Investigating the Impact of Interactive Immersive Virtual Reality Environments in Enhancing Task Performance in Online Engineering Design Activities

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Presentation Overview

- INTRODUCTION
- RESEARCH MOTIVATION
- LITERATURE
- RESEARCH OBJECTIVE
- METHODOLOGY
- CASE STUDY
- CONCLUSIONS
- FUTURE WORK
Engineers employ *virtual* and *tactile* approaches during learning activities.

Virtual Learning (e.g., CAD)

Tactile Learning (e.g., Product Dissection)

McKenna et al, 2008; Lewis and Simpson (2009); Grantham et al. 2010; Moore-Russo et al (2010); Kremer et al., 2013; Tucker et al., 2014; Toh et al. (2014)
Virtual Design in Industry
What is Virtual Reality?

“Real-time graphical simulation with which the user interacts via some form of analog control, within a spatial frame of reference and with user control of the viewpoint’s motion and view direction” (Moshell and Hughes, 2002)
Virtual Reality Literature

• 3D virtual worlds are more effective than text-based or 2D environments and can lead to better student engagement in learning activities (*Tashiro and Dunlap, 2007*)

• VR enables students to visit virtual environments and interact with objects and space in real time, which overcomes the traditional distance, time, or safety constraints (*Çaliskan, 2011; Ramasundaram et al., 2005*)
Types of Virtual Reality Paradigms

Two major types of Virtual Reality (VR) Paradigms

- **Immersive VR System**
- **Non-immersive VR System**
Research Objective

Hypothesis: There exists a statistically significant difference in task completion times between students using immersive VR and non-immersive VR system.
Methodology

Classify Students into Two Groups Randomly

Group 1: Immersive VR system
- Complete pre-experiment questionnaire
- Perform activity and record completion time
- Complete post-experiment questionnaire

Group 2: Non-Immersive VR system
- Complete pre-experiment questionnaire
- Perform activity and record completion time
- Complete post-experiment questionnaire
Study Sample

• 54 undergraduate students

• Immersive VR Group (29 students)
  – Head-mounted displays (Oculus Rift®) + game joystick

• Non-Immersive VR group (25 students)
  – Computer Screen + game joystick

• Activity Performed: Product Functional Assembly of Coffeemaker
Spatial Aspects of Immersive VR

Yaw, Pitch, Roll

Case Study
Immersive VR Demo
Click to Play
Experimental Setup

Random Classification of Students

Non-Immersive VR Group

Immersive VR Group

Product Functional Assembly in the Virtual Environment

Record Task Completion Time and Perform Statistical Analysis

Case Study

http://www.engr.psu.edu/datalab/
Measure Task Completion Time

• Task completion time has been used as a performance metric to evaluate the effectiveness of VR technology in research (Hwang et al., 2006); (Newmark et al., 2007); (Jennett et al., 2008); (Lendvay et al., 2013)
Test for Normality

Samples do not follow normal distribution and sample sizes are not significantly large enough to assume normality – Select a Non-Parametric test (Mann-Whitney U Test)
Difference in Task Completion Times

<table>
<thead>
<tr>
<th>Group</th>
<th>N (Sample Size)</th>
<th>Median Completion Time (in Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1: Immersive VR</td>
<td>29</td>
<td>23.21</td>
</tr>
<tr>
<td>Group 2: Non-Immersive VR</td>
<td>25</td>
<td>49.04</td>
</tr>
</tbody>
</table>

Mann-Whitney U Test.
(p-value = 0.0001)

Immersive VR group students’ task completion time significantly less than non-immersive VR group students
Investigate Why Differences Exist

• Three other hypotheses were tested to explore the reasons for the observed difference in performance outcomes between the two groups of students:
  – Gender
  – Prior level of joystick experience
  – Class Standing
## Hypothesis: Gender Differences

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Levels</th>
<th>Statistical Test</th>
<th>P value</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>Mann-Whitney U Test</td>
<td>0.0002</td>
<td>Immersive VR students performed better than non-immersive VR students</td>
</tr>
</tbody>
</table>

![Boxplot of Male - Immersive VR Group, Male - Non-Immersive VR Group](http://www.engr.psu.edu/datalab/)
Hypothesis: Joystick Experience Level

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Levels</th>
<th>Statistical Test</th>
<th>P value</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior Level of Joystick Experience</td>
<td>&gt;5 Years</td>
<td>Mann-Whitney U Test</td>
<td>0.0066</td>
<td>Immersive VR students performed better than non-immersive VR students</td>
</tr>
</tbody>
</table>

Boxplot of >5 years - Immersive VR, >5 years - Non-Immersive VR

Task Completion Time (in seconds)

Case Study

http://www.engr.psu.edu/datalab/
Hypothesis: Class Standing

<table>
<thead>
<tr>
<th>Class Standing</th>
<th>Levels</th>
<th>Statistical test</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td></td>
<td>Mann-Whitney U test</td>
<td>Immersive VR students performed <strong>better</strong> than non-immersive VR students*</td>
</tr>
<tr>
<td>Sophomore</td>
<td></td>
<td>Mann-Whitney U test</td>
<td>Immersive VR students performed <strong>identical</strong> to non-immersive VR students*</td>
</tr>
<tr>
<td>Junior</td>
<td></td>
<td>Mann-Whitney U test</td>
<td>Immersive VR students performed <strong>better</strong> than non-immersive VR students*</td>
</tr>
<tr>
<td>Senior</td>
<td></td>
<td>Mann-Whitney U test</td>
<td>Immersive VR students performed <strong>identical</strong> to non-immersive VR students*</td>
</tr>
</tbody>
</table>

* - Tests performed using small sample sizes – results need further validation
Summary of Students’ Feedback

S1: I find it useful to be able to virtually manipulate objects when I am doing engineering design

<table>
<thead>
<tr>
<th>Response</th>
<th>Immersive VR System</th>
<th>Non-Immersive VR System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>60%</td>
<td>34%</td>
</tr>
<tr>
<td>Agree</td>
<td>52%</td>
<td>24%</td>
</tr>
<tr>
<td>Neither Agree</td>
<td>14%</td>
<td>8%</td>
</tr>
<tr>
<td>Disagree</td>
<td>8%</td>
<td>0%</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

S2: I find it easier learning when I am virtually manipulating objects

<table>
<thead>
<tr>
<th>Response</th>
<th>Immersive VR System</th>
<th>Non-Immersive VR System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>52%</td>
<td>41%</td>
</tr>
<tr>
<td>Agree</td>
<td>41%</td>
<td>36%</td>
</tr>
<tr>
<td>Neither Agree</td>
<td>24%</td>
<td>28%</td>
</tr>
<tr>
<td>Disagree</td>
<td>7%</td>
<td>8%</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>4%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Summary of Students’ Feedback

- **Statement 3:** *Virtual reality technology such as Oculus Rift® can be useful as a classroom tool*
- **Statement 4:** *I will be interested in enrolling in a class that uses virtual reality technology such as Oculus Rift®*
Virtual Reality in Education

Product Design

Medicine

Flight Training

Chemistry

Physics

Astronomy
Data Mining Driven Design

Environment Data

Individual’s Data

http://www.engr.psu.edu/datalab/
Conclusion and Future Work

• Performance outcomes of the students using immersive VR systems are significantly better than students using non-immersive VR systems

• Future work
  – Integration of 3D interactive technology with immersive visual displays
  – Effectiveness of immersive VR systems among users of different gender and age group
  – Extension of immersive VR systems to MOOCs
Acknowledgement & References

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References
Questions

[Image of a person using a VR headset with labels for Yaw, Pitch, and Roll]

Research Extensions

http://www.engr.psu.edu/datalab/