Design and Development of Virtual Reality: Analysis of Challenges Faced by Educators

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ABSTRACT
There exists an increasingly attractive lure of using virtual reality applications for teaching in all areas of education, but perhaps the largest detriment to its use is the intimidating nature of VR technology for non-technical instructors. What are the challenges to using VR technology for the design and development of VR-based instructional activities, and what are the recommended approaches? This paper addresses the issues regarding identifying the appropriate techniques for integrating VR into traditional instructional design, and the considerations for development for non-technical educators. Recommendations are grounded within our own project involving virtual anesthesia. The discussion considers budgetary limitations, funding, and other factors.

Keywords
Virtual reality, Instructional design, Immersive systems, Instructional development

Introduction
Technology is a pervasive force, it impacts the way that business is conducted, communication is relayed, healthcare is negotiated and knowledge is acquired. Major strides continue to develop in immersive technologies, and educators have taken notice, especially in the applications of virtual reality (VR) to teach engaging abstract conceptual relationships. Perhaps the booming computer and console game industry, with open-source and game engine toolkit opportunities, that is partly responsible for the shift to an increased interest in using immersive technologies for education. Educators want to take advantage of the immersive qualities that today’s technology can provide with the intent to engage students in learning activities. Students have the opportunity to take advantage of the affordances of simulated environments, exploring a scenario’s dimensions and pitfalls as they learn. It is exactly this type of motivational iterative process, the learning-while-doing, that lures today’s educator to VR technology (see Bouras, Triantafillou & Tsiatsos 2002; Milrad, 2002; Sampson, Spector, Devedzic & Kinshuk, 2004).

Despite the growing interest, educators without engineering backgrounds still face significant challenges when trying to implement VR technology in their classrooms. Beyond the more obvious limitations of budget and technical knowledge, most teachers do not have a clear idea of what design and development considerations are important when planning to implement a VR system. We offer a consideration of why VR environments remain compelling to educators in non-engineering disciplines and how utilizing aspects of VR in their lessons remains a unique challenge. Based on our experiences, we then offer a reflection on the challenges of design and development of these applications on a personal level, and offer recommendations on an approach that may make sense for using VR based on traditional instructional practice. We offer our own project on teaching techniques for administering local anesthesia in dentistry as a specific example of utilizing this approach within the discussion. Therefore, the purpose of this paper is a conceptual exploration—using a synthesis of literature and approaches from engineering, computer science and education—offering a descriptive piece of our process with VR as educators. It is important to consider the issues that novice educators face, not only to help teachers form a plan-of-attack when considering implementing VR, but also to help inform engineers about the challenges that novices encounter. The result of sharing these issues should create new ideas for more complete instructional products that take advantage of immersive technologies for classroom use.

To this end, the following sections are organized in a way that first offers a synthesis of theory for VR and examples of VR applications before outlining the challenges of design: theory, processes and procedures. We then offer an
Learning Theory and VR

Most educators have either experienced or observed the application of some sort of immersive technology, and there are good reasons why it looks compelling for use outside of the traditional science-based boundaries. Most adult higher education is traditionally done in non-immersive settings where the students learn contextual information in a decontextualized situation (Winn & Windschitl, 2001; Driscoll, 2000). Often students experience a cognitive disconnect when they attempt to apply knowledge learned in a “hands-on” application setting. Many newer computer gaming environments like those of 1st person shooters and massively multiplayer online role playing games (MMORPGs), while not exactly VR, have immersive qualities that gives a user sense of reality whilst manipulating virtual 3D objects (e.g., Robertson & Good, 2005; Tews, 2001). This ability to work “hands-on” and view objects from multiple viewpoints can potentially deepen learning and recall for a student because the student is experiencing the construction of new knowledge (Nugent, 1982; Salzman, Dede, Loftin & Chen, 1999; Dede, Salzman, Loftin, & Sprague, 1999; Barab, Barnett & Squire, 2001).

Experiential learning promotes the construction of knowledge by the student, where learning is characterized as a series of cognitive restructurings. The learner’s conceptual framework undergoes structural modifications or revisions based upon new experiences, information, or concepts the learner encounters (Ueno, 1993). This process would allow the learners’ cognition to move from representational learning to conceptual learning, a process enabled by VR technologies (Winn, 1993; 1997). If this process does not occur, then the learner stays in the stage of representational learning, which is analogous to rote memorization (Barab, Barnett & Squire, 2001; Novak & Gowan, 1984). Utilizing rote memorization as an educational strategy is no longer an option as, in many academic areas, students’ success may depend upon their ability to envision and manipulate abstract multidimensional information spaces (see Alkhalifa, 2004; Gordin & Pea, 1995).

Shelton and Hedley (2003) state learning in artificial environments is successful because students can cognitively construct knowledge for themselves as they interact with the virtual environment and observe the consequences of their actions. Artificial environments allow networks of systems and variables to operate in synergy, thus allowing students considerable freedom to choose experiences and, especially, make mistakes as they interact with the environment. The identification of errors, and the opportunity to correct them, are necessary strategies in complex learning environments (Winn & Windschitl, 2001). Barab, Barnett and Squire (2001) referred to an environment that supports the development of rich conceptual understandings as a participatory learning environment in which students are allowed to ground their knowledge via participation by knowing and doing, thus directing their own learning process. In this type of environment the curriculum is learner centered, hence shifting away from the concept of the learner as a person to be changed.

An interface that allows for the manipulation of 3D objects in virtual space offers the student control over what they saw and when they saw it, thus offering them a certain level of autonomy and virtual feeling of reality. This type of environment would maximize the potential of the way people acquire new knowledge by physical manipulation of objects and/or concepts, which in turn, allows the learner to physically see causal relationships between action and result (Shelton & Hedley, 2003). As a result, the brain can more rapidly make assessments and connections as the learner interacts in their virtual environment than it can when learning takes place in a largely decontextualized, non-immersive setting. While multiple sensory exploration of an object is valuable for triangulating perceived information, visual perception is most effective during motion. Motion produced information is critical for effective vision in part because it provides valuable information about objects in relation to one another in the environment, and the movement of the perceiver in relation to those objects.

Well-designed artificial environments meet three criteria: they permit students to experience high levels of presence, they are interactive and they are autonomous (Winn & Windschitl, 2001; Salzman, Dede, Loftin & Chen, 1999). Some learning-related factors that include using an interface that allows for the manipulation of 3D virtual objects has been researched. For example, Shelton and Hedley (2003) explored learning using advanced spatial visualization tools using augmented reality (AR) interfaces. With their method, users manipulated a hand-held card that served as a platform on which to project the 3D objects seen via a liquid crystal head mounted display (HMD) (see Figure 1).
Their purpose was to teach earth-sun relationships via a first person perspective where the students had control over what they wanted to see and how they wanted to see it (see Figure 2). In addition, the students were offered a way to make a change in certain variables within the interface and investigate the effects. This study’s findings revealed that the most beneficial activity included the physical manipulation of the virtual objects and the utilization of visual spatial cues. The researchers postulated that people learn relative spatial relationships by using perceived referents during the physical manipulation of virtual objects.

Figure 1: VR using a card to view 3D objects

Figure 2: Virtual world from student point of view

Another example of an effective VR learning exercise includes Mangan’s (2000) research, which provided students with a non-invasive, immersive environment for the purpose of practicing and building skills for surgery via the virtual Minimally Invasive Surgery Trainer (MIST) system. This system allows a surgeon to insert a device consisting of a slender tube, a system of lenses, and a tiny video camera through a small hole in the abdominal wall of a mannequin and observe the image and movements in the virtual world on a television screen. Mangan’s research methods included participant observation and interview while the students interacted with the MIST system. Her findings were that most surgeons enjoyed the opportunity to practice in a realistic, non-stressful environment that allowed them the latitude for failure. In addition, students learned faster and were more ready for actual live patient surgeries. This finding supports the concept that an AR interface will decrease the time needed for learning certain skills and decrease the cognitive load experienced while learning.
A third example of a well-designed VR environment is the virtual anatomy lab (VAL) established and available via the Internet that offers a 3D computer interface for learning about human body parts (Campbell, Rosse & Brinkley, 2001). Students are allowed to create and modify their virtual lab space to be visited at their own discretion. In this lab, students dissect and rebuild the body as if it was a physical cadaver. In addition, instructors are offered the means to assist the students in doing instructional exercises. Research related to the VAL demonstrated that students benefited from 3D simulation, even though it was a desktop interface, and that the affordance for advisement and direction from faculty was especially attractive.

A final example is of a virtual environment that was built to distract users from reality. Hoffman, et. al., (2004) created a virtual world that could be used by patients who have been severely wounded. It was found that the opioid form of pain management during the wound care sessions for these patients was inadequate. As a result, because it was believed that pain perception had a strong psychological component, developers sought to distract the psyche with VR to keep pain signals from entering the brain. Hoffman and his team developed a virtual world called SnowWorld where a patient could navigate their experience with a fingertip-controlled joystick.

“SnowWorld depicts an icy three-dimensional canyon with a river and waterfalls. The patient shot snowballs at snowmen, igloos, robots, and penguins by aiming his gaze and pressing the trigger button on the joystick. The snowballs exploded with animations and three-dimensional sound effects upon impact” (Hoffman, et. al, p. 192).

The Challenge of Design

An obvious place to begin for someone wanting to use VR for an instructional lesson is to consider the design of the virtual environment. How do I create an environment to teach what I am trying to teach? The conundrum lies in the struggle between the ideal learning environment and the pragmatic solution based on available resources. Should an educator first consider technological decisions and the accompanying constraints that follow those decisions? Or should a traditional approach to create education based in instructional design and learning objectives be followed? This section will offer a perspective on design-based theory, process and procedure, and one recommended approach when considering the design for VR.

Design-based Theory

When first designing an instructional project with VR, most educators might consider traditional design models and principles. These considerations might include the ADDIE approach or Merrill’s First Principles of Instruction (Merrill, 2002). Within ADDIE, an educator may first consider the Analysis and Design components to formulate the project. For explanation of components within these areas and how they apply, see Table 1.

<table>
<thead>
<tr>
<th>Table 1: Analysis and design within ADDIE for VR</th>
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<tbody>
<tr>
<td>Analysis</td>
</tr>
<tr>
<td>• Familiarize yourself with VR technology, its uses, and how a user needs to interact with it.</td>
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<tr>
<td>• Analyze the audience.</td>
</tr>
<tr>
<td>• Identify the people who are content experts that can translate material to VR environments.</td>
</tr>
<tr>
<td>• Choose content so that the material is appropriate to take advantage of affordances of VR technology.</td>
</tr>
<tr>
<td>• Is the content time-based?</td>
</tr>
<tr>
<td>• Spatially and size dependent?</td>
</tr>
<tr>
<td>• Can you reify objects?</td>
</tr>
<tr>
<td>• Is the content too expensive or unsafe for other methods of instruction?</td>
</tr>
<tr>
<td>• Is repeatability a factor?</td>
</tr>
<tr>
<td>Design</td>
</tr>
<tr>
<td>• Conceptualize the components of the VR lesson, and those components that are companions to the lessons.</td>
</tr>
<tr>
<td>• Characterize non-computer based resources needed for completion of the instructional lesson.</td>
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<tr>
<td>• Develop outline of procedural steps for building a course with VR.</td>
</tr>
<tr>
<td>• Recognize constraints of the VR system. How will these affect the instructional objectives?</td>
</tr>
<tr>
<td>• Design a test of the VR lesson designed for piloting the learner experience.</td>
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A similar approach is to consider designing your instruction using Merrill’s (2002) first principles, keeping in mind the central component that the learning environment should be problem-based. The VR lesson should address appropriately complex learning issues, such as those within electromagnetism, geographic visualizations, or astronomy (Barab, Hay, Barnett, & Keating, 2000; Hedley, 2003; Squire, Barnett, Grant, & Higginbotham, 2004; Winn, 2002). The instruction within the VR environment should be geared toward addressing the learning issue. Merrill suggests the phases that surround the issue can be conceptualized through Activation, Demonstration, Application, and Integration. To incorporate each of these phases into the instructional VR lesson, the educator needs to address certain questions and design appropriately. For Activation, how is the material introduced so that it is compelling to the learner? How is the material presented to build upon pre-existing understandings of the material? For Demonstration, consider how the learner will interact with the virtual environment? What role does the learner play in creating his or her own understanding? The immersive nature of the technology may help in showing how certain processes work. The Application portion should define how the learners are guided within the VR environment, what order in which they interact with information within the environment, and the nature of how complexity is increased during the VR lesson. The final phase of Integration may take place outside of the VR environment, when the learner is able to use the knowledge they have acquired, but is an important consideration when designing a “complete” instructional exercise that uses VR technology.

Design Process and Procedure

The educator should be aware of four basic steps going into the design process. We have found through experience that these steps assist to alleviate the stress of the design process (see Table 2).

<table>
<thead>
<tr>
<th>Design Process Steps</th>
<th>Description</th>
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| Articulate Expectations      | • State how the conceived of lesson plan will be enhanced with the utilization of VR technologies.  
                                • State specifically what it is expected that the user will see, hear and/or feel in the virtual world. |
| Become Familiar with VR      | • Research articles and textbooks.                                           
                                • Browse the Internet for valuable information.                             
                                • Join Listserves.                                                           
                                • Investigate open sourced VR toolkits and applications.                    
                                • Start networking and making professional contacts.                       
                                • Contact colleagues.                                                       
                                • Contact leaders in the VR industry and the authors of articles of interest. |
| Evaluate Design Considerations| • Design of the virtual world.                                               
                                • Level of desired immersion.                                               
                                • Modes of sensory feedback.                                                
                                • Degree of user interactivity.                                             |
| Consider Necessary Resources | • Intellectual capacity for VR technologies.                                 
                                • Funding resources and amount of funding needed.                           
                                • Write funding proposals.                                                  |

First, it is important to articulate the expectations of VR as a medium for each specific educational application. This will help in understanding how VR will enhance learning outcomes over other instructional strategies. Additionally, an understanding of the final user interface and VR experience will clarify some of the complex design decisions. For example, for the local anesthesia VR project, we expected students would be able to utilize one hand to feel for intra-oral bony landmarks while holding a syringe in the other hand to perform the injection. Therefore, this design would necessitate the use of haptic (sensory) feedback for both hands (see Figure 3). Knowing this information assisted the project developers in making important decisions at the beginning of the design process. Primarily, we decided that bimanual haptics would be too expensive for our budget; other accommodations were considered to allow for a similar sensorimotor-related experience on a lower budget.
Second, become familiar with VR early on in the design process. Once it is understood how VR could enhance a specific educational application, an investigation can take place of other VR applications that have had similar goals. This process will enable the mistakes that other developers have made to emerge and provide fodder for strategies to creating a superior VR system. Be willing to re-evaluate project expectations based on findings about the strengths and limitations of VR. It may be discovered that a framework already exits that could be altered or augmented to meet the design needs of the VR team. However, if it is decided to build a VR system from scratch, be prepared for a larger commitment of time and resources for the project. The following recommendations will help in understanding VR:

- Research articles that discuss VR applications with specific learning goals and technological aspects mentioned. We have found the most helpful and relevant articles by searching with keywords (virtual reality, augmented reality, advanced visualization) on academic databases such as EBSCOHost. Many of the reference articles used in this piece were found through this method of search. Purchase support textbooks that can help in furthering an understanding of the articles that are amassed. We recommend VR textbooks written in the most basic technical language for beginners, then transitioning to more complex texts written for the experienced developer. One particularly useful resource is *3D User Interfaces* (Bowman, Kruijff, LaViola & Poupyrev, 2005). This book provides VR taxonomy as well as simple descriptions of hardware and software options based on individual development considerations. Others books such as *Spatial Augmented Reality* (Bimber & Raskar, 2005) provides actual coding and algorithms for those that are ready to dive into the development stage of their project.

- Browse the Internet for reputable websites that offer excellent information on VR technology and include listerves that can be joined by the most novices of users. Some recommended websites include the Human Interface Technologies Lab (HITLab) at the University of Washington, the New Media Consortium’s (NMC) Virtual Worlds website, MIT Computer Science and Artificial Intelligence Laboratory and the Georgia Tech website on Graphics, Visualization and Usability. Membership on a quality listserve such as the HITLab and/or Georgia Tech can prove to be very beneficial. Just observing the dialogue that takes place on these listerves can be educational as readers are exposed to relevant jargon, complex technical concerns and collaborative problem solving. In addition, look for open sourced (freely available) VR content on the Internet. A lot of VR toolkits and other valuable resources have been open sourced. Try using ARToolKit which can be downloaded off the HITLab’s website or Vrui VR Toolkit found at the University of California’s Davis Campus website. Searching the Internet with the keyword *VR Toolkits* will provide a list of options for authoring software. We have found that reading and researching with a specific objective in mind metes a higher level of applicable
learning in the design process. Suddenly, VR becomes less intimidating as novice designers engage in the VR instructional exercise. We got our feet wet experimenting with ARToolKit, but then wound up using a commercially available authoring program called VirTools.

- Start making professional contacts. Do not allow embarrassment or intimidation to prohibit asking even the most novice questions. Be prepared to receive a variety of responses both positive and negative. Start with inquiries within the workplace or local institution. We have found that some of our most valuable contacts were made in the most unexpected way. Some professional colleagues may be too busy to contribute but can forward information to other great contacts. Once colleagues are aware of active projects, the word gets around and those that are interested will make the effort to contact the VR team. Graduate students, aspiring programmers and support staff are generally eager to contribute to an innovative project. Collaboration is a great way to benefit from an aggregate knowledge base and may assist with pooling resources.

- Contact some of the authors of the most prominent articles that have been researched to get advice or answers to questions. We have experienced the most success when our inquiries are prepared ahead of time and can be communicated in writing. Most authors and/or experts are happy to help with a well thought-out question but less willing to do the groundwork. Make sure that it is evident that effort has been done on the part of the VR team and can demonstrate effort and willingness to work and learn.

A third step in the design process is to evaluate design considerations. The following are some issues that should be considered based on the articulated learning goals: the design of the virtual world, the level of desired immersion, sensory feedback and user interactivity. First, the virtual world is the space that would be manifested through that VR medium. The virtual world requires a description of the collection of objects in virtual space and the rules and relationships governing those objects. Second, the level of immersion has to do with the degree of disbelief that the user is willing to suspend while engaging in the virtual world. The sense of presence involves the sensation of being in environment and having a feeling of “being there” in that space. This sensation can be enhanced through a variety of tools relating to one’s cognitive state, physical sensations, or both. Third and relating to the sense of presence, physical feedback mechanisms have to do with sensations of a VR experience such as sight, touch and sound. Sensory feedback is an essential ingredient to virtual reality, it allows the user to identify a sense of self in space and affect events in the virtual world. Fourth, interactivity in a virtual world allows the user to affect change in that world.
A design allowance that impacts the level of user immersion with our local anesthesia project is the use of a remote tracking system to follow the learners’ changes in points-of-view. Initially we experimented with a pattern recognition tracking system like ARToolKIT, but found that the level of immersion decreased for the learner as the 3D object would often become unrenderable with various interactions. Therefore we ended up with human magnetic trackers to solve this problem; the combined small visual field with the injection needle as “extension of one’s hand” would prove to be the best combination of visual and real-object haptic feedback (see Figure 4).

A fourth step in the design procedure is to consider the available and necessary resources, especially monetary support and intellectual capacity for VR technologies. Before investigating funding, establish the skills and intellectual support that are accessible and can be recruited as part of the VR design and development team. Once a VR team is in place, it will be easier to prioritize costs, components and hardware. At the design phase, a ballpark figure can be hypothesized but may be difficult to firmly establish without first having brainstormed all development considerations. Making accurate monetary estimations is a difficult task, but the cart cannot be put before the horse. The team needs to know what purchases may be necessary to estimate a budget. We recommend investigating options for funding on a several scales from the more moderate to the more robust. Create a funding proposal of the intended project that can be re-crafted for each funding solicitation identified.

The Challenge of Development

Once an educator/VR team has created a lesson based in part on VR technology, other considerations emerge with regard to the development of the proposed system. These considerations are centered on the components that need to be assembled and created that allow the VR system to work.

Development-based Theory

The educator should know going into the development process the following traditional components that constitute a VR system (Burdea & Coiffet, 2003).

1. **input** -- the data sent to the computer for analysis based on the user’s interactions with the virtual world, **output** - - the computer rendering of the analyzed input that the user senses as a result of their interactions,
2. **software and databases** -- allow for the modeling of the 3D objects in the virtual world from a geometric, kinematics, physical and behavioral standpoint as well as the crafting of integration software to allow all the pieces of the VR system to work and cooperate as intended,
3. **VR engine** -- the computer architecture needed to run the designed virtual environment,
4. **user** -- the person interacting with the VR system, and
5. **task** -- the problem-based activity that is the center of the VR world (Bowman, Kruijff, LaViola & Poupyrev, 2005).

Noted that not all VR experts list the same traditional components for a VR system, but most recommended systems have similar components. For example, Bimber and Raskar (2005) label their components as building blocks with **tracking and registration, display technology and rendering** on the bottom level, **interaction devices and techniques** as the next level up, then **application** and finally **user** on top (p. 6). The challenge for the educator is to understand these components and identify the pieces fit into each category. Our strategy was to rearrange the sequence of these components and give them titles to which an educator could better relate. As a result, our component list is as follows: 1) **Learning goal**, 2) **Data and Integration**, 3) **VR activity**, 4) **Software** and 5) **Hardware** (see Table 3). The user was not listed as an essential component because the establishment of learning goals takes into consideration the learner and the expected learning outcomes of the VR system.

Development Process and Procedure

For each VR component, the design team should ask and answer questions that will impact the actual pieces that are pulled together, creating a VR system (see Table 3). It can be difficult for an educator to process some of the visual displays, created by VR experts to explain VR components, which are interlaced with vernacular germane to
engineering and developers of immersive systems. While our visual graph contains esoteric descriptors, it is a little simpler to pull into practice those components that need to be considered and compiled for a successful VR application (Figure 6). In reference to the graph, Hardware and Software components are difficult to separate from the other components. We feel that Hardware and Software are heavily integrated in both the Data and Integration and VR Activity phases. It is for this reason that Hardware and Software are listed at the bottom of our graph almost as a foundation on which all other components rely on for support.

<table>
<thead>
<tr>
<th>Table 3: Educator’s view of the components of a VR system</th>
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<tbody>
<tr>
<td>An Educator’s View of Components of a VR System</td>
</tr>
<tr>
<td>Component</td>
</tr>
<tr>
<td>Learning Goal</td>
</tr>
<tr>
<td>Data and Integration (Input &amp; Interactivity)</td>
</tr>
<tr>
<td>VR Activity (Output)</td>
</tr>
</tbody>
</table>
The **Learning Goals** are listed as the topmost component because the goal of the VR application will dictate the decisions made for all other component systems. **Data and Integration** are titled and listed according to the actions that need to take place. As the user interacts with the virtual world, data is communicated to the computer that needs to be analyzed. Once analyzed, software that was specially created integrates all of the VR components so that information can be output or communicated back to the user, the **VR Activity** phase. We utilized this approach with our project on local anesthesia (Figure 6). This project involves the use of a VR system that allows dental hygiene students to practice performing injections on 3D objects in virtual space. The objective is to allow students to construct understandings of the complex spatial and dimensional cranial relationships that effect techniques for administering local anesthesia for dental procedures. Students experienced the iterative process of trial and error as they attempted to perform injections based on visual and haptic referents. This picture within Figure 5 represents the user interacting with the virtual world. It sits in the center of the cycle of interactivity and communication for our VR application.

It is difficult for an educator to grasp all of the complex software needs of a VR system. For our local anesthesia project, we overlooked the need to create an integration system that would allow all of the other systems to operate and communicate together. We understood the need for input and output components but did not realize there was another, very important step. This oversight delayed the timeline of our project, as we needed to find more funding to pay for yet another component piece. Because we lacked the programming skills to integrate the other VR components ourselves, we had to outsource this phase for a cost. It is true that the more knowledge and skills that the VR team possesses, the cheaper the cost of the VR system. A brief listing of the components that we compiled for each category of development is listed in Table 4 along with examples of components used on existing VR projects.

![Figure 5: Our instructional approach considering components of VR systems](image)

**Table 4**: A brief listing of the components compiled for our VR system

<table>
<thead>
<tr>
<th>Components of VR System</th>
<th>Our Local Anesthesia VR Application</th>
<th>Pilot Outcomes/System Changes</th>
</tr>
</thead>
</table>
| **Learning Goals**      | • The use of 3D manipulatives will allow for a greater understanding of anatomical spatial and dimensional acuity.  
• Students will develop conceptual understanding | • Students did gain a greater understanding of anatomical and dimensional acuity.  
• Students had a difficult time |
understandings with a virtual interface that allows them to direct their own learning.
• Students will experience and iterative cycle of cause and effect as they manipulate virtual objects.

### Data and Integration (Input & Interactivity)

- Human Tracking Equipment: Flock of Birds
- Haptic Device: PHANToM Omni
- Navigation: PHANToM Omni
- Integration: Specific programming created by expert programmers (Imprint Interactive Technology Inc.)

• Flock had some glitches; need to learn to transfer in and out of user window without losing tracking.
• Investigate a more realistic feeling liquid rubber.
• Left hand need to be reified with data glove.
• Calibration needs to be done to align visual and haptic.

### VR Activity (Output)

- What the user will see: 3D Objects specially created for application
- What the user will hear: N/A
- What the user will feel: sensory force feedback

- Realistic 3D image
- No audio
- Need prosthetic cheeks.

### Software

- Integration: VirTools VR Toolkit utilized by Imprint Interactive Technology Inc. programmers
- Modeling: Geometric modeling was outsourced to expert programmers specific for the human cranium (Zygote Media)
- Input/Output Device Mapping: Programmed by Imprint Interactive

- VirTools worked well.
- Need to reify left hand.

### Hardware

- VR Engine & PC Graphics Architecture: Dell XPS Laptop
- Graphic Display: i-glasses PC/SVGA

- Data glove.
- Trackers for left hand.
- HMD 1280.

### Discussion

As synthesized in Table 3, a variety of disciplines have incorporated the use of VR technology for different purposes within education training environments. For each purpose, the learning expectations or goals were different but for some the use of hardware and software were similar. For the purposes of input hardware, the options are limited to desktop devices, tracking devices and/or 3D built-in special-purpose input devices. The strategies for input ranged from pattern recognition, magnetic trackers, haptic (desktop) forcefeedback devices and navigational joysticks. Whereas, with output and the hardware and software used, the developmental strategies ranged from specially created 3D objects in virtual space, audible feedback delivered via a head mounted display or helmet, the use of a hand-held stylus for haptics called PHANToM. The creation of the 3D models were accomplished with modeling software such as Maya and integrated using a virtual player like VirTools or ARToolKit. Most examples used some sort of head mounted display (HMD) with one using a computer console and another a large television screen. We hope to have helped inform educators thinking of implementing such technology of the current challenges they may face and considerations that may need to address.

The appeal of VR technologies has lured non-traditional users to learn about and consider what VR has to offer. An investigation into learning theory and the epistemic tradition of constructing knowledge substantiates the application of virtual systems as an instructional strategy that leverages the natural skills of the learner. We conducted a pilot study using our VR system for local anesthesia. The methodology included a pre and posttest exam on local anesthesia for the bottom jaw, a single time 20-minute interaction with the VR system for 10 students that were digitally recorded and a post treatment questionnaire. The digital video was evaluated according to a skills competency rubric for local anesthesia and viewed to watch for observable epistemic shifts. The evidence suggested
that learning took place however; there were flaws with the system that impeded user presence. This included an offset in calibration of the virtual object with haptics. Nevertheless, students seemed to overcome this dissonance between visual and haptic by demonstrating proper injection technique in the virtual world. The post questionnaire revealed that students liked that the virtual world allowed for the transparency of tissue and the visualization of landmarks for anesthesia, but felt it was difficult to navigate the anesthetic needle and get a sense of their other hand. We have considered changes to our system to increase user presence and decrease user distractions; those changes are outlined in Table 4. These outcomes support our recommendations and further, previous research qualifies the effectiveness of educational VR applications, while more research is encouraged to validate these findings.

We addressed the design aspects of VR from the perspective of the ADDIE model and Merrill’s (2002) First Principles of Instruction, feeling that a traditional approach to creating instruction may be a stumbling point for novice designers. Further, we have recommended that the educator should articulate their expectations for learning at the beginning of the design phase as well as become familiar with VR technologies. This familiarity will provide the educator with an understanding of how component systems work together to reach their desired goals. In addition, it is realistic to consider certain design characteristics and monetary factors before the development phase begins. This would include specifying how the virtual world will be reified, the amount of immersive qualities to be included, the level of sensory referents and feedback, and the degree of user interactivity planned for the VR application. Finally, the development phase should include the components of a VR system: the learning goals, data and integration, VR activity, software and hardware components.

As educators with non-technical backgrounds, the process of building a VR system for educational application has been extremely challenging. We have found few articles that cover the basics of VR for novice developers. The impetus for this contribution is to express what we have learned about VR design and development with the hope of creating a community of novice educators who embrace VR technology. Along these lines, we encourage continued dialogue and research on the struggle of building VR applications outside of the traditional realm of computer sciences and for those educators less economically blessed. In order for VR to become mainstream, educators need to be able to build applications that utilize the technology for the sake of learning rather than for the novelty of the technology. As more disciplines embrace the technology, it will get easier to use and cheaper to create. Iteratively, further research will help substantiate the use of VR interfaces as a legitimate instructional tool to learn complex material and confirm its legitimacy as an effective tool for skills competency.

Our biggest challenges remain the high cost of creating a VR system, the extreme learning curve that novice developers face when considering a VR application on a limited budget, and the rapid speed of advancing technologies that threaten to outdate an expensive system within the early stages of its development. All of this may lead an educator to ask, is it worth it? What will I be gaining in this odyssey to create a VR system? When considering the educational basis for learning-by-doing in the vein supported by virtual environments, Dewey (1938) wrote that a connection exists between education and personal experience. He advocated that while not all experience is education, all education should be experiential. Because VR supports experiential learning, we recommended the use of VR technologies across a variety of disciplines and embrace its design and development despite the struggles.

References


