as computer hardware, the ease of computer use by the students and the non-interference by the investigator while the students were using the VR simulation.

Reference material – booklet

To alleviate some of the concerns on the assumptions of the computer experience (or lack of computer experience) of the students, the investigator developed a student booklet of information on the reason for the VR simulation and instructions for the use of the VR simulation. She also included some terminology on the anatomy and physiology

of the human hand (in case students were not required by their instructor to read certain items in the textbook). When the students were in class, they were given the booklet before they used the computer applications, and they were requested to read the booklet before they used the computers. A copy of the booklet is located in Appendix B.

Questionnaire

The investigator prepared a questionnaire that contained fifteen Likert scale type questions and a summary evaluation of seven questions using a semantic differential scale (Gay, 1996). In researching the literature, one paper (Stredney et al., 1998) was found with somewhat similar questions. The students were permitted to use the VR simulation for as long as they wished to give them the experience of a first time VR simulation being used as an enhancement to their class. Since the understanding and use of a VR simulation may not be that difficult, the repeated use may be time consuming, and this could distract from the true nature of a VR simulation to act as an enhancement to the quick learning of a procedure.

The Likert-type and semantic differential type variables were analyzed using frequency distributions. The ordinal items in the questionnaire were analyzed using the mode of analysis. A copy of the questionnaire and summary are located in Appendix B.

Evaluation

To date there are very few evaluations of the use of VR simulations in the classroom, especially in the undergraduate college level. As detailed in Chapter II, there are some VR simulations in use in the medical schools, but that was the only place where assessment evaluations were found. The investigator developed a post-test to do an evaluation on the learning outcome of the use of a VR simulation in the undergraduate

college classes. The post-test had five multiple choice questions pertaining to questions on the physiological movement of the fingers and thumb. In addition, one of the phalanges had a physiological problem (the VR simulation was set up so that the distal phalanx of the index finger was "frozen" – there was no movement permitted). There was an essay question after the multiple-choice questions addressing the physiological problem. The essay question enabled the investigator to make some conclusions on the potential of constructive thinking on the part of the student. A copy of the Post-Test is located in Appendix C.

Projected Outcomes

Considering the experimental nature of the implementation of the VR simulation as an enhancement to the Human Anatomy/Physiology class, the investigator addressed some general uses of the VR simulation:

1. in the classes of Human Anatomy/Physiology as an enhancement to the class material,

2. in the library as another mode of study,

3. in the home of the student, if computer equipment was available, as a mode of study,

4. as an introductory VR simulation which would encourage the development of future VR simulations of the human body, and

5. as a beginning use of VR simulations that would help the students in their future classes, both undergraduate and graduate, which may be using VR simulations.

Hypotheses to be tested

In Chapter II three hypotheses were listed for consideration based on the objectives of this research. However, at this time only the first two hypotheses were achievable. The third hypothesis would require a prolonged period of study of the subjects using the VR simulation. That would not be possible in this present research, but such a follow-up research would make for a very important future research.

The two hypotheses that the investigator tested were:

1. A virtual reality simulation will help college students master some of the physiological movements of the human hand and

2. Students who develop an in-depth understanding of the physiology of the hand through a virtual reality simulation will want similar experiences for each of the other parts of the body studied.

A point of reference is there were no independent or dependent variables listed because the VR simulation was not made a direct part of the classes at the time of implementation and testing. Rather the VR simulation was being used as an enhancement to the class. Use was not reflected on the students' grades in the course, and no student was required to use the VR simulation.

Resource Requirements

The investigator used software programs, for the creation of a non-immersive virtual reality simulation, at the Chandler-Gilbert Community College Maricopa Institute of Virtual Reality Technology (Mesa, AZ). The primary software programs were *Multigen-Creator 2.1 (1998)* and *EON Studio 2.5 (1999)*.

She implemented the non-immersive virtual reality simulation into Human Anatomy/Physiology classes at Gateway Community College (Phoenix, AZ). Instructors, other than the investigator, taught the classes. At Gateway Community College, a Human Anatomy/Physiology professor (Dr. James Crimando), who created the 2-D multimedia application, assisted her. The VR simulation was made part of a split-screen application in a laboratory setting.

In the Human Anatomy/Physiology class at Central Arizona College (Apache Junction, AZ) that was taught by the investigator, another Human Anatomy/Physiology professor (Dr. Mary Puglia) assisted her. The investigator was not directly involved with the implementation of the simulation at either college. According to Mandel (1997) the developers of simulation programs should not get involved in usability tests, because they usually are very knowledgeable about how the product works, and it would be easy for them to cue the test participants. The investigator, with the help of the instructors of the classes, administered a questionnaire and post-test in all the classes utilizing the virtual reality simulation in the on-site classes.

The investigator also experimented with some of the potentials of using the non-immersive virtual reality simulation in the Human Anatomy/Physiology courses at Rio Salado Community College (Tempe, AZ). Those courses that she teaches there are taught as distance-learning, web-based courses.

Reliability and Validity

Considering the newness of the research and the unknowns, two full-time faculty members, who teach Human Anatomy/Physiology, reviewed the VR simulation, the

questionnaire, and post-test. The two full-time faculty selected students who had completed the full course (one semester) of BIO201 Human Anatomy/Physiology, and they had those students review the VR simulation, the questionnaire, and post-test. According to Gay (1996), reliability means dependability, or trustworthiness. Basically, reliability is the degree to which a test consistently measures whatever it is meant to measure. High reliability indicates minimum error variance, and errors of measurement can be caused by characteristics of the tests themselves. Reliability is much easier to assess than validity, considering the scant availability of comparable questionnaires and post-tests on the subject of VR simulations in the undergraduate college curricula.

Summary

The investigator has spent a number of years teaching Human Anatomy/Physiology, and observing the need for enhancements in the teaching of physiology, namely, VR simulations. She created a VR simulation of the human skeletal hand, and implemented and tested the VR simulation in the undergraduate courses of Human Anatomy/Physiology in on-site classes. She prepared a supplemental booklet for the students' use in class prior to their using the VR simulation, the questionnaire and post-test. In addition, she experimented with the VR simulation on an Internet-based Human Anatomy/Physiology class, but she did not conduct formal testing on the Internet.

Chapter IV

Results

In this chapter, the investigator details the events of the virtual reality simulation leading up to the implementation of the VR simulation in three college Human Anatomy/Physiology labs, the testing and the results. Information is also given on the outcomes after looking at the potential implementation of the VR simulation into an Internet class of Human Anatomy/Physiology.

Introduction

Changes in the college curricula are being researched, developed, and implemented, and a new enhancement of a virtual reality simulation of the human skeletal hand was one of the goals of this investigation as the potential of a new paradigm in teaching Human Anatomy/Physiology. The VR simulation of the human skeletal hand was developed to provide the students with a physiological representation of some of the movements of the hand. It was necessary to master the software-modeling program MultiGen (1998) to create the polygon model of the human skeletal hand. Also mastered was the software simulation program EON (1999) to import the database file of the polygon model into the simulation program and to set up all the parameters to create the 3-D real-time VR simulation. Appendix D contains representative prints of the various stages of the VR simulation with an explanation of each stage so that the reader may form a mental model of the VR simulation. The reader is reminded that it is not possible to

experience three-dimensional dynamics and any action of simulation on paper, nor the coloration of the "hand" in the VR simulation. For a copy of the simulation and instructions to run the simulation, write to the investigator at hstaubin@msn.com.

Following completion of the simulation relevant print materials were developed. A student booklet (Appendix B) which contained the questionnaire and summary were prepared. The student booklet contained an explanation of the experiment, why the experiment was being conducted, an introduction on the investigator, definitions relative to the human hand, how a virtual reality simulation is different from an animation, and directions to use the VR simulation (using the mouse to maneuver on the computer screen).

Further clarification was also given on the concept that the VR simulation is not an exact replica of the human skeletal hand, it is a representation and the simulation is to be used in the context of learning some of the physiological movements of the hand. Instructions were also given in the booklet that when the students were finished, they could voluntarily do a questionnaire containing fifteen questions based on a Likert scale (strongly agree, agree, undecided, disagree, strongly disagree). After the questionnaire there was a Summary containing seven statements based on a semantic differential scale (Excellent...Poor, 10-1). The final print material was a Post-test (Appendix C) containing five multiple choice questions to voluntarily test the students after they had worked with the VR simulation.

Two faculty members, Drs. Mary Puglia and James Crimando (Central Arizona College and Gateway Community College), performed alpha tests on the VR simulation

and booklet. Their oral responses were very positive. Both recommended no changes and agreed to use the simulation with their classes and to conduct the testing.

The treatment took place in three labs of Human Anatomy/Physiology at two colleges named above. The students were given the student booklets in their lab classes, and they were given time to read the booklets and ask the instructor present any relevant questions. Then the students were taken to the computer labs where the VR simulation had been installed on the computers. The students did not have to set up the simulation on the computer. The VR simulation was ready to be viewed and manipulated on each computer for each student. The screen had been split with the 2-D multi-media program on the left side of the screen and the VR simulation on the right side of the screen. The 2-D multi-media screen gave text-based written material and pictures of the human hand. The VR simulation had only the hand, no text. The students viewed and manipulated the VR simulation for as long as they wished by using the mouse "pointer". By clicking on the tip of the finger, the full finger would move into a flexion mode. By clicking on the tip of the finger again, the finger would return to the extension mode. The students could click on the tip of the thumb to see flexion and again click on the tip to the thumb to see extension. They could click on the various "knuckles" of the fingers and see only one of the phalanges move. See some of the movements in drawings in Appendix D. They were free to discuss the VR simulation with other students. Some students checked their student booklets on occasion. The investigator was in the background, but there was no communication with her during the time the students were using the VR simulation. (Students spoke with the investigator after everything was finished.) The instructor was also available, but did not help the students very much. The investigator had asked the

instructor to see how well the students could do on their own and with other students. The students had recently finished their study of the skeletal system in their class and were in the process of studying the articulations of the human body. Some students may have read some information in the textbooks, while others had not. (Some students wait until just before a test to read the material in their textbooks!) The students viewed and manipulated the VR simulation for as long as they wished.

When the students finished with the VR simulation, they completed the questionnaire and summary found in the back of their student booklet. When they finished the questionnaire and summary, the booklets with the questionnaire and summary were placed in a folder. Then the students sat away from the computers with the VR simulations or turned off their computer screens and they took a short post-test. The post-tests were placed in a separate folder. The booklets in the one folder and the post-tests in the other folder were filed randomly so the investigator had no idea from which college the items came. The findings presented in this chapter reflect the goals and objectives outlined in Chapter I.

The primary objectives of this study were to construct a VR simulation, assess the use of the VR simulation by college students and to assess the potential learning outcomes of students in their use of the VR simulation. A secondary objective was to look at the potential of using the VR simulation in an Internet class of Human Anatomy/Physiology. No testing was to be done in the Internet class part of the study.

The hypotheses considered based on the objectives were:

1. A virtual reality simulation will help college students master some of the physiological movements of the human hand, and

2. Students who develop an in-depth understanding of the physiology of the hand

through a virtual reality simulation will want similar experiences for each of the other

parts of the body studied.

Investigating the potential implementation of the VR simulation into an Internet

class of Human Anatomy/Physiology had to be deferred to the Fall of 2000 due to the

unavailability of the faculty member who had offered to conduct the treatment.

However, the investigator spoke with technical support of the EON Company, and it is

possible to imbed the EON viewer into a Web page and import the "hand" file into the

EON viewer imbedded into the Web page. The EON viewer can be downloaded from the

EON company (it is public domain software) by any student, and a copy of the "hand"

file could be sent to the students either on a floppy disk or as an attachment to an e-mail

file.   Two students in a computer class that the investigator taught volunteered to try

downloading the EON viewer. Then a file of the "hand" VR simulation was sent as an

attachment to an e-mail. The students reported back to the investigator that the

experiment worked fine on their computers. However, computer hardware capabilities

could be the constraint from student to student. The "hand" VR simulation file is small

enough to fit on a 1.44-megabyte floppy disk, and it is small enough to be sent as an

attachment to an e-mail file. The "hand" VR simulation file is 785 kilobytes and it has

2,411 polygon faces.

Data Analysis

The following six tables are analyses of the written material in the two folders

containing the booklets with the questionnaires and summaries and the post-tests. Visual

observations by the investigator, while in the three labs observing the students, will be discussed in the section called Findings in this chapter.

Table 1: Distribution of Student Answers on Post-test

(The question is given with the five selections. The answers in the chart are those selected by the students and all 31 students answered all five questions.)

1. In the movements of the fingers of the hand, this is the movement that decreases the angle of the joint, for example, bending the finger from a straight to an angled position.

a. opposition   b. extension   c. adduction   d. flexion   e. abduction

	a.	b.	c.	d.	e.	Total
Answers	0	4	2	**23**	2	31

Correct answer is "d" and the **mode** is "d"

2. In relation to the fingers this action splays them laterally, but in relation to the thumb this action points the thumb anteriorly

a. opposition   b. extension   c. adduction   d. flexion   e. abduction

	a.	b.	c.	d.	e.	Total
Answers	4	3	10	1	**13**	31

Correct answer is "e" and the **mode** is "e"

3. This action refers to the movement of the thumb – moving the thumb toward the little finger, across the palm of the hand

a. opposition   b. extension   c. adduction   d. flexion   e. abduction

	a.	b.	c.	d.	e.	Total
Answers	**23**	1	3	2	2	31

Correct answer is "a" and the **mode** is "a"

4. In relation to the fingers this action draws them close together in an extended position, but in relation to the thumb this action points the thumb posteriorly

a. opposition   b. extension   c. adduction   d. flexion   e. abduction

	a.	b.	c.	d.	e.	Total
Answers	3	5	**14**	1	8	31

Correct answer is "c" and the **mode** is "c"

5. In the movements of the fingers of the hand, this is the movement that increases the angle of a joint, the straightening of the bent finger

a. opposition   b. extension   c. adduction   d. flexion   e. abduction

	a.	b.	c.	d.	e.	Total
Answers	0	**20**	2	7	2	31

Correct answer is "b" and the **mode** is "b"

Note: in viewing the responses to all five questions, the correct answer for each question was also the **mode** response for all five questions.

Table 2: Distribution of Correct Answers on Post-test Per Student – 31 Students

Number of correct answers	0	1	2	3	4	5
Number of students	2	6	2	**9**	4	8
Percentage out of 100%	6.5	19	6.5	**29**	13	26

Note: the **mode** on the analysis of correct answers per student was three correct answers out of five answers obtained by **nine** students out of a total of thirty-one students.

Table 3: Student Responses to Essay Question on the Post-Test

Essay Question: What finger had a physiological problem? Give a general explanation of what could be the reason for such a problem.

Responses

(As written by the students.)

1. "The thumb looked to be at a disadvantage because of the lack of a third digit. This is a guess!!"

2. "The thumb. It has only 2 joints as compared with the rest of the fingers three joints."

3. "The thumb. It doesn't have the versility like the others."

4. "The thumb because it has only two phalanges for adduction and abduction so it will alway have physiological problems."

5. "The thumb because you are not really able to do anything with it."

6. "Either the thumb or the index finger (last joint did not move)."

7. "Thumb or pointer finger."

8. "The thumb, the distal part was bent upward, possibly a problem with arthritis."

9. "The thumb had a physiological problem it bent backward like a stairway. Would the problem be a computer gliche?"

10. "The thumb it was unable to bend as much as the rest of the bones in the fingers."

11. "I think it was the thumb because it could not be shown to point towards little finger this may be because the thumb points anteriorly."

12. "The Thumb – The action did not resemble the thumb as much as the others did. fingers were fairly accurate. The Thumb did not act as well."

13. "The thumb, it could not bend all the way."

14. "The pointer finger it's first part of the diget would not bend."

15. "Last digit of the index finger – frozen – maybe broken."

16. "Index finger – last digit – stiff – broken – cut nerve/muscle?"

17. "The 3rd digit. Not as much range of motion because of its anatomical location."

18. "The fifth phalange would not extend/flex every time the joints were instructed by the action of the mouse."

19. "4th Digit. Old fracture."

20. "2 digit The compute wasn't fast enough a maybe a problem."

21. "Not sure."

Note: the **correct answer** was that the distal digit of the index finger was an immobile joint, not movable due to a possible cut in the nerve or muscle. Statements one through thirteen reference the thumb. Statements six, seven, and fourteen through sixteen reference the index finger. Statements seventeen through twenty-one are miscellaneous statements. From this information, the thumb was the focus of attention and constructivist thinking. The results give an indication that the students may not have read their student booklets prior to taking the Post-test. It was detailed in the booklet, under the definition of "opposition" that the thumb movements are different from the movements of the fingers because the thumb lies at a right angle to the rest of the hand. The thumb flexes by bending medially along the palm, not anteriorly, as do the other fingers. The thumb extends by pointing laterally (as in hitchhiking), not posteriorly, as do the other fingers. The action of opposition of the thumb also entails the movement of the two phalanges and the metacarpal bone, which articulates with the carpal bones. In the VR simulation there was no opposition because there was no movement of the metacarpal bones. The only movement was flexion and extension of the two phalanges of the thumb, which is a very limited movement, compared to what students normally are used to seeing in their own hand.

The observation also may have been different due to the fact that the students were looking at a skeletal representation, without any muscle and skin. This also gives a different viewpoint and understanding of the movements of the skeleton. A point of clarification is that the students study the articulations of the joints after they have finished their study of the bones of the skeleton and before they begin their study of the muscles.

Table 4: Distribution of Student Answers on Questionnaire

Note: the Questionnaire (the full questionnaire is found in Appendix B) rates the VR simulation on 15 items with the following scale:

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

The student responses for each category are listed under each item statement.

Item

1. The VR simulation significantly enhanced my learning some of the hand movements

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
10	16	4	1	0

2. By using the VR simulation, I have a better understanding of flexion of the fingers

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
10	19	1	1	0

3. By using the VR simulation, I have a better understanding of extension of the fingers

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
11	17	2	1	0

4. By using the VR simulation, I have a better understanding of adduction of the fingers

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
6	**12**	7	6	0

5. By using the VR simulation, I have a better understanding of abduction of the fingers

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
6	**12**	7	6	0

6. By using the VR simulation, I have a better understanding of opposition of the thumb

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
9	**11**	5	6	0

7. I would like to see other VR simulations of the joints (articulations) of the human body

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
19	11	0	1	0

8. I would like to see other science courses use VR simulations

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
20	10	1	0	0

9. I prefer using a VR simulation rather than just reading the textbook for learning information about the movement of the hand

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
20	10	0	1	0

10. I enjoyed using the VR simulation as part of the BIO201 Anatomy/Physiology course

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
19	12	0	0	0

11. I would use the VR simulation, if available, outside of class time for study purposes

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
18	11	1	1	0

12. I would use the VR simulation, if available, for other classes

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
17	11	3	0	0

13. I would recommend that other students take the BIO201 course that has this VR simulation

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
19	10	2	0	0

14. As I worked my way through the VR simulation, I felt that I was being encouraged to think more about the movements of the hand

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
13	**14**	3	1	0

15. As I worked my way through the VR simulation, I felt that I was being encouraged to think more about the movements of the other joints (articulations) of the body

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
12	**15**	2	2	0

Note: All 31 students answered all fifteen questions. The **mode** for questions 1 through 6 was **Agree**, for questions 7 through 19 was **Strongly Agree**, and for questions 14 and 15 was **Agree**. There were no Strongly Disagree selections.

Table 5: Distribution of Student Summary Evaluations

(Note: the Summary rates theVR simulation on 7 items on a scale of 10 – 1, Excellent to

Poor. All 31 students answered all the questions.)

Scale	Excellent									Poor	Total
Item	10	9	8	7	6	5	4	3	2	1	31
1. Usability	**11**	**11**	5	1	1	2	0	0	0	0	31
2. Navigation	**12**	8	5	3	1	1	1	0	0	0	31
3. Layout	**13**	9	5	2	2	0	0	0	0	0	31
4. Academic Content	8	5	**11**	3	1	2	0	1	0	0	31
5. Clear Directions	**16**	9	2	2	1	0	1	0	0	0	31
6. Attainment of learning objectives	8	**12**	5	4	1	0	0	1	0	0	31
7. Fitting well with the rest of the course material	**14**	10	4	1	1	0	0	1	0	0	31

Note: the **mode** for the seven items, with a tie for number 1, is:

Item	Scale Number	Mode
1. Usability	10	11
	9	11
2. Navigation	10	12
3. Layout	10	13
4. Academic Content	8	11
5. Clear Directions	10	16
6. Attainment of learning objectives	9	12

7. Fitting well with

the rest of the   10   14

course material

Table 6: Student General Comments on the VR Simulation

(Note: After finishing the Questionnaire and Summary the students were asked to write their comments on the back of their booklet.)

Student Comments

(As written by the students.)

1. "very realistic and enjoyable way to learn"

2. "As the VR stimulation of the hand move, I think it will be a great idea to also state or lavel the movements. Great Job."

3. "I think it would be good to also give a description of what is happening with the hand to help us (the students) learn plus think."

4. "Very intrested and educational for useage."

5. "Although this is a very neat program and it helps you visualize the movements of the human body in an entirely different way, I believe that it would be more beneficial to the student who had a clearer understanding of the vocabulary involved. Some directions on what to <u>do</u> would be helpful as well."

6. "More of this"

7. "I liked this – thanks"

8. "Interesting"

9. "Neat – more computers in class"

10. "This would help for the whole skeleton"

11. "This made me think!"

Findings

The benefits of the VR simulation were many. The investigator observed the three lab classes while the students worked with the VR simulation and some analyses were made. It was the first time students worked with a VR simulation in their college courses and comments were made from student to student addressing this fact. Other observations were that students enjoyed working with the simulation, and some of them re-did the VR simulation a number of times. Students agreed that such VR simulations would give their instructors more time for other items while the students used the VR simulation in the lab.

Another observation was that students looked at the VR simulation and discussed aspects of the VR simulation with each other. They used their own hands to demonstrate the movements of the "hand" in the VR simulation. This activity reflects the constructivist theory of education where students learn by doing some activity on their own or with other students. The students think through what they are doing on their own without the intervention of an instructor. A final observation was made that many of the students approached the investigator before leaving the lab, and they made the request to have more VR simulations. There were no negative comments on the VR simulation by the students who experimented with the simulation.

As with any new technological implementation, there were difficulties at every stage. In developing the VR simulation many difficulties were encountered with the investigator having to learn the modeling program (MultiGen) and the simulation program (EON). The programs were used at the Maricopa Institute of Virtual Reality at Chandler-Gilbert Community College in Mesa, Arizona and the two software companies

were located in California. With very little technical support available for either program on-site, neither program was intuitive. Obtaining technical support for both programs from the respective companies was difficult. Usually the best method was to e-mail specific questions to the technical support of the respective companies, but it would have been easier for a technical support person to actually view the simulation in order to assist with the problems.

Some problems occurred in the development of the VR simulation in transferring files from computer to computer (hardware configuration problems), and setting up all the parameters in the simulation file to make the degrees of freedom of the hand respond correctly. Another problem encountered was in the coloration of the modeling file and the results of the color in the simulation file. They were not consistent. When the file was created in the modeling program, coloration was applied as a material. When the file was transported into the simulation program, the color was much different and many changes had to be made within the simulation program. Technical support said that such a problem should not exist!

The computers available at the Maricopa Institute of Virtual Reality Technology, Chandler-Gilbert Community College, for the modeling and simulation, had hardware constraints. These problems usually consisted of not enough computer memory and not a fast enough microprocessor.

Installation of the VR simulation into the three labs presented problems. In one college (Central Arizona College) there was only one computer in the Human Anatomy/Physiology lab, so arrangements had to be made to have the students go to the computer lab in another building on campus. The computers in the computer lab had a

number of software programs resident on the hard drives, for computer classes. When the VR simulation ran, it worked in real-time but the mouse arrow (pointer) would "flicker" and indicate a small lag time.

In the other college (Gateway Community College), there were computers in the Human Anatomy/Physiology lab, but they were older models, with limited memory, and a number of programs already on the computers. With these limitations, the VR simulation could not function optimally. Also the monitor screens were of a smaller size (11 inches wide by 8 inches high). When the split screen was used to place the VR simulation on one half the screen and the 2-D multi-media program on the other half, the viewing of the VR simulation was too small. Arrangements were made for the students to go to a new computer lab in the Science Building, where the computers were new and powerful enough (in memory and microprocessor speed) to handle both the 2-D multimedia and VR simulation on the screen.

Student issues, also, impacted on the implementation of the project. Students varied in their computer ability and use of the mouse. One student had never even used a computer. Manual dexterity in the use of the mouse was varied. Visualizing the 3-D concept was new to some students, and some students had difficulty in "watching" the fingers "move". The strangeness of the new computer application elicited some comments and questions

Another observation centered on the fact that some students did not take time to read the material in the booklet that was provided prior to their going to the computer lab. Some students had difficulty with the mouse actions in moving the "hand" VR simulation from right to left and left to right on the screen. They did not have a good sense of

control of the simulation. It was obvious that they approached computer applications without reading directions, and when there was a problem, they would go back to quickly read the directions.

It was also evident the students had not read in their booklets in reference to their responses on the "thumb". It was detailed in the booklet, under the definition of "opposition" that the thumb movements are different from the movements of the fingers because the thumb lies at a right angle to the rest of the hand. The thumb flexes by bending medially along the palm, not anteriorly, as do the other fingers. The thumb extends by pointing laterally (as in hitchhiking), not posteriorly, as do the other fingers. The action of opposition of the thumb also entails the movement of the two phalanges and the metacarpal bone, which articulates with the carpal bones. In the VR simulation there was no opposition because there was no movement of the metacarpal bones. The only movement was flexion and extension of the two phalanges of the thumb, which is a very limited movement, compared to what students normally are used to seeing in their own hand. After the test some students asked about the thumb. When they were shown how to hold their metacarpal bone rigid and just move the two phalanges of the thumb for flexion and extension, then they understood the limited action of the thumb versus the actions of the three phalanges of the four fingers. Based on this observation it probably would be advisable to have a demonstration of the movements of the thumb and what bones are involved before the VR simulation is used. It was clear that the students were not informed as to the difference in movements of the thumb and the fingers.

Summary of Results

Despite the software, hardware, and other problems, the investigator observed very positive attitudes exhibited by all the students when they used the VR simulation. The experience was new, the students were interested, some were excited, some were amazed, and some were taken back when they saw the fingers and the thumb move in the VR simulation. It was a first-of-a-kind experience. Observing the students was a positive experience, and seeing the positive results of the questionnaire, summary and post-test were encouraging for the new technology of VR simulation.

Introducing a new paradigm of instruction into a class has problems, but the advantages can outweigh the disadvantages. The learning experience gained by the students was the priority and that priority was met and exceeded the investigator's expectations.

Chapter V

Conclusions, Implications, Recommendations and Summary

Introduction

In this chapter, the investigator examines the goals, objectives, and research questions and assesses the extent to which these were met. The implications of the impact of the study on the college course of Human Anatomy/Physiology are reviewed and recommendations are made for future research in the methods and concepts of enhancing the college course and curricula of Human Anatomy/Physiology.

In Chapter I, the goals were listed as the creation and implementation of a 3-D real-time virtual reality simulation of the human skeletal hand with some degrees of freedom movement in the fingers and thumb and the implementation of the VR simulation in two modes of an educational application in the Human Anatomy/Physiology college curricula. The primary objectives were to assess the use of the VR simulation by college students and to assess the potential learning outcomes of students in their use of the VR simulation. The following hypotheses were generated by the objectives:

1. A virtual reality simulation will help college students master some of the physiological movements of the human hand, and

2. Students who develop an in-depth understanding of the physiology of the hand through a virtual reality simulation will want similar experiences for each of the other parts of the body studied.

The conclusions reached by the investigator were based largely on the data analyses presented in Chapter IV. This data included: Table 1: Distribution of Student Answers on Post-test, Table 2: Distribution of Correct Answers on the Post-test Per Student, Table 3: Student Responses to Essay Question on the Post-test, Table 4: Distribution of Student Answers on Questionnaire, Table 5: Distribution of Student Summary Evaluations, and Table 6: Student General Comments on the VR Simulation. Further conclusions were reached from observations made in the three labs as the students worked with the VR simulation. Also considered were open-ended interviews that were conducted by the investigator and information garnered from the literature.

Conclusions

The goal of the creation and implementation of the VR simulation of the human skeletal hand with some degrees of freedom movement in the fingers and thumb was achieved. The implementation of the VR simulation took place in three labs of Human Anatomy/Physiology in on-site classes. It was developed to show that it was a teaching skill that was relevant to the real task performance (Smith, Wan, Taffinder, Read, Emery & Darzi, 1999). Although it was not totally realistic, a virtual environment needs only to be realistic enough so that the students who use the VR simulation feel they have learned something or done something they could not ordinarily learn or do. Absolute realism is

not what a VR simulations is all about; VR simulations are not the same as actual reality (Weiss, 1996)

A limitation was the size of the file needed to give a good visualization and real-time effect, but small enough to run on standard computers in the colleges. Developing the polygon structure of the bones is a limitation in that to make the semblance of rounded bones, many polygons are needed. Due to the computational and real-time update requirements of virtual reality interfaces, however, the complexity of polygonal surfaces that can be displayed is limited (Cameron, Manduca & Robb, 1996). To sustain the illusion, the VR interface needed to be able to generate a smoothly animated image. Due to the limitations of the computer hardware available in the colleges, the requirements limited the complexity of the displayed images.

The skeletal hand was chosen for the experiment rather than a fleshed-out hand (one that would have the muscles and skin attached to the skeletal bones). To model a fleshed-out hand would have created a very large file of polygons that would have prohibited the VR simulation from running on the computers available at the colleges.

In practical terms, the desktop VR simulation was a basic level of technology that was achieved on most of the college computers at no cost to the colleges. A key issue in this study was the VR simulation's ability to facilitate constructivist learning activities (Youngblut, 1998), and it did improve the student motivation in their use of the VR simulation as observed by the investigator. The notion of building knowledge through experiencing reality is the cornerstone of the constructivist learning paradigm. The knowledge acquisition process in the VR simulation is one in which the student is constantly exploring and constructing reality for themselves (Cronin, 1997). In the VR

simulation of the hand, the students viewed the simulation a number of times and compared their hand movement with the simulation movement. As they used the simulation, they looked at their own hand and had to discern the movement of the fingers of the "skeletal" hand of the simulation against their own human muscle and flesh covered human hand. They asked each other questions and interacted without the intervention of the instructor. These are key concepts in the constructivist theory.

The results of the student questionnaire, summary and post-test make the two hypotheses listed in Chapter II true. The first hypothesis was that a virtual reality simulation will help college students master some of the physiological movements of the human hand. The second hypothesis was that students who developed an in-depth understanding of the physiology of the hand through a virtual reality simulation will want similar experiences for each of the other parts of the body studied.

From the student answers on the questionnaire, it was concluded that the VR simulation enhanced the student learning of hand movement and gave them better understanding of the movement of the fingers and thumb. The results indicated that students want to see other VR simulations of the human joints, want to see other science courses using VR simulations, prefer to use a VR simulation to just reading the information in the textbook, enjoy using the VR simulation, and were encouraged to think more about the movements of the hand and the other joints of the body.

From the student summary evaluations, it was concluded that the VR simulation was usable and navigable. The positive responses gave high approval ratings to the layout, academic content, clear directions, attainment of learning objectives, and the VR

simulation fitting well with the rest of the course materials. Many of the student comments on the VR simulation were of a positive nature.

From the student answers on the post-test, it was concluded that the virtual reality simulation helped the college students master some of the physiological movements of the human hand. In reviewing the essay answers to the question posed at the end of the post-test, students did constructive thinking. They observed the thumb and the fact that there are only two phalanges rather than three as in the four fingers. They also saw that the thumb did not have the movement like the fingers. They observed that the thumb did not have the ability to "bend" as much as the rest of the joints in the fingers. The thumb motion was very limited if the metacarpal bone was not movable. The action of opposition was not available. The action of flexion and extension was limited and the thumb acted differently than the finger actions.

Some of the students observed that the index finger had a physiological problem. The distal digit did not bend. (The investigator had set the articulation of the distal and medial phalanges at zero degrees of freedom to "freeze" the joint and create the physiological problem.)

Most of the students looked at the thumb as the problem. One of the reasons may have been the way the thumb moved and the fact it was just the skeletal bones in the VR simulation rather than a "fleshed-out" thumb in real life. Looking at a VR simulation of the physiological movement of the thumb for the first time, may have been a strange experience for some students, especially when the thumb could not act in opposition to the fingers.

The investigator gave four presentations to faculty and administration. One presentation was to the Maricopa Community College Advisory Board, where the presidents of the ten Maricopa Community Colleges (Arizona) were present, plus various other administrators and some faculty. The second presentation was given to the Arizona State Board of Colleges (the presentation was too short in time and many people present were not aware of what VR simulations were all about). The third presentation was given at the Gateway Community College Math/Science monthly faculty meeting (one of the colleges where the testing was done). Reaction was mixed. Some faculty, who had never seen a VR simulation, did not go to the demonstration that was held in the computer lab. The fourth presentation was given at Central Arizona College, which was the other testing site. Some faculty members and some administrators were present for a VR demonstration in the computer lab. The fourth presentation received the greatest amount of interest.

Faculty commitment to the VR simulation was of a mixed nature. Some faculty were very impressed with the presentation, some were skeptical, and some were not interested. Some faculty are very interested in new computer technology, some are conservative in their outlook with the belief that until the new is tried and tested, they will hold judgment, and some are not interested because they do not look at computer technology as a need in their classes. Administrators are also mixed in their reactions. Their primary concern is the high cost of quality computers to run VR simulations.

Again, the problem of uniformity and conformity in the design of the curricula of Human Anatomy/Physiology cannot be agreed upon. Faculty members continue to differ in their views of what should be covered in the course BIO201 Anatomy/Physiology

(especially at Gateway Community College where there are a number of faculty, both full-time and part-time, who are teaching the course). The information taught varies from instructor to instructor. Students may receive a demonstration of the physiological movements of the articulations of the body or they may be instructed to only read the textbook. Some instructors will test the students on the different articulation movements of the body and other instructors will only ask one or two questions on the test and they tend to ignore many of the "minor" articulations such as those of the hands and feet.

Some of the faculty members do not use computer applications as much as others and they find they do not have time to institute new modes of instructions such as a VR simulation until it has been really tried and tested, and there will be no problems with the enhancement. Their concern is to not over-load the students, but others believe the students should have a wide variety of resources to learn from.

According to Barker (1997), in order for VR simulations to move from the research and development laboratory to the teaching classroom on a large-scale basis, four conditions must be met: faculty involvement, student cooperation, affordable equipment and administrative support. Based on this study, colleges have a long way to go because the faculty involvement is very mixed, student cooperation is positive but again there are some students who lack computer experience and become frustrated. Affordable computer equipment is limited.

Outcomes of the Use of VR Simulations

The high visual nature of virtual reality and its ability to provide interactions not possible in the real world make it a compelling and motivating learning environment

(Hoffman & Vu, 1997). One of the positive outcomes of the students using the VR simulation of the hand was the fact they did not have to memorize data to use the VR simulation. They had available their student booklet for directions and definitions.

Students used their cognitive ability to reason the need for the simulation and how it applies to the human body (Cliff & Wright, 1996). When students used the VR simulation, they were also looking at the movements of their own hand. They had to reason the movements of the VR skeletal simulation and their own hand. There is a difference between the two as stated in Chapter IV.

VR-based anatomy/physiology programs will allow students to investigate structures in ways not possible in the real world. If instructors cover the articulations of the body, there are no methods of demonstration, at present, to show the various articulations except by giving a demonstration of their own body movements. This may be difficult for some instructors to demonstrate (due to arthritic joints, especially in their hands). VR-based systems have the potential to make broad-based training experiences available to students at all levels, without the risks and ethical concerns associated with using animal and human subjects (Hoffman & Vu, 1997). In this study, the VR simulation enhanced the class were only plastic models were used.

The exploration and manipulation of an object in a virtual environment recalls the theory of constructivism as detailed in the previous section. Visualization and navigation tools have great pedagogical potential, because students select the strategies for discovering the characteristics of the object (Salis & Pantelidis, 1997). Students in this study could read their booklet, converse with fellow students, view the VR simulation multiple times and compare their viewing of the VR simulation with the

movements of their own hand. Furthermore, they could look in their textbook for further explanation or check their lecture notes on material on articulations.

Another important issue relative to the students using the VR simulation is that what is learned persists if it is practiced, and this is true of cognitive as well as of psychomotor learning. The VR simulation of the hand is ideal for permitting students to repeat activities with or without variations, for as long as it may take them to master the concepts. The more the students viewed the VR simulation, the more they discovered relative to movement. This reinforcement of knowledge is a process of learning. Manipulation and direct experience of things that cannot be manipulated and experienced in the real environment are probably some of the most useful attributes of the VR simulation for education. According to Furness, Winn and Yu (1998) VR environments motivate students to learn. The VR simulation permitted the students to manipulate the hand and observe some of the movements of the articulations of the fingers and thumb. Students raised concerns as to why the thumb looked and acted "funny" in its movements and appearance. Having only the skeletal representation instead of a "fleshed-out" representation created a different concept to think about. It may have been better to have a VR simulation of a "fleshed-out" hand, but actually the VR skeletal simulation allowed the students to see the lack of movement of the thumb due to no movement in the metacarpal bones.

As previously stated in Chapter II, the constructivist theory asserts that students learn by taking in information from their environment and constructing their own meaning from the experience. The use of the VR simulation of the hand enhanced this constructivist concept when the curriculum role of the instructor changed to facilitator

and more control was turned over to the students. During the student use of the VR simulation, the instructor was not called upon for any explanations. Instructions had been given before the students used the VR simulation, that the instructor was not going to be available for information or instructions. The students were advised to use their booklets to assist them or they were to assist each other.

The modes of technology expand in the use of virtual reality simulations where activities are problem-based rather than drill-and-practice. Questions were designed to challenge students to look beyond the apparent, and to delve into issues deeper to form their own understanding (Sprague & Dede, 1999). The essay question on the physiological problem in the Post-test was an example of challenging the students to think and form a logical conclusion to the physiological problem

Recommendations

For an effective curriculum for the course of Human Anatomy/Physiology, better cooperation, understanding, communication, and compromise need to take place among the faculty and administration. Also needed is a consensus on the use of computer-based enhancements for the course. For an effective curriculum, access to a wealth of information must be provided and there must be an exchange of information and formal learning between the instructors and students. An effective curriculum must integrate problem-solving and decision-making experiences with knowledge acquisition and reinforcement of learning outcomes that provide follow-up learning activities and feedback, such as are available with the use of virtual reality simulations (Khonsari & Fabri, 1997). The author concurs with this concept and proposes that an effective

curriculum in Human Anatomy/Physiology must integrate a problem-solving and decision-making experience as was given by the "physiological problem" essay question in the Post-test.

Faculty resistance is one of the most commonly cited reasons for the lack of widespread implementation of new technologies, such as virtual reality simulations. Faculty members believe that they may be held liable for the outcome of proposed enhancements such as the virtual reality simulation. Also, a majority of faculty members are resistant to technological advances which may require an increase in the time and effort that they must put forward (Gupta et al., 1996). The virtual reality simulation of the hand in this study would take about three to four hours for an instructor to master the technology and develop the applications for use by the students. Change will have to start with the faculty. Faculty will need to be more open to the use of various computer applications such as VR simulations. These VR simulations will open new venues of ways to present physiological material in ways not possible for students to experience.

Students learn best when a variety of teaching methods are used, and different students respond best to different methods. Computers are being used more as teaching tools, to give students a wider variety of learning experiences, but high-quality solutions are not yet affordable, and affordable solutions are not yet high-quality. Bell and Fogler (1995) state that it is prudent to begin developing virtual reality education applications today, so educational institutions will be prepared for the advances in equipment software when they become available. Further ethical issues precipitate a need for a new paradigm. Within the past decade, popularity of the new VR simulation technology has driven software prices down and the quality of VR simulations up. VR is designed to

pull the students into the experience, and anything that can be done to get students more enthused and interested in the subject matter of Human Anatomy/Physiology will be a good thing. In addition, those students who experience VR simulations in their undergraduate courses will have an additional edge when they encounter VR simulations in their graduate courses.

The Internet is perceived to be a powerful medium for VR simulations, and there is a very good chance that it will develop into a major player in the educational environment. Planning and implementing this medium for VR simulations in the sciences has begun and will expand rapidly. VR has matured very quickly and offers powerful future solutions to some very difficult problems, especially in the medical fields. VR is no longer a technology looking for an application, it is a solution to any problem that involves the real-time visualization of complex 3-D data (Vince, 1999). The investigator plans on further research on the use of the VR simulation in physiology on the Internet. Although there still are some constraints, it is possible for students to use VR simulations on the Internet. This ability will increase with more powerful computers and higher bandwidth.

Summary

The author became interested in the field of artificial intelligence in the early 1980s. That interest progressed into the field of virtual reality in the early 1990s. With a background in the Biological Sciences, with an emphasis in Human Anatomy/Physiology, and a background in the Computer Sciences with an emphasis in

virtual reality, she saw a potential to combine the two sciences to develop a new paradigm for the instruction of Human Anatomy/Physiology.

Although the undergraduate college course is called Human Anatomy/Physiology, there is more emphasis on the anatomy aspect, probably due to the lack of materials to use in the instruction of physiology. Further complications arise by the ever-increasing volume of available physiological data on the human body. This creates issue of how and what should be included in undergraduate college courses. Add to that the limited time that instructors have in class and the heavy loads carried by students who have many every-day time constraints, and it is evident that a new mode of instruction to enhance the class, where only plastic models were used, is needed.

A review of literature confirmed the non-agreement by instructors as to what information should be covered in the college course called Human Anatomy/Physiology. The literature also revealed that there are many VR simulations in the construction, implementation, and usage stages in various medical schools, but very few VR simulations appear in undergraduate programs. They are basically non-existent.

The goals of this research involved the modeling, simulation, and implementation of an anatomical and physiological 3-D real-time, non-immersive virtual reality simulation. The intent was to develop an enhancement for use in the changing paradigm in the undergraduate course called Human Anatomy/Physiology. The VR simulation is reusable and can provide students with the opportunity for repeated practice.

Two software programs had to be mastered in order to develop the polygonal model of the skeletal human hand. The developed file was imported into a simulation to create a 3-D real-time VR simulation. An instructional booklet, questionnaire, summary

and post-test were created. The VR simulation was implemented into three lab classes of Human Anatomy/Physiology, where the students used the VR simulation, took the questionnaire, summary and post-test.

The primary objectives of this study were to assess the use of the VR simulation by college students and to assess the potential learning outcomes of students through their use of the VR simulation. Based on these objectives, the first hypothesis stated that a virtual reality simulation would help college students master some of the physiological movements of the human hand. The second hypothesis stated that students who develop an in-depth understanding of the physiology of the hand through a virtual reality simulation will want similar experiences for each of the other parts of the body studied. Conclusions proved true for both hypotheses.

Based on the positive results of the students' answers to the questionnaire, summary and post-test, it is reasonable to conclude that virtual reality simulations of the physiological movements of the articulations of the human body enhance the learning ability of the students. This enhancement takes place by providing a method whereby students can interact with the VR simulation in class, in the library, or at home. Another learning advantage is that the VR simulation can be repeated at will, and still another benefit of VR simulation use is that students may construct their own knowledge bases of how physiology operates. They can obtain their information from a variety of sources such as lecture material, their textbook, lab materials such as the models of the human body and the cadaver and they can further enhance their knowledge base with VR simulations that encourage their constructivist thinking. This constructivism develops the critical thinking needed by students when they enter into the medical environment where

they will need to do deductive reasoning in a constructivist environment with fellow students.

By introducing students to VR simulations in their undergraduate classes, they will have a better chance achieving positive results when they encounter VR simulations in graduate and medical schools. Virtual reality is the language of the new generation of medicine (Satava, 1996) where with VR simulations instructors will be able to electronically educate, train, prototype, test and evaluate students. Student time will not be comprised in medical school since they won't be at a disadvantage not knowing how to use VR simulations. Time is of the essence for students both in their under-graduate and graduate programs. Furthermore, a VR simulation can be used many times by the students, thereby, enhancing their learning by reinforcement. This concept was shown in the many times that the students reviewed the VR hand simulation.

Some constraints and limitations in this research were identified such as the availability of hardware and software, the computer expertise of the students, and the acceptance of computer enhancements into the classes by the instructors. Since some medical graduate programs are presently experimenting with VR simulations, there is truly a need for students to be introduced to VR simulations in their undergraduate programs. The author concurs with Barker (1997) that instructors will need to believe that VR simulations offer an exciting opportunity to develop a realistic risk-free teaching methodology. When the VR simulation is incorporated into the curricula, its effects will be carefully evaluated and the results will provide valuable data for future VR simulation efforts. Future experimentation will need to be done on increasing the number of VR simulations, incorporating the VR simulations into the undergraduate courses, testing the

outcomes, and following the progression of the students into graduate programs. Khonsari and Fabri (1997) state that an effective curriculum must integrate problem-solving and decision-making experiences with knowledge acquisition and reinforcement of learning outcomes that provide follow-up learning activities and feedback. These concepts were evident with the use of the VR simulation, the questionnaire, summary and post-test.

A serious consideration needs to be made by faculty and administration to consider the paradigm of VR simulations. Bell and Fogler (1995) state that students learn best when a variety of teaching methods is used, and as a follow up, different students respond best to different methods. Further, VR stands to add to the variety of educational delivery mechanisms and to address those areas where traditional methods are weakest. One of the values of VR is its ability to give tangible, corporeal substance to otherwise abstract ideas and concepts. VR is excellent for reaching the active, visual, inductive and global learners, who are not always served well through traditional teaching methods.

Uniformity and conformity need to be addressed and concurred upon in the course called Human Anatomy/Physiology and serious consideration must be taken to make the course a course of instruction in both the concepts of anatomy and physiology. This issue will take time to resolve as evident in the lack of agreement in the literature on what should be covered in the course of Human Anatomy/Physiology and how it should be covered. This issue is worldwide. Enhancements, such as VR simulations, can free up time for the instructors, and provide students with new modalities of instruction in a constructive and cooperative environment of learning.

Instructional methods are changing in the 21st century, and it is imperative for instructors to keep up with change to assist the students to further their educational goals and be interested in learning. While the author continues to teach her courses in Human Anatomy/Physiology on-site, she is concurrently teaching Human Anatomy/Physiology courses on the Internet and also teaching courses in computer applications. She believes that all three modes will mesh together to help her assist her students in the biological and computer sciences. New modes of instruction will enhance and replace the old and students will benefit from a better quality of instruction and a more robust source of factual material in the areas of anatomy and physiology and computer enhancements.

Appendix

A. Permissions

Letters sent to and letters received from:

Dr. James Crimando
Human Anatomy/Physiology Professor
Gateway Community College
108 North 40th Street
Phoenix, AZ 85034

Dr. Jackie Ferguson
Science Division Chair
Gateway Community College
108 North 40th Street
Phoenix, AZ 85034

Dr. Jeff Ross
Science Division Chair
Central Arizona College
Superstition Mountain Campus
273 E. U.S. Hwy 60
Apache Junction, AZ 85219

Dr. Mary Puglia
Human Anatomy Physiology Professor
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273 E. U.S. Hwy 60
Apache Junction, AZ 85219

Ms. Mary Graci
Maricopa Institute of Virtual Reality Technology
Chandler-Gilbert Community College, Williams Campus
7360 East Tahoe Avenue
Mesa, AZ 85212

From: James Crimando <james.crimando@gwmail.maricopa.edu>
To: Helen St. Aubin <hstaubin@email.msn.com>
Sent: Friday, February 25, 2000 8:24 AM
Subject: Re: virtual reality

Hi Helen,

I have reserved the Computer Lab (upstairs Room 2121 where we worked before) for Wednesday March 1 and Monday March 6 from 9:00am-12:30pm. We probably won't need it for the whole time (especially since lab starts at 10:00am) but it will give you time to get in before lab to double check things.

The Leaning Center Staff will download and install EonViewer to all 24 computers. BUT - they need the information on where to download it from and what version to install. Please send that information to:

yvonne.zeka@gwmail.maricopa.edu

and CC a copy to me also.

Thanks,
Jim Crimando

Permission Granted

Dr. James Crimando, Ph.D.
Biology Professor

GateWay Community College
108 N. 40th St.
Phoenix, AZ 85034

(602) 392-5297
james.crimando@gwmail.maricopa.edu
www.gwc.maricopa.edu/home_pages/crimando

looks Great Helen, !

J. C.

February 27, 2000

Dr. James Crimando, Ph.D.
Biology Professor
Gateway Community College
108 N. 40th St.
Phoenix, AZ 85304

Dear Dr. Crimando:

In compliance with the rules and requirements of the Interview Review Board of NOVA
Southeastern University of Fort Lauderdale, Florida, I, Helen St. Aubin, request
permission to test students in the Anatomy/Physiology class.

I wish to have the students do the following:
1. Read a booklet of information, that I have prepared
2. View and interact with a virtual reality simulation of the human skeletal hand, which
   I have prepared
3. Do a questionnaire and summary evaluation
4. Take a post-test.

The above 4 items are completely voluntary.

There will be no acknowledgment of:
1. The names of any students
2. The sex, race, or computer ability of any student.

All student volunteers will be totally held in confidentiality.

All student questionnaires and evaluations will be placed in a folder, as will the post-tests
be placed in a separate folder. All student responses from all classes from all colleges
tested will be placed in the folders. When all testing is completed, I will have a professor
shuffle the papers in both folders to mix the papers for total confidentiality.

I will give credit to the individual colleges and Instructors/Professors who are so
graciously helping me in my research.

I sincerely thank you for all your time and help and look forward to testing the students
with a virtual reality simulation that I perceive to be a new paradigm in the teaching of
Anatomy/Physiology.

Sincerely,

Helen St. Aubin

February 29, 2000

Ms Jacqueline Fergusson
Chair of Math/Science Dept.
Gateway Community College
108 N. 40th St.
Phoenix, AZ 85304

Dear Ms. Fergusson:

In compliance with the rules and requirements of the Interview Review Board of NOVA Southeastern University of Fort Lauderdale, Florida, I, Helen St. Aubin, request permission to test students in the Anatomy/Physiology class.

I wish to have the students do the following:
1. Read a booklet of information, that I have prepared
2. View and interact with a virtual reality simulation of the human skeletal hand, which I have prepared
3. Do a questionnaire and summary evaluation
4. Take a post-test.

The above 4 items are completely voluntary.

There will be no acknowledgment of:
1. The names of any students
2. The sex, race, or computer ability of any student.

All student volunteers will be totally held in confidentiality.

All student questionnaires and evaluations will be placed in a folder, as will the post-tests be placed in a separate folder. All student responses from all classes from all colleges tested will be placed in the folders. When all testing is completed, I will have a professor shuffle the papers in both folders to mix the papers for total confidentiality.

I will give credit to the individual colleges and Instructors/Professors who are so graciously helping me in my research.

I sincerely thank you for all your time and help and look forward to testing the students with a virtual reality simulation that I perceive to be a new paradigm in the teaching of Anatomy/Physiology.

Sincerely,

Helen St. Aubin

March 1, 2000

I, Jacqueline Fergusson, Chair of Math/ Science Department, at Gateway Community

College, grant Helen St. Aubin permission to use the Computer Lab in

room 2121, to test her research project of a virtual reality simulation. She ~~will be testing~~ *has tested*

two classes of Anatomy/Physiology students (taught by Dr. James Crimando) on March 1

and March 6, 2000.

Signed: *J.Y. Fergusson*

(permission sought + given 4/5/00)

April 2, 2000

Ms. Jacqueline Fergusson
Chair of Math/Science Dept.
Gateway Community College
108 N. 40th St.
Phoenix, AZ 85304

Dear Jackie:

I wish to express my sincere thank you to you and others for all the help and support given to me as I complete my dissertation for my Ph.D. First, I wish to sincerely thank you for permitting me to use the computer lab and to test students in two classes of anatomy/physiology at Gateway Community College. Also, thank you for giving me the opportunity to give a presentation on virtual reality simulation to members of the math/science division at their meeting on March 3.

Second, I wish to sincerely thank Dr. James Crimando for his excellent words of advice and encouragement, and his continued support. His use of computer applications in his anatomy/physiology classes is very impressive, and the programs he has developed are indeed an enhancement to the modes of teaching anatomy/physiology. It has been a pleasure to work with Dr. Crimando in the computer environment.

Third, I wish to sincerely thank Christine Taccone, Lab Technician, for all the help she has given me and her continued support of my work. Christine is one who always has some very valuable bit of advice to offer, and I sincerely appreciate that. Further, she is quick to assist with whatever task may occur in the lab, at any time she is called upon to assist.

Fourth, I wish to sincerely thank Tracy Smith, Learning Associate, Computer Lab, Room 2121. On three occasions she assisted me is downloading files from the Internet, setting up files on the computer, and arranging the room to make everything run with perfection for the three times that I was using the Computer Lab. I am sincerely grateful for all her work. She is excellent.

Last, I wish to sincerely thank the students who participated in my testing. I was very impressed with their enthusiasm and their patience. Furthermore, some interesting results surfaced in my testing, that gave support to my research, but also gave a good of example of the constructive method of learning that was taking place on the days of my research testing. The results make for some very favorable research documentation and future publication.

Once again, my very sincere thank you to you and all those mentioned in this letter.

Sincerely,

Helen St. Aubin
7302 E. Edgewood Ave.
Mesa, AZ 85208   e-mail: hstaubin@msn.com

cc: Dr. James Crimando, Christine Taccone, and Tracy Smith

March 9, 2000

Dr. Jeff Ross
Science Division Chair
Central Arizona College
Superstition Mountain Campus
273 E. U.S. Hwy. 60
Apache Junction, AZ 85219

Dear Dr. Ross:

In compliance with the rules and requirements of the Interview Review Board of NOVA Southeastern University of Fort Lauderdale, Florida, I, Helen St. Aubin, request permission to test students in the Anatomy/Physiology class.

I wish to have the students do the following:
1. Read a booklet of information, that I have prepared
2. View and interact with a virtual reality simulation of the human skeletal hand, which I have prepared
3. Do a questionnaire and summary evaluation
4. Take a post-test.

The above 4 items are completely voluntary.

There will be no acknowledgment of:
1. The names of any students
2. The sex, race, or computer ability of any student.

All student volunteers will be totally held in confidentiality.

All student questionnaires and evaluations will be placed in a folder, as will the post-tests be placed in a separate folder. All student responses from all classes from all colleges tested will be placed in the folders. When all testing is completed, I will have a professor shuffle the papers in both folders to mix the papers for total confidentiality.

I will give credit to the individual colleges and Instructors/Professors who are so graciously helping me in my research.

I sincerely thank you for all your time and help and look forward to testing the students with a virtual reality simulation that I perceive to be a new paradigm in the teaching of Anatomy/Physiology.

Sincerely,

Helen St. Aubin

March 10, 2000

I, Dr. Jeff Ross, Science Division Chair, at Central Arizona College, Superstition

Mountain Campus, College, grant Helen St. Aubin permission to use the

Computer Lab in room 314, to test her research project of a virtual reality simulation.

She will be testing one class of Anatomy/Physiology students (taught by Helen St.

Aubin) in March 2000.

Signed:

March 9, 2000

Dr. Mary Puglia
Human Anatomy/Physiology Professor
Central Arizona College
Superstition Mountain Campus
273 E. U.S. Hwy. 60
Apache Junction, AZ 85219

Dear Dr. Puglia:

In compliance with the rules and requirements of the Interview Review Board of NOVA Southeastern University of Fort Lauderdale, Florida, I, Helen St. Aubin, request permission to test students in the Anatomy/Physiology class.

I wish to have the students do the following:
1. Read a booklet of information, that I have prepared
2. View and interact with a virtual reality simulation of the human skeletal hand, which I have prepared
3. Do a questionnaire and summary evaluation
4. Take a post-test.

The above 4 items are completely voluntary.

There will be no acknowledgment of:
1. The names of any students
2. The sex, race, or computer ability of any student.

All student volunteers will be totally held in confidentiality.

All student questionnaires and evaluations will be placed in a folder, as will the post-tests be placed in a separate folder. All student responses from all classes from all colleges tested will be placed in the folders. When all testing is completed, I will have a professor shuffle the papers in both folders to mix the papers for total confidentiality.

I will give credit to the individual colleges and Instructors/Professors who are so graciously helping me in my research.

I sincerely thank you for all your time and help and look forward to testing the students with a virtual reality simulation that I perceive to be a new paradigm in the teaching of Anatomy/Physiology.

Sincerely,

April 20, 2000

Dr. Jeff Ross
Science Division Chair
Central Arizona College
Superstition Mountain Campus
273 E. U. S. Hwy. 60
Apache Junction, AZ 85219

and

Dr. Mary Puglia
Human Anatomy/Physiology Professor

Dear Jeff and Mary:

I wish to express my sincere thank you to you both and others for all the help and support given to me as I complete my dissertation for my Ph.D. First, I wish to sincerely thank you for permitting me to use the computer lab and to test students in one class of anatomy/physiology at Central Arizona College. Also, thank you for giving me the opportunity to give a presentation on virtual reality simulation to other faculty members and employees of CAC.

I also wish to sincerely thank the students who participated in my testing. I was very impressed with their enthusiasm and their patience. Furthermore, some interesting results surfaced in my testing, that gave support to my research, but also gave a good of example of the constructive method of learning that was taking place on the day of my research testing. The results make for some very favorable research documentation and future publication.

Once again, my very sincere thank you to you and those mentioned in this letter.

Sincerely,

Helen St. Aubin
7302 E. Edgewood Ave.
Mesa, AZ 85208   e-mail: hstaubin@msn.com

April 2, 2000

Ms. Mary Graci
Maricopa Institute of Virtual Reality Technology
Chandler-Gilbert Community College
Willams Campus
7360 East Tahoe Avenue
Mesa, AZ 85212

Dear Mary:

Since I am near completion of my Ph.D. dissertation, I want to clarify the status of the data file I created of the virtual reality simulation data file of the human skeletal hand. I developed the virtual reality simulation data file using the software program MultiGen and then placed the file into the EON simulation software to create the virtual reality simulation data file of the human skeletal hand.

As the developer of the virtual reality simulation data file of the human skeletal hand, I claim full and complete priority rights to said file. The said file shall not be copied in any fashion or manner to be given away or sold without my written permission.

However, I give you permission to embed the file in a Power Point presentation to be given by you on behalf of the Maricopa Institute of Virtual Reality Technology. I am to receive full recognition as the developer of the VR simulation as - Dr. Helen St. Aubin, Instructor of Anatomy/Physiology. No other function is permissible without my written permission. The file may not leave the Maricopa Institute of Virtual Reality Technology for any other reason without my written permission.

I thank you for your help and guidance on this issue and am reassured you will comply with my wishes.

Once again thank you.

Sincerely,

Helen St. Aubin
7302 E. Edgewood Ave.
Mesa, AZ 85208   e-mail: hstaubin@msn.com

cc: Helen St. Aubin
     Peter Mayrand, Attorney

April 2, 2000

Ms. Mary Graci
Maricopa Institute of Virtual Reality Technology
Chandler-Gilbert Community College
Willams Campus
7360 East Tahoe Avenue
Mesa, AZ 85212

Dear Mary:

I wish to express my sincere thanks to you for all the help and support given to me as I complete my dissertation for my Ph.D. I wish to sincerely thank you for permitting me to develop my virtual reality simulation of the human skeletal hand, using the computer hardware and software at the Institute. I sincerely appreciate your sharing your books and materials with me. I appreciate all the helpful words and suggestions you gave me.

Although Dr. Ken Schultz, resigned as director of the Institute, it was he who invited me to develop my VR simulation at the institute for my doctoral research, and I thank him.

Thanks to all who indirectly helped me at the Institute.

I wish you the very best at the Institute, and I look forward to my continuing to work with you in virtual reality in some way.

Thank you.

Sincerely,

Helen St. Aubin
7302 E. Edgewood Ave.
Mesa, AZ 85208   e-mail: hstaubin@msn.com

B. Student Booklet

BIO 201 Human Anatomy/Physiology

Before you begin this experiment, I wish to sincerely thank you for volunteering to take the time to use this virtual reality simulation, to fill in the questionnaire, and take the post-test. Since this is an experiment, you can stop whenever you wish and you can decide to take the questionnaire and post-test or not take them. I do not want you to place your name or any mode of identification on your booklet, questionnaire and post-test. I do not need to know the names of any students in this experiment, and all results will have no indication of student names, sex, or level of education. The experiment is being conducted at two colleges and all questionnaires will be placed in one folder, and all post-tests will be placed in another for both colleges.

As a bit of introductory information, I have been teaching Human Anatomy/Physiology and Computer classes. I am finishing my requirements for my Doctorate in Computing Technology in Education. My research involves developing a virtual reality (VR) simulation for use in the physiological study of some of the movements of the human hand. I am looking at a VR simulation to be used as an enhancement to the class material. At the present time there is no interactive physiological representation of the movements of the various articulations of the human body.

For your information I am including some definitions in this booklet for your review relative to the human hand. You may have already covered this material. **Abduction** – in relation to the fingers is to splay them laterally, but to abduct the thumb is to point it anteriorly. The fingers and thumb in this VR simulation are abducted.

Adduction – is to draw the fingers back so they are touching each other, and adduction in the thumb is to point the thumb posteriorly.

Articulation – is the joint or juncture of two or more bones.

Extension – is the movement that increases the angle of a joint, for example, the straightening of the bent finger.

Flexion – is the movement that decreases the angle of the joint, for example, bending the finger from a straight to an angled position.

Opposition – refers to the movement of the thumb – moving the thumb toward the little finger. This action enables the person to grip objects in the palm of the hand. Thumb movements are different from the movements of the other fingers, because the thumb lies at a right angle to the rest of the hand. The thumb flexes by bending medially along the palm, not anteriorly, as do the other fingers. The thumb extends by pointing laterally (as in hitchhiking), not posteriorly, as do the other fingers. The action of opposition of the thumb also entails the movement of the two phalanges and the metacarpal bone, which articulates with the carpal bones. In this experiment there is no opposition because there is no movement of the metacarpal bones.

A virtual reality simulation is different from animation. A VR simulation allows you to interact with the simulation and watch the movements of the fingers.

You will only need to know how to use a mouse – more specifically the left button on the mouse. The VR simulation will be set up for you.

Directions for use of the VR Simulation.

1. First you will see that the screen is divided into two halves, one half has a 2D-multimedia program that you can use with the mouse left button acting as a pointer.

2. The right side of the screen is the VR simulation, and by clicking on the left mouse button, holding down the button, and placing the arrow in the simulation you can do the following:

    a. move the arrow to the right and the whole hand moves across the screen

    b. move the arrow to the left and the whole hand moves back across the screen

    c. move the arrow to the top and the hand fades to the back of the screen

    d. move the arrow to the bottom and the hand comes forward

    e. click on the "knuckles" of the various phalanges and watch the movement of the phalanges

Note: A point to remember – the VR simulation is not an exact replica of the human skeletal hand, it is a representation. You will be viewing this VR simulation in the context of learning some of the physiological movements of the hand.

I will be present to help you with any technical questions, but you must think your way through the physiological questions.

When you have finished with the VR simulation, please answer the questions in the **Questionnaire** and the **Summary**. Then place the whole booklet into the designated folder.

I ask you to please take the **Post-test** to assist me in my research. When you are finished, place the post-test in the designated folder.

Once again, I sincerely thank you for volunteering in my experiment.

Helen St. Aubin

Questionnaire

Questionnaire

Virtual Reality Simulation of the Human Skeletal Hand

(NOTE: the bones of the wrist are not included as they are not part of this research, and the movements of the hand with the wrist and any movement associated with the metacarpals are not part of this research.)

This is a voluntary survey for research on the effects of a Virtual Reality simulation on learning. Your responses will help assess the use of a VR simulation in future classes of Human Anatomy/Physiology. Please do not put your name anywhere on the survey. The data collected will be kept confidential. All completed questionnaires will be placed in an aggregate collection, regardless of the class or institution where the questionnaires were administered.

Please circle only one answer per question.

1. The VR simulation significantly enhanced my learning some of the hand movements
   Strongly Agree   Agree   Undecided   Disagree   Strongly Disagree
          1   2   3   4   5

2. By using the VR simulation, I have a better understanding of flexion of the fingers
   Strongly Agree   Agree   Undecided   Disagree   Strongly Disagree
          1   2   3   4   5

3. By using the VR simulation, I have a better understanding of extension of the fingers
   Strongly Agree   Agree   Undecided   Disagree   Strongly Disagree
          1   2   3   4   5

4. By using the VR simulation, I have a better understanding of adduction of the fingers
   Strongly Agree   Agree   Undecided   Disagree   Strongly Disagree
          1   2   3   4   5

5. By using the VR simulation, I have a better understanding of abduction of the fingers
   Strongly Agree   Agree   Undecided   Disagree   Strongly Disagree
          1   2   3   4   5

6. By using the VR simulation, I have a better understanding of opposition of the thumb
   Strongly Agree   Agree   Undecided   Disagree   Strongly Disagree
          1   2   3   4   5

7. I would like to see other VR simulations of the joints (articulations) of the human body

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

8. I would like to see other science courses use VR simulations

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

9. I prefer using a VR simulation rather than just reading the textbook for learning information about the movement of the hand

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

10. I enjoyed using the VR simulation as part of the BIO201 Anatomy/Physiology course

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

11. I would use the VR simulation, if available, outside of class time for study purposes

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

12. I would use the VR simulation, if available, for other classes

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

13. I would recommend that other students take the BIO201 course that has this VR simulation

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

14. As I worked my way through the VR simulation, I felt that I was being encouraged to think more about the movements of the hand

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

15. As I worked my way through the VR simulation, I felt that I was being encouraged to think more about the movements of the other joints (articulations) of the body

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

In Summary

Circle only one number for each of the following

Having reviewed the VR simulation, I would rate the VR simulation in terms of

1. Usability

Excellent   **Poor**

| 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

2. Navigation

Excellent   **Poor**

| 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

3. Layout

Excellent   **Poor**

| 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

4. Academic Content

Excellent   **Poor**

| 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

5. Clear Directions

Excellent   **Poor**

| 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

6. Attainment of Learning Objectives

Excellent   **Poor**

| 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

7. Fitting well with the rest of the course material

Excellent   **Poor**

| 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

Your Comments: please write your comments on the back of this page.

After you have finished your questionnaire

1. please close the booklet
2. place the booklet in the designated basket
3. ask the instructor for the post-test

Thank you for taking this survey.

C. Post-Test

Post-test

Circle only one answer in each of the following questions

1. In the movements of the fingers of the hand, this is the movement that decreases the angle of the joint, for example, bending the finger from a straight to an angled position

a. opposition   b. extension   c. adduction   d. flexion   e. abduction

2. In relation to the fingers this action splays them laterally, but in relation to the thumb this action points the thumb anteriorly

a. opposition   b. extension   c. adduction   d. flexion   e. abduction

3. This action refers to the movement of the thumb – moving the thumb toward the little finger, across the palm of the hand

a. opposition   b. extension   c. adduction   d. flexion   e. abduction

4. In relation to the fingers this action draws them close together in an extended position, but in relation to the thumb this action points the thumb posteriorly

a. opposition   b. extension   c. adduction   d. flexion   e. abduction

5. In the movements of the fingers of the hand, this is the movement that increases the angle of a joint, the straightening of the bent finger

a. opposition   b. extension   c. adduction   d. flexion   e. abduction

Essay question: which finger had a physiological problem? Give a general explanation of what could be the reason for such a problem. Please write your answer on the back of this page.

When you are finished with this post-test, please place the test in the designated basket.
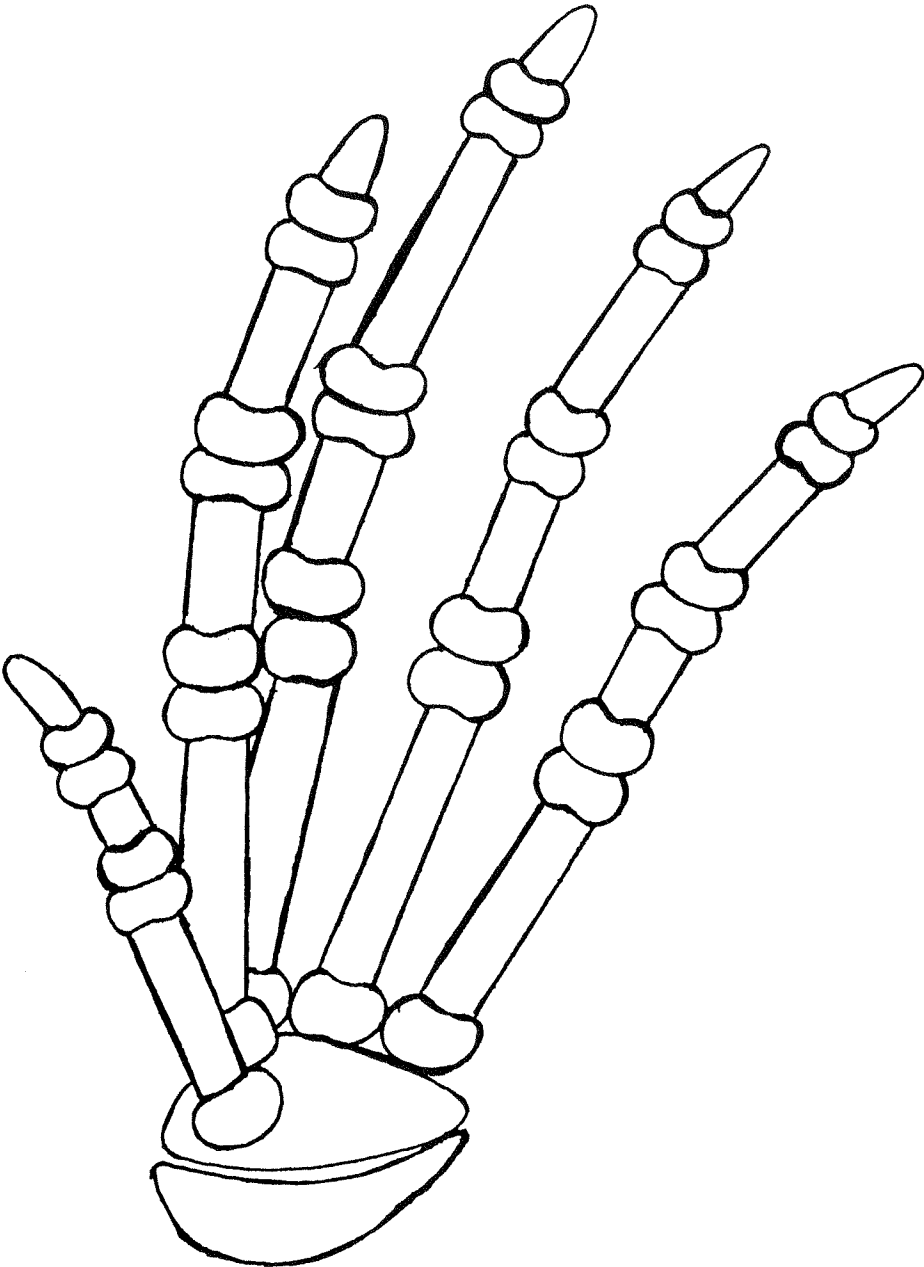
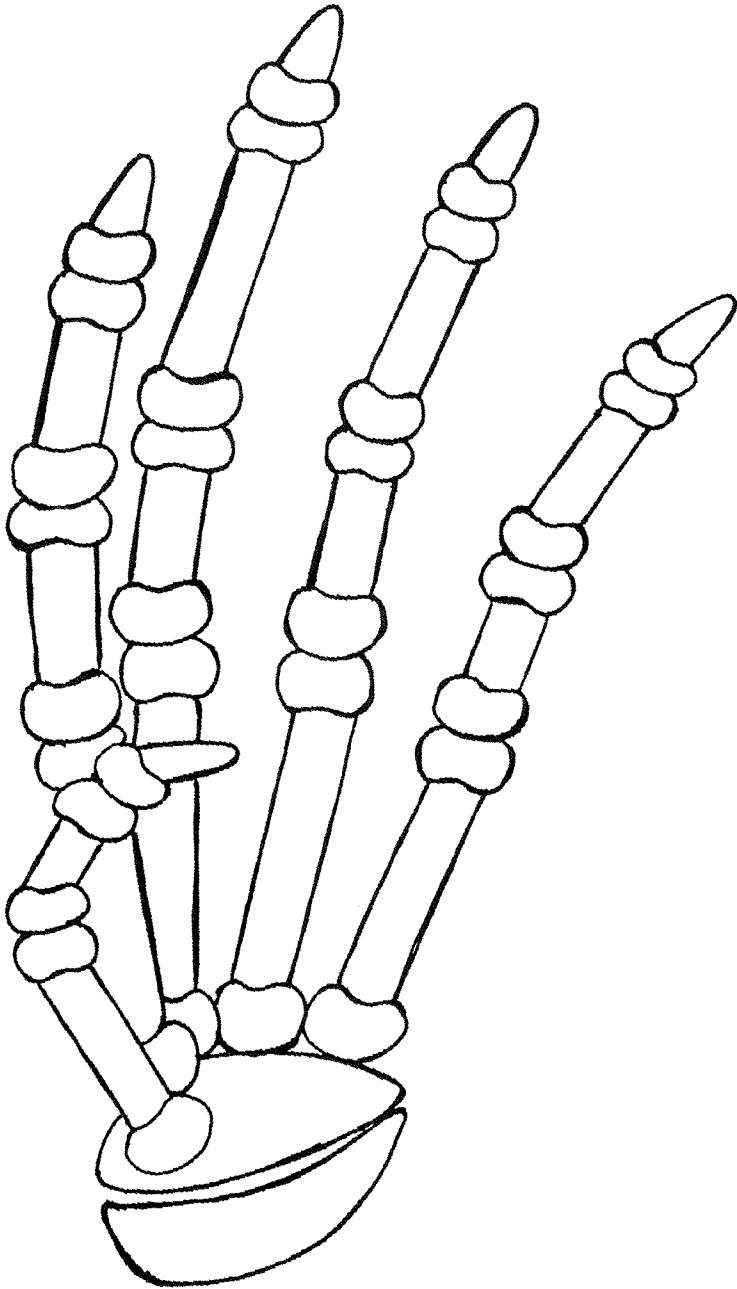Once again, a very sincere thank you.

D. Screen Prints

1. Normal, relaxed, anatomical position of left hand, fingers and thumb extended.
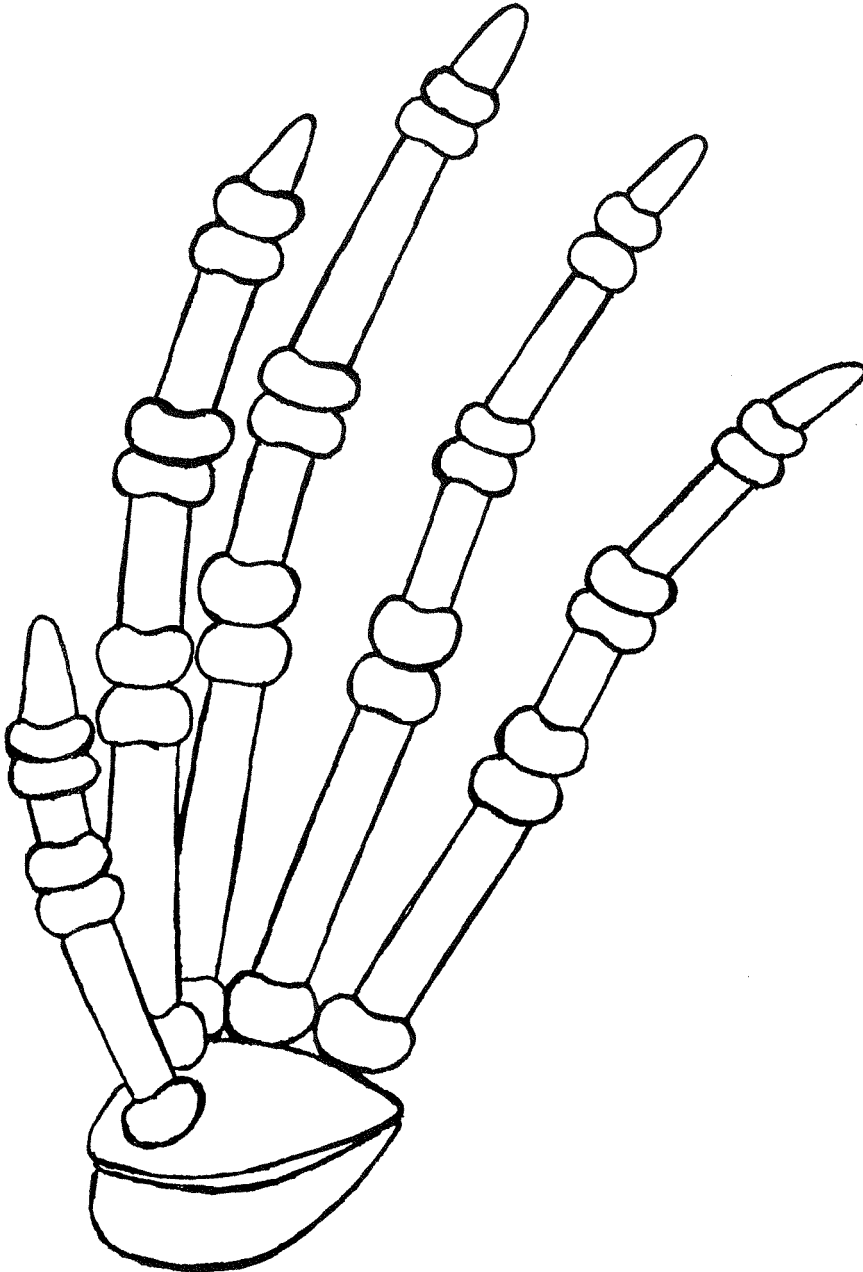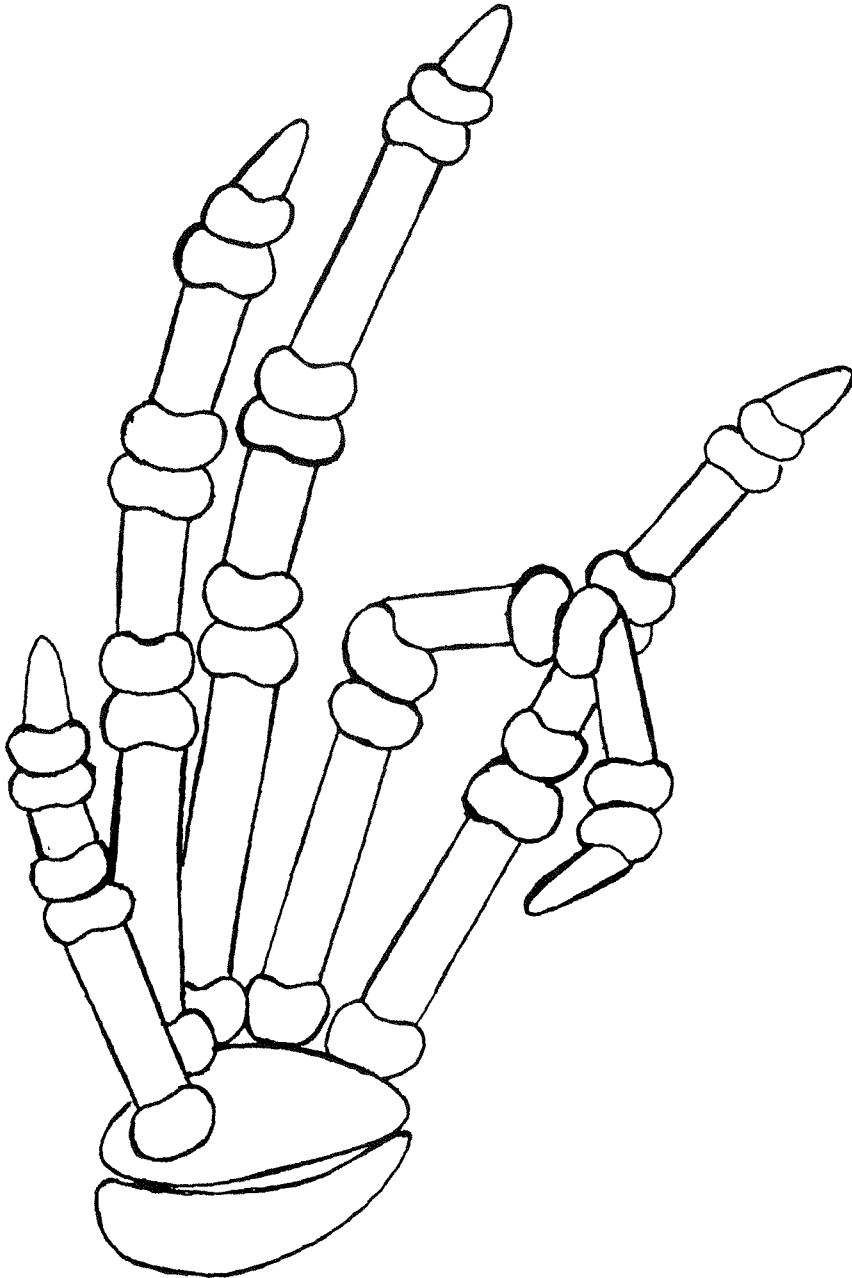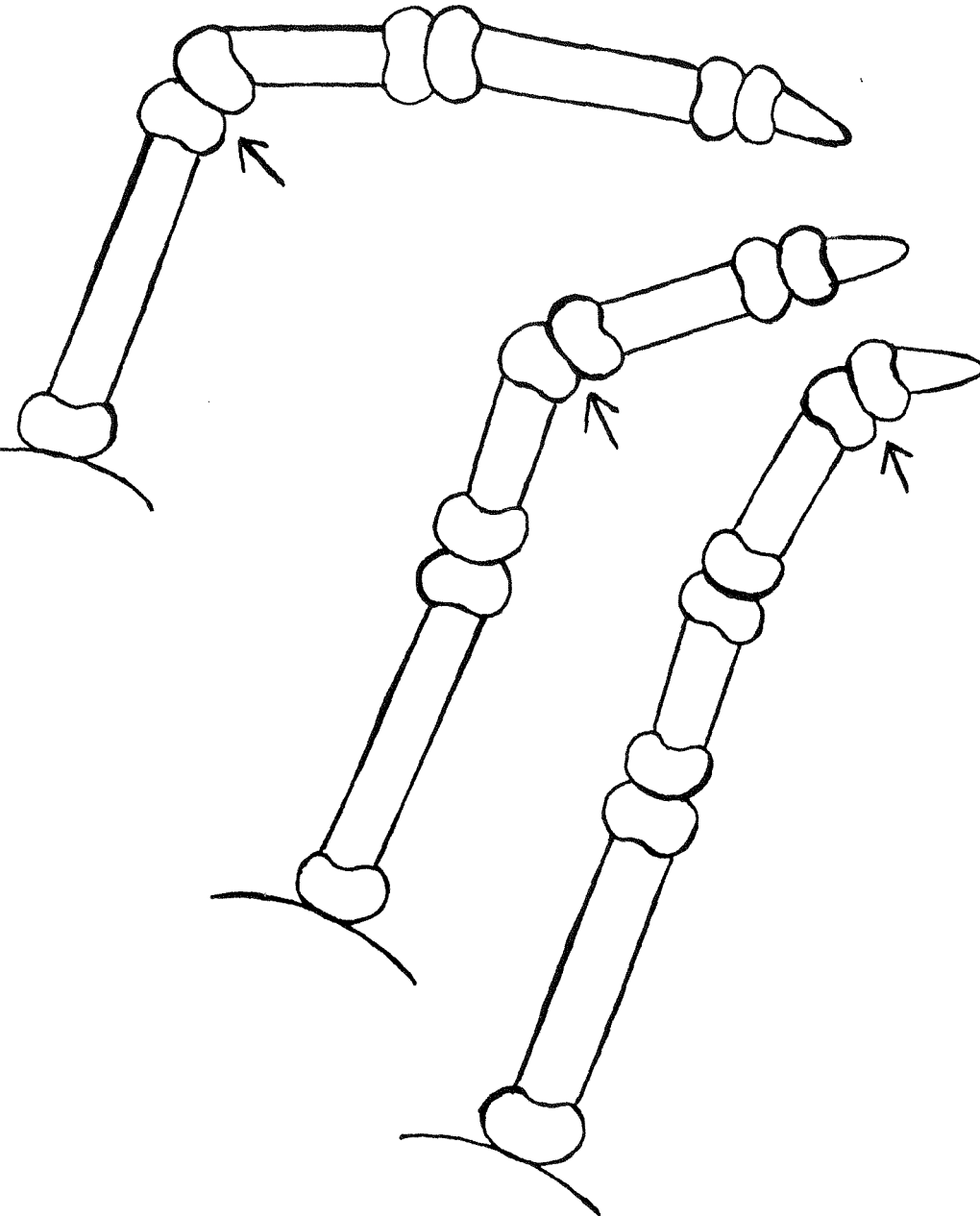
2. Thumb fully extended.

Thumb flexed.

4. "Ring" finger flexed.

5. Other movements permitted with the "Ring" finger in the VR simulation.

NOTE: all movements in drawings 4 and 5 were permitted in all four fingers, except for the "physiological" problem of the Index finger (no bending movement of the distal phalanx) .

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