Collaborative Virtual Worlds and Productive Failure: Design Research with Multi-disciplinary Pedagogical, Technical and Graphics, and Learning Research Teams

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Abstract: This session reports on an ongoing project funded by the Australian Research Council's Discovery initiative that is conducting design research into learning in collaborative virtual worlds (CVW). The session will describe three design components of the project: (a) pedagogical design, (b) technical and graphics design, and (c) learning research design. The perspectives of each design team will be discussed and how the three teams worked together to create the project's CVW. The development of productive failure learning activities for the CVW will be discussed, and there will be an interactive demonstration of the project's CVW.

Description

This session reported on an ongoing project funded by the Australian Research Council's Discovery initiative. Its aim was to investigate learning in collaborative virtual worlds (CVW) in terms of three central research questions:

1. How might learners construct deep and transferable understandings of important and challenging scientific knowledge and inquiry skills through specifically designed pedagogical experiences involving CVWs?
2. Might activities for learning science that involve CVEs motivate students to learn scientific knowledge and inquiry skills as well as to develop positive attitudes and predispositions towards science?
3. What types of pedagogical shifts will teachers experience when teaching with CVEs and what types of professional development and support will they need in order to effectively integrate and use CVE systems in their classrooms?

The methodological framework underlying this project is *design research* involving the use of a CVW (described below) in secondary science classrooms. Design research conducts formative studies in real world contexts such as classroom environments that test an innovative theory or research based educational design, and that in turn iteratively refines the design of the learning environment over time (Brown, 1992; Collins, Joseph, & Bielaczyc, 2004). In terms of learning theory, the design of the technology and the curriculum are informed by general learning sciences theories such as situated cognition (Brown, Collins, & Duguid, 1989) and distributed cognition (Salomon, 1993) as well as what might be called "focused" cognitive theories of conceptual change (diSessa, 2006), transfer (Bransford & Schwartz, 1999; Gick & Holyoak, 1987), and productive failure (Kapur, 2008).

There are three main design phases of this project. First, the *pedagogical* design phase has been shaped by meetings with various stakeholders in the project from the beginning of the proposal writing and is actively continuing as the project nears the end of its first year. In late 2008, the research team met with secondary science teachers from two schools where discussions were held about what subjects the teachers felt were challenging and difficult for students to learn, where topics were mentioned such as ecosystems, evolution, genetics, electricity, and chemical equilibrium. As part of these meetings, the teachers were shown and some were able to use the Virtual Singapura multi-user virtual environment that had been developed in earlier research in Singapore (Jacobson, Kim, Miao, Shen, & Chavez, 2010). The research team explained that the proposal would obtain funding to develop a new collaborative virtual world (CVW) that would be based on curriculum topics in New South Wales (NSW), as well as to align with the topics in a new Australian national curriculum that was being discussed and developed at that time (and is now being implemented).

Once funding was obtained, the *pedagogical design team* began meetings with a core group consisting of learning scientists, a university biologist, teacher education and learning technology researchers, and graduate students. The team came up this basic scenario for the CVW:

> You and your team are scientists working for the Interplanetary Environmental Investigation Agency (IEIA). Your assignment is to investigate environmental issues on different planets

> that have been reported to IEIA. Your team is visiting "Omosa," a terrestrial class planet, where the Laok people live. They have reported that the populations of certain species of megafauna—an important food source in their society—were declining. Your team's job is use your scientific knowledge and inquiry skills to conduct investigations into possible reasons for this decline Your team will make a report to the IEIA and to the Laok people on the results of your investigation and suggest possible ways to respond to this environmental challenge.

Working with Charlotte, the biologist and content expert, and with feedback from teachers, the pedagogical design team identified a number of conceptual dimensions of ecosystems and food webs that aligned with the new Australian secondary science curriculum and the curriculum currently being taught in secondary schools in NSW, as well as the main aspects of conducting scientific inquiry (e.g., hypothesis generation, dependent and independent variables, data collection, analysis and interpretation, reporting).

Concurrent with the work of the pedagogical design team, Debbie led the *technical and graphics design team* at Macquarie University, which consists of a computer scientist, graphic artist, and computer programmer who are creating the immersive 3D CVW using Unity3D. Bi-weekly meetings were held, some face to face and some using Web-based video conferencing software, where the pedagogical and technical and graphics design teams discussed issues about how the scenario and learning activities could be brought to "virtual life." Figure 1 shows two screen shots from an early version of the Omosa CVW.

Figure 1. Screen Shots of Omosa: Tani of the Laok People (Top) and Grazing Herbivores (Bottom).

The *learning research design team* is led by Michael, and its members overlap with the pedagogical design team. The main task of this team is to ensure that the research questions of the project are systematically investigated and the reports, papers, chapters, and so on are prepared for dissemination. Of particular relevance to this project is a recently articulated learning sciences pedagogical approach— productive failure (Kapur, 2008, 2010)—that is being used to inform the design of the learning activities in the Omosa CVW to investigate the first two research questions. Situative and sociocognitive theoretical perspectives in the learning sciences (Bransford, Brown, Cocking, & Donovan, 2000; Brown et al., 1989; Sawyer, 2006) and conventional teaching practices tend to initially provide learners who are involved with learning challenging knowledge or solving problems with greater amounts of structure, which are removed over time with the intent of minimizing student failures and frustrations. "Structure" may be broadly conceived in a variety of forms such as structuring a problem, scaffolding, instructional facilitation, providing tools or expert help, and so on. Indeed, a substantial amount of research has examined the effects of structuring and scaffolding learners within ill-structured problem-solving activities (Puntambekar & Hübscher, 2005). However, there is research that suggests this

theoretical and a "common sense" perspective may not always be most efficacious for deeper learning outcomes or preparations for knowledge transfer in new problem solving situations (for a discussion, see Kapur (2008)). This project will conduct a program of research in which learning activities being designed for the Omosa CVW will initially challenge the learners with open-ended, low-structure tasks that they will likely struggle with or even fail at, followed by high-structured experiences (e.g., direct instruction by a teacher, worksheets, scaffolding provided in the CVW by intelligent agents). This pedagogical design may be characterized as a low-to-high structure (LHS) trajectory, which sharply contrasts with the more typical high-to-low structure (HLS) activities such as guided inquiry that are used in most other educational virtual learning research (e.g., Barab, Warren, & Ingram-Goble, 2006; Dede, Clarke, Ketelhut, Nelson, & Bowman, 2005). During year two, the research plans are to conduct a quasi-experimental study with a LHS productive failure experimental condition and a guided inquiry HLS comparison condition. We expect to find higher-level gains on declarative knowledge assessments and higher performance in near and far transfer problem-solving tasks by participants in the LHS experimental condition. In order to understand process dimensions of learning, there will also be audio and screen recordings of a small number of students as they collaboratively work with the Omosa CVW, classroom qualitative observations, and interviews with students and teachers following the intervention. Based on these findings and suggestions, the Omosa CVW will be revised and decisions made about the appropriate next stages for research in year three of the project. An additional school will be included in the year three research, with planning meetings with these teachers beginning in 2011.

Session Themes and Outcomes

The main session theme is *collaborative design teams for collaborative learning*. We view the process of developing innovative collaborative learning technologies as one in which multi-disciplinary perspectives are required with iterative feedback, advice, and suggestions from all relevant stakeholders. However, there are very real challenges with bringing together professionals who have very different content backgrounds and epistemic assumptions embedded in the discipline specific conduct of their respective crafts. For example, the pedagogical design team began with very *general* narrative of the scenario for the CVW that was to be elaborated on and made more specific over time with feedback from teachers and other members of the project team. However, the technical and graphics design team felt frustrated initially as they typically start projects with very *detailed* specifications. An expect outcome for participants in this session to appreciate that in collaborative designs, the different design teams and stakeholders need to respect each others perspectives and styles of working, while also not being threatened by the diversity of the disciplinary ways of working and communicating.

Another important session theme is *design research to foster innovations in learning technologies*. Design research has many advantages for researchers interested in better understanding how people learn. We also believe it is a powerful methodology to help create and iteratively revise and enhance new types of learning experiences mediated by rich affordances and interactive capabilities enabled by increasingly powerful and affordable technologies.

The final session theme is *design research for buy in*. By this we mean the overall planning, development, implementation, research findings, and final project deliverables that are intended to create a collaborative learning innovation that the users of the innovation—the teachers and students—actually want to use. By listening to teachers and state education agency staff from the very beginning of the conceptualization of the project and the proposal writing, we tried to identify real problems that teachers and education agency staff have, and to shape the trajectory of design decisions in ways that will hopefully help create viable solutions to their problems. Also, teachers know their students have trouble learning threshold concepts and skills in science (Meyer & Land, 2005). We hope the rigorous research design we have in place will generate a range of quantitative and qualitative information that future teachers could examine and then (hopefully) decide to try using one of our collaborative virtual worlds with their students. For staff in education agencies and at policy levels, their problems are having an appropriate range of information to make decisions about resources to provide in schools (e.g., particular types of technologies and networking infrastructures), data about learning costs/benefits associated with a potential new learning innovation to perhaps recommend for wider scale implementation in the educational system, and so on. Consequently, another outcome is for participants to appreciate that it is important for design researchers and teams to think broadly and to plan carefully. Overall, we hope that this will be a valuable session for participants as it will share real world case experiences from a design-based research and development team that is linking theory to practice so that research outcomes in the classroom will inform our theories of learning and technology design, as well as create viable and robust learning modules based on collaborative virtual worlds for use in science classroom settings in Australia and internationally.

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