Integrating Virtual World Spatial Presence into Constructivist Learning

Nancy Wood
Texas A & M University, College Station
13747 Stoney Hill
San Antonio, TX 78231
210-846-0152
nancy@pixelpaint.com

Lauren Cifuentes, Ph.D.
Dept. of Educational Psychology
649 Harrington Office Building, Mail Stop 4225
Texas A & M University
College Station, TX 77843
979-845-7806
laurenc@tamu.edu

Descriptors: Spatial presence, Virtual learning environments

Abstract
Spatial presence is an integral part of virtual learning environments (VLE's). Research findings indicate that spatial presence in VLE's may positively affect learning by stimulating abstract thinking and problem solving capabilities. This paper proposes research into the two principle components of spatial presence, the style of the visual display and the organization of interactive elements, to better understand design elements that make this emerging medium instructionally effective.

Introduction
Virtual reality (VR) is an engaging and attractive form of multimedia computing that is gaining a strong foothold in our daily lives. VR’s unique array of affordances and opportunities for interactivity allow for a wider range of user controls than other forms of multimedia. Use of virtual reality in science, engineering, aeronautics, and medicine has been developing since 1987 in projects funded by the federal government, particularly the Department of Defense, the National Science Foundation, and the National Aeronautics and Space Administration (Virtual reality, 2008). Over the past decade, the use of virtual reality in entertainment games has increased dramatically. Currently, scientific research based on computer simulation, called e-Science, is a successful method used in the physical and natural sciences, medicine and engineering for experimental scientific discovery (Getov, 2009).

Educational use of virtual worlds is increasingly rapidly (Bainbridge, 2007; Chittaro, & Ranon, 2007). Contemporary VLE’s are used for many types of subject matter and learning outcomes, including medicine, accounting, business, art, history, science and math; and for training of soft skills such as management and negotiation. Two popular multi-user web based virtual reality programs used by educators are Second Life and Active Worlds.

VR has been described as a “partnership between computers and the human brain” accomplished through the use of various input devices (Virtual reality, 2008). The experience is predominantly visual, but can include the other senses: sound, touch, smell. What distinguishes it from other multimedia computer experiences is the user’s sense of being there, in the virtual world, accomplished through interaction with a vivid, immersive simulated environment. This is referred to in the literature as presence. Presence is a state of mind, the user’s sense of being present in a virtual space (IJsselsteijn, 2003; Lombard & Ditton, 1997; Winn, 1993). Presence may include a spatial sense of being in the virtual environment, and/or a social sense of being in a space with other sentient beings (Spagnolli, Varotto, & Mantovani, 2003). Social presence can occur in text chats or teleconferences without graphics or simulations (Jacobsen, 2001), but spatial presence requires a visual display (Schubert, Friedmann, & Regenbrecht, 2001).

Spatial presence is a theoretical construct that can guide design and development of virtual learning environments. Effective VLE’s will utilize the affordance of spatial presence through carefully designed visual
displays and user interactivity. This reflection paper reviews current scholarly literature into the nature of spatial presence in VLE’s, and how spatial presence may affect and impact learning outcomes. Based on conclusions from this literature review, the authors describe and propose new research into the interactive component of spatial presence.

Literature selected for this review consists of peer reviewed articles from scholarly journals in the fields of education, psychology and human- computer interaction. This includes publications devoted exclusively to the study of presence, such as Presence-Teleoperators and Virtual Environments (published by MIT press journals) and the International Society of Presence Research website, and other publications whose focus is educational technology and research. Relevant research into the effects of spatial presence in formal education or training settings, with adult or high school-age populations, is examined for conclusions and need for further research. Studies that use children as participants are excluded unless adult populations are included in the same study. Studies that use VLE’s to examine or treat psychological disorders, such as phobias or hallucinations, are also excluded from this report. Social presence is discussed only as it affects the user’s sense of spatial presence.

Defining Spatial Presence

Spatial presence includes realism, transportation (the ability to move to different spaces, or bring objects closer to the viewer) and immersion or user involvement. The user’s perception of their potential for action in the space and the resulting consequences are important dynamics in the experience of spatial presence (Chertoff, & Schatz, 2008; Mantovani, & Castelnuovo, 1999; Spagnolli, Varotto, & Mantovani, 2003). Spatial presence defines virtual reality and separates it from other multimedia programs (Mikropoulous, 2006; Romano, & Brna, 2001; Stanney, 2002).

Spatial presence fits the definition of a perceived affordance as described by Norman (2004) because it affords the user a unique perception of potential interaction with a simulated environment. In a non-virtual interface, the user perceives icons and text links as having the potential for displaying different web pages, windows, or activating specific programs. In virtual reality, the user perceives the interface as an interactive spatial environment in which they have a presence that is separate or in addition to their existence in the real world. Their actions in the virtual world can affect the virtual environment itself.

Sensory stimuli make spatial presence an external as well as an internal state (Marsh, 2003; Waterworth, & Waterworth, 2001). Virtual reality can include audio and haptic sensations, but it is primarily the visual display and user interactivity that creates the sense of being in a virtual space (Schubert, Friedmann, & Regenbrecht, 2001). The virtual spatial experience blends the learner’s internal visualization with the computer generated one.

Spatial presence is sometimes associated with the theory of embodied cognition (Wilson, 2002) because it is characterized by a sensation of a strong perception-action link between the display and the user (Schubert, Friedmann, & Regenbrecht, 2001). Presence includes the user’s conscious suspension of disbelief, a willingness to immerse oneself in the simulated environment and to block out the real environment (ISPR, 2000). This results in the user’s sense of being in two worlds simultaneously, the real and the virtual, in a sort of blended reality.

The International Society for Presence Research describes presence as

“A psychological state or subjective perception... of an individual's experience... filtered through human made technology... part or all of the individual's perception fails to accurately acknowledge the role of technology in the experience... To some degree the environments are experienced as if the technology was not involved” (2000).

Virtual Learning Environments in Education

The convergence of presence with constructivist learning theories became of particular interest with the development of computer generated three dimensional environments that could create first person experiences in a simulated environment (Winn, 1993). In early research with virtual reality simulations during the 1990’s, Winn pointed out that the users’ sense of interaction with an environment stimulates deep learning. The immersive environment eliminates the need for a symbol system, and enables direct first person learning experiences that are “…direct, personal, subjective and often tacit…” in a safe and controlled environment (1993). This fits well with constructivist learning theories of knowledge construction. That is, that knowledge construction occurs most efficiently when learners are actively involved in activities that are personally relevant (Chittaro, & Ranon, 2007). Subsequent research indicates that spatial presence is important in virtual worlds to accomplish learning goals (Jacobson, 2001) and has positive effects on students’ perceptions of the course communications and relevance (Nishide, Shima, Araie, & Ueshima, 2007; Reznick, & MacRae, 2006; Takatalo, Nyman, & Laaksonen, 2008).
Spatial Presence

Spatial presence in VLE’s is generally considered to benefit learning by creating first person experiences, as in simulations, and by enabling observation of processes or phenomena that would be difficult, expensive or impossible to observe in the real world. But some of the most intriguing observations from research into spatial presence are its effects on higher thought processes: conceptual understanding and creating mental models (Chittaro & Ranon, 2007; Kontogeorgiou, & Bellou, 2008; Limmou & Roberts, 2008; Zacharia, 2007), problem-solving (Cai, Lu, Zheng, & Li, 2005; McClean & Saini-Edukat, 2001), metacognitive and abstract thinking (Antonietti & Cantoia, 2000; Cai et al., 2005).

In virtual reality, the user perceives the interface as an interactive spatial environment in which they have a presence that is separate or in addition to their existence in the real world. The learner’s awareness of being in the two environments simultaneously may stimulate metacognitive reflection. The experience of presence that occurs in VLE’s can connect learners’ imagination and internal mental models with an external guided stimulus to help them “...find points of convergence and divergence between different worlds to understand their relationships to one another...” (Thomas & Brown, 2007, p.150).

The interactive element of spatial presence is important in helping users build mental models and connect them to existing knowledge. Learners interpret their experiences and use them to refine their mental models (Dede, 1995). Mental models help the learner visualize the phenomena and construct analogies (Seel, 2006). The reciprocal nature of learning and doing in VLE’s can build conceptual understanding (Barab, Hay, Barnett, & Squire, 2001).

Constructivist Learning Theories and VLE’s

Most educational programs in virtual worlds are designed around constructivist learning theories, that is, that deep learning is achieved through active student involvement in the learning process. Two constructivist learning theories that might help guide design and development of VLE’s to include spatial presence as an affordance, are multimedia learning theory (MLT; Mayer, 2001) and cognitive flexibility theory (CFT; Spiro, Coulson, Felteovich, & Anderson, 1992). Both MLT and CFT consider how student involvement with media might enhance or decrease deep learning. MLT applies Sweller’s cognitive load theory to learning from words and pictures and recommends arrangement of text and media that will result in germane cognitive load. CFT advocates richness of content in a flexible, open environment, with multiple representations at different levels of instruction (Spiro, Collins, & Ramchandran, 2007). CFT emphasizes unstructured learner control of content selection and pace to encourage flexible thinking by the learner, whereas MLT proposes a more structured program control of media. Both theories aim for what Sweller calls germane cognitive load, the optimum effort required for deep learning (Clark, Nguyen, & Sweller, 2006).

Design of VLE’s

How should virtual reality interactive displays be designed to develop flexible habits of mind, and help the learner integrate new knowledge with existing knowledge? How does style and manner of presentation of the visual display and interactive elements affect and impact learning outcomes? The two most significant components of spatial presence are the visual display and user interactivity (Lessiter, Freeman, Keogh, & Davidoff, 2001; Schubert, Friedmann, & Regenbrecht, 2001).

Visual Design

Effective visual design of VLE’s is governed by the same fundamental principles used in visual art, graphic design, animation and cinema, grounded in psychological theories of perception. Traditional visual media create memorable experiences and direct the viewers’ attention to key elements through judicious combinations of the scientific principles of optics, accepted practices of illustrating spatial depth, and psychological theories of perception and the viewer’s organization of images. Theoretical foundations include Gestalt theories of visual perception, Mayer’s multimedia theory, Sweller’s cognitive load theory, Paivio’s dual coding theory.

Visual design principles and theories can be applied to the visual design of graphic elements in VLE’s to enhance the users’ sense of spatial presence and reduce extraneous cognitive load. In VLE’s, as in other types of visual design, adherence to real world imagery that is not relevant to the learning outcome may create extraneous cognitive load. Luo, & Duh (2009) concluded that detailed architectural and landscape features in VLE’s can cause slower learner reaction times and reduced memory. Circular environments seem to be easier to navigate and
remember than square environments, possibly because the weaker ecological features of cylindrical rooms (fewer angles to perceive and navigate) reduce extraneous cognitive load (Luo & Duh, 2009; Jansen-Osmann, Wiedenbauer, Schmid, & Heil, 2007).

Interaction Design

Research findings indicate that the users’ interaction or sense of potential for interaction, in the virtual world is the most significant factor in the experience of spatial presence (Chertoff, & Schatz 2008; Lessiter, Freeman, Keogh, & Davidoff, 2001; Mantovani, & Castelnuovo, 1999; Schubert, Friedmann, & Regenbrecht, 2001; Spagnolli, Varotto, & Mantovani, 2003). Students’ interaction with computer mediated technologies can combine for powerful teaching and learning (Cifuentes, Carpenter, & Bulu, 2008). A meta-analysis of studies of distributed learning environments that have analyzed subjective vs. objective control concludes that any type of learner control enhances learning (Kraeger & Jerden, 2007). Spatial presence is a metacognitive awareness of the potential for action in both the real world and the virtual world. More research is needed to develop models for the design of learner interaction in VLE’s that will optimize learning outcomes and minimize extraneous cognitive load. User control features such as free navigation, first-person point of view, manipulation of size and reification of concepts should be studied for their effects on learning.

Proposed Research into Components of Spatial Presence

Merrill refers to instructional strategies as “…algorithms for manipulating data (knowledge objects)…” His instructional transaction theory proposes that patterns of learner interactions can be designed to teach specific skills and knowledge (1999). The proposed research will test two possible algorithms for learner interaction in a VLE to teach visual design concepts. In the high interaction tutorial, the knowledge objects will be interactive graphic elements that learners will be required to manipulate. The high interaction tutorial will combine what Cifuentes calls “…learner interaction with subject matter…” and “…learner interaction with technology…” (personal communication September 16, 2009) to the degree that is practical and reasonable, making the technology a reification of the subject matter. The design of the virtual space will maximize learner interaction with reified subject matter, and minimize extraneous interactions with technology. In the low interaction tutorial learners will interact with generic graphic elements to display non-interactive knowledge objects that they will view passively.

Research Questions

Does use of increased interactivity in the form of controllable, reified subject matter in a VLE improve transfer of learning? How does it help learners build mental models of concepts? Does it increase the learners’ sense of spatial presence? Does increased interaction and/or spatial presence affect the mechanisms associated with constructivist learning and increase critical thinking?

Research Design

For the pilot study the research will be qualitative, due to the small number of participants. Participants will be students enrolled in a graduate education course. Two different tutorial environments will be designed, each with different degrees of user control and interaction. The graphics and text in each tutorial space will contain the same information. Half the class will start with the high interaction tutorial; the other half will start with the low interaction version. After they complete each tutorial, students will be given a text instructional message and be asked to create a graphic illustration of the message that emphasizes the important concepts. They will then repeat the process using the other version of the tutorial, and completing a different post-tutorial assignment. The interactive tutorial space is shown in Figure 1.
Figure 1. The high interaction tutorial will be unguided, to intensify the users’ perception of their potential for action in the space.

Participants will answer questions from the Witmer and Singer Presence Questionnaire following their use of each of the tutorials and before completion of each design assignment. Their completed design assignments will be evaluated by two or three experts in instructional visual design. Participants will write a paragraph describing the process they used in creating their design after they complete each design assignment. These reports will be analyzed using qualitative coding analysis methods, for evidence of critical thinking, such as the frequency of “how” or “why” statements or questions (high critical thinking), compared to “what” statements or questions (low critical thinking). They will also complete post-treatment questionnaires that measure the occurrence of mechanisms associated with constructivist learning and their perceptions of the effectiveness of the tutorial for transfer of learning.

Participants will receive detailed instructions for joining Second Life, obtaining an avatar, and practicing basic skills in Second Life about two weeks before starting the assignment. They will complete these activities on their own schedule before beginning the exercise. When they begin the exercise, they will receive instructions for using each tutorial. The course requires use of image editing software, so it can be assumed that they have sufficient technical skills to complete the design assignments.
Measures

Measure One

Does increased interactivity increase learners’ sense of spatial presence while using the tutorial?
From Witmer, & Singer’s 1998 presence questionnaire:

1. How much were you able to control events?
2. How responsive was the environment to actions that you initiated (or performed)?
3. How natural did your interactions with the environment seem?
4. How much did the visual aspects of the environment involve you?
5. How natural was the mechanism which controlled movement through the environment?
6. How aware were you of events occurring in the real world around you?
7. How aware were you of your display and control devices?
8. How compelling was your sense of objects moving through the environment?
9. How completely were you able to actively survey or search the environment?
10. How compelling was your sense of moving around inside the virtual environment?
11. How well could you examine objects from multiple viewpoints?
12. How well could you move or manipulate objects in the virtual environment?
13. To what degree did you feel confused or disoriented at the beginning of the tutorial?
14. How involved were you in the virtual environment experience?
15. How distracting were the control mechanisms?
16. How quickly did you adjust to the virtual environment experience?
17. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?
18. How well could you concentrate on the assigned tasks or required activities?
19. Were you involved in the task to the extent that you lost track of time?

Measure Two

Does use of increased interactivity in the form of controllable reifications of the subject matter in a VLE improve transfer of learning? How well do students understand the concepts presented in the tutorial and transfer them to novel design problems?

Post treatment questionnaire item stems:

1. The concepts were presented clearly in the tutorial.
2. I was able to understand the topics presented in the context of instructional design.
3. I used the concepts presented in my design assignment.
4. I will apply what I learned in future tasks.
5. I learned.

Following their use of the tutorial, the participants will create a visual instructional message based on an assigned text message. Their completed designs will be assessed by two to three raters, using the rubric shown in Table 1.
Table 1. Rubric for Design Assignment.

<table>
<thead>
<tr>
<th>Grading Criteria</th>
<th>Maximum Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>The design utilizes the <strong>shape</strong> and <strong>level of detail</strong> of graphic components to place emphasis on one to three crucial concepts of the message, de-emphasize less important elements, and create an overall visual unity.</td>
<td>10</td>
</tr>
<tr>
<td>The design utilizes the <strong>size</strong> of graphic components to place emphasis on one to three crucial concepts of the message, de-emphasize less important elements, and create an overall visual unity.</td>
<td>10</td>
</tr>
<tr>
<td>The design utilizes <strong>position</strong> of graphic components to place emphasis on one to three crucial concepts of the message, de-emphasize less important elements, and create an overall visual unity.</td>
<td>10</td>
</tr>
<tr>
<td>The design utilizes <strong>color and/or brightness</strong> of graphic components to place emphasis on one to three crucial concepts of the message, de-emphasize less important elements, and create an overall visual unity.</td>
<td>10</td>
</tr>
<tr>
<td>The designs utilizes <strong>texture or pattern</strong>, of graphic components to place emphasis on one to three crucial concepts of the message, de-emphasize less important elements, and create an overall visual unity.</td>
<td>10</td>
</tr>
<tr>
<td>The design uses <strong>proximity, common fate and variance</strong> to connect related elements and create unity.</td>
<td>10</td>
</tr>
<tr>
<td>Style and detail of imagery is appropriate to the message.</td>
<td>10</td>
</tr>
<tr>
<td>Selected imagery promotes a conceptually clear and unified message.</td>
<td>10</td>
</tr>
<tr>
<td>Written explanation of design process describes impact of Second Life tutorial on transfer of concepts to finished design.</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

Measure Three

Does the design facilitate the mechanisms associated with constructivist learning as measured by learners’ self reports? Does the design engage and challenge learners, motivate learners to take responsibility for learning, and foster active social discovery of meaning and dynamic interactions between learners and the environment? Post treatment questionnaire item stems:

1. Experience in the environment helped me develop and refine my ideas for the subsequent assignment.
2. I understood the concepts that were presented in the environment.
3. The learning goals were clear to me.
4. I felt like an active member in the environment.
5. I actively explored the principles and concepts presented.
6. I felt that I had control to explore the environment in a manner that interested me.
7. I was able to create a valuable learning experience during the time I spent in the VLE.
8. The environment stimulated my interest in learning the concepts.
9. The subsequent assignments were challenging.

Data Coding and Entry

Student names will be replaced by a code number for the reports. Questionnaires will be conducted anonymously on the internet, with encryption used to protect their identity. Questionnaires will not be matched to self reports.
Analyses

Students’ design projects will be assessed by 3 experts in instructional visual design using a common rubric. Students’ responses to interview questions and written assignment will be analyzed using qualitative coding and analysis methods. Results from this pilot study will be used to design a larger, more detailed study involving a sufficient number of participants to use quantitative methods of analysis of learning outcomes and sense of spatial presence.

References


