Interactivity and Learning: Examining primary school children's activity within virtual environments

Maria Roussou

A dissertation submitted in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

of the

University of London.

Department of Computer Science

University College London

July 18, 2006

I, Maria Roussou, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

To my family.

And in memory of Professor William Winn, HITLab - University of Washington, who was a pioneer in researching the use of Virtual Reality for Education, and a true scholar.

Acknowledgements

The effort contained in this thesis has grown out of and essentially synthesises ideas from over 10 years of work and research, while the number of individuals that have contributed -practically, intellectually, or emotionally- to this process has been proportionally large. First and foremost, I would like to thank my supervisors, Professor Mel Slater for his insightful and gentle guidance, which gave me a clearer perspective on the scientific process that constitutes true research, and Dr. Martin Oliver for all the quality time he spent guiding me through the theories and complications of evaluation and the learning technologies. I have been privileged to have Professor Tom Moher as a mentor and friend. He has been the most profound inspiration behind this work from the first moment I stepped in his class at the University of Illinois at Chicago in 1993, and deserves my deepest appreciation and admiration.

I have been extremely fortunate to have the support of very special friends to whom I am truly grateful: Vali Lalioti and Dougie Brew for their amazing support; they were family in London, providing me with a home for the first three years. Anna and Vassilis Voukias who took on that role for the final months. Dimitris Nastos, my fantastic 'makebelieve' business partner, who kept the real world in perspective by maintaining the "headquarters", and helped with the media transfer and storage of all the video data. I am deeply indebted to George Drettakis, whilst not involved in my particular area of research, expressed great interest in my work from the outset, helped in the acquisition of the funding (the CREATE project), and continued to motivate and support me throughout with sustained confidence, encouragement, stimulating conversations, resources, and practical help, beyond and above measure.

For the development of the Virtual Playground, special thanks are due to Dimitris Christopoulos and Alexandre Olivier Magnon; their talent and help in programming, modelling, and animation is reflected in the wonderfully fun and engaging virtual environment that was created. I would like to express my gratitude to my very creative friends and couple par excellence, Josephine Anstey and Dave Pape; Josephine for being "the voice" behind the virtual characters, Dave for being one of the smartest people I know and for creating the authoring environment used for the development of the virtual environment (a whole generation of VR artists were able to realise their creative visions because of his Extended Performer (XP) work). To Lesley Axelrod for her help in recording voices and all the information she has provided with such energy and enthusiasm. To Matt Szymanski of VRCO, a great professional and friend, for donating and supporting me with the CAVELib anytime I needed it. To Prof. Ann Blandford and Dr. Ken Kahn for reading and commenting in detail on the thesis draft. To everyone at the Electronic Visualization Laboratory in Chicago for being a constant source of creativity, a family, and a community

of support that I can refer to no matter how many years have passed since I left. And, finally, to Mina Vasalou for her support and to my fellow researchers of the VECG group at UCL, especially Dr. Vinoba Vinayagamoorthy for helpful tips and the crash course on logistic regression, and Katrien Jacobs for her invaluable support at the final moments.

I wish to thank all the children that participated in the studies and their parents, as well as the educators that volunteered to help with the design of the learning content, the long recruitment process, and the validation of observations and interpretations. Most importantly, Maria Mplouna for her ideas and for the devotion and pathos she transmits for teaching, knowledge, and the support of critical thinking: she is a role model for every educator; Marinos Skolarikos and his class at the 18th primary school of Glyfada; Melina Iliopoulou for introducing me to both teachers; Maria Klini and Christos Markou of The Hellenic College of London.

Finally, on practical matters and funding, I acknowledge the EU-funded IST project CREATE (IST-2001-34231), through which UCL's Department of Computer Science was able to cover my fees for the period of 2002 to 2005. And, I cannot help but to acknowledge 'Stelios', founder of Easyjet, for establishing the concept of the low cost airline in Europe. Without the flexibility of inexpensive flights, I would not have been able to even consider this PhD in the first place (seriously!).

Above all, I am grateful to my parents, Chris and Dena, my husband Aristophanes, and my sister Katerina, for their continuous support, love, patience, and example. This dissertation is dedicated to them and to the memory of my father-in-law Aristotelis Papadimitriou.

Abstract

This research investigates user interaction in virtual reality learning environments, focusing on the role and the effect of interactivity on learning and change in conceptual understanding. The goal has been to examine if children learn better by interacting in an immersive virtual environment (VE), i.e. exploring, reacting to, and acting upon events. The two essential properties of a virtual reality (VR) experience, especially in entertainment and informal learning applications, are immersion and interactivity - each of which is advertised widely to attract and motivate participants. In particular, it is commonly considered that a learning environment is more effective if it is interactive. However, little systematic research has been available to substantiate this assumption and no clear evidence has existed that interactive VE applications can bring "added value" to learning, especially in children.

In this research, empirical studies were carried out with 60 primary school students (ages 8 - 12), in a number of different studies. An exploratory study was carried out to test the methodology and prepare for the main study. The main study, a large scale experiment, was conducted with a VE designed to simulate a 'virtual playground', which focused on a presentation of problems in mathematical fractions. Three conditions - an interactive VR, a passive (or guided) VR, and a non-VR condition - each with different levels of activity and interactivity, were designed to evaluate how children accomplish the various conceptual tasks. Pre-tests, post-tests, interviews, video, and computer activity logs were collected for each participant, and analysed both quantitatively and qualitatively. The results indicate that activity based on the cues or feedback provided by the VE led participants to complete the tasks successfully (i.e. problem solving) compared to the non-VE condition. However, it was the passive rather than the interactive condition that provided evidence of sustained conceptual change.