Research into Learning in an Intelligent Agent Augmented Multi-user Virtual Environment

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Abstract

This paper describes ongoing learning and intelligent agent research involving a new class of educational Interactive and Digital Media (IDM) that integrates computational intelligent agents with the functionality and affordances of 3D Multi-User Virtual Environment (MUVE). This research builds upon a proof-of-concept Virtual Singapura immersive learning environment project. Ongoing technical development work and planned learning research are described.

1. Introduction

The use of immersive multi-user virtual and game environments in educational settings has been receiving increasing interest for several years [1-5]. However, despite the promise of interactive video games for learning, a previous review of the literature on learning in agent and non-agent enhanced MUVEs [6] identified two main research issues. First, relatively few rigorously conducted empirical studies have reported significant learning of formal subject specific content using non-intelligent or intelligent MUVE systems. Second, there have been few research projects to date in which a collection of intelligent or adaptive agents have been integrated into a 3D MUVE system to provide support that recent learning theory suggests may help students achieve deeper learning outcomes. We next provide an overview of important recent research findings from the field of the learning sciences, followed by a discussion of the ongoing development and research our team is conducting that is integrating specially programmed intelligent agents into a virtual learning world.

2. Background

Recent research has been moving away from a view of learning as a received body of “facts” to be memorized or acquired, to one that is a dynamic and constructive activity that involves cycles of problem finding, question asking, information gathering, analysis, performance, and reflection [7]. Put another way, learning for the 21st century should involve student-centered activities and experiences that are aligned with authentic practices found in real contexts of application, such as “doing science.” The challenge, of course, is how to implement research validated and authentic pedagogies for learning core subject knowledge and skills in ways that are logistically viable in formal and even informal learning environments.

Our research is informed by theory and research in two main areas. In terms of learning theory, the design of the technology and the curriculum resources is informed by general learning sciences theories such as situated cognition [8] and distributed cognition [9] as well as what might be called “focused” cognitive theories of conceptual change [10-12], and knowledge transfer [13-16]. The intelligent agent perspectives are informed by research by Shen, Miao, and colleagues [17-24].

3. Project Team and Design

Our research team is an international collaborative that involves learning scientists at the Centre for Research on Computer-supported Learning and Cognition (CoCo) at the University of Sydney, the Singapore Learning Sciences Laboratory (LSL), as well as computer scientists at the Emerging Research Lab (ERLab) and graphic artists at the School of Art, Design, and Media at Nanyang Technological University in Singapore. The research builds upon the prototype Virtual Singapura MUVE (VS-1) project that was funded from November 2006 to May 2008. The new ongoing program of research has three main components: (a) to enhance the intelligent agents to be used in a new VS-2 MUVE based on data collected in the pilot VS-1 studies, (b) to conduct small scale, focused studies of students using the newly developed agent capacities in VS-2 in which screen capture, logging, and focus group data is collected on usability and learning, and (c) new classroom-based research studies into the learning efficacy of the new VS-2 in terms of learning content knowledge, knowledge transfer, and student motivation.

4. Scenario for Virtual Singapura MUVE

The scenario that has been used for both VS-1 and now VS-2 is based on historical information about disease epidemics in 19th century Singapore. In this
virtual world, 21st century Singapore students go back in time to help the 19th century Governor of Singapore, Sir Andrew Clarke, and the citizens of the city figure out what is causing the illnesses and to propose viable 19th century solutions to stop the epidemics. When students teleport back to 19th century Singapore, they arrive at the Boat Quay in 1874 and then use their avatars (computer generated characters on the screen that they control and communicate through) to explore portions of the historical city that include the Tan Tock Seng Hospital (Chinese Pauper Hospital, St. Joseph’s Institution (the third oldest Singaporean school founded in 1852), a Traditional Chinese Medicine Hall in the merchant area by the Marina, rickshaw tenement houses in Chinatown, houses in the wealthy European neighborhood, and so on.

As the 21st century student scientists investigate the causes of diseases that manifest during different seasons of the year, they will meet computer-generated Singaporean citizens (i.e., agents) and visit various locations in the city to view pictures (that include written descriptions and information relevant to the inquiry activities), inspect various digital objects to gather information, and obtain air, water, and insect samples at virtual data collection stations. The students communicate with their team members (usually groups of 4) using the group-chat function and also chat with the various 19th century agents they meet, such as the doctor and nurse in the hospital, the Peranakan wife of the traditional Chinese doctor, coolies on the street, a scholar at the medical school, the poor mother of a sick child, and so on. There is also a Virtual Singapura Lab Book that has various sequenced activities for 10 class periods to help students develop an understanding of what scientific inquiry is and to “do science” in the virtual world in which they collaboratively use these inquiry skills.

The setting of VS-1 in the 19th century allows secondary students to have a virtual context in which their developing 21st century scientific knowledge and inquiry skills are “authentically” useful. For example, by using science inquiry skills such as questioning, problem finding and defining, forming hypotheses, collecting data, data analysis, and hypothesis revision, students have the opportunity to do experiments that demonstrate the accepted 19th century scientific miasma theory that cholera was caused by something in the air is wrong and that it, in fact, was generally a disease spread via feces contaminated water. The LSL research team worked closely with Singapore secondary teachers and a NIE science education faculty member to get their perspectives and suggestions about content in the pilot VS-1 so that it is aligned with the Singapore secondary science curricula related to science inquiry skills and science content about communicable diseases.

5. Intelligent Agents in Virtual Singapura

The focus of the ongoing research is to improve the functionality of intelligent agents in Virtual Singapura in order to enhance student learning outcomes from their experiences in the virtual world. The intelligent agents in Virtual Singapura are modeled by Goal Net, which is a tool for modeling goals of an agent in a multi-agent system [22]. A Goal Net is composed of goals and transitions. Goals are used to represent the goals that an agent needs to pursue, and transitions specify the relationship between two goals. Each transition is associated with a task list that defines the possible tasks the agent needs to perform in order to transit between two goals. A goal net defines all the possible paths by which a goal can be reached or achieved from another goal. There are two kinds of goals in Goal Net: atomic goals and composite goals. An atomic goal is a primitive that cannot be further decomposed, whereas a composite goal can be split into sub-goals connected via transitions. A complex goal thus can be recursively decomposed into sub-goals and sub-goal nets. This hierarchical structure simplifies the goal modeling process with different levels of abstraction.

In Goal Net, there are four types of relations of goals represented by transitions that connect the input goals and output goals: sequence, choice, concurrency, and synchronization. The combination of the different types relations and connections between goals defines all possible goal pursuit paths. The selected path in real time is dynamically determined with the built-in goal selection algorithm in the runtime environment.

The development of adaptive and responsive synthetic characters is a challenging problem in the field of artificial intelligence and intelligent agents that is just beginning to be explored in conjunction with educationally oriented 3D multi-user virtual and serious game environments. In our research, the Goal Net technology that the ERLab research group has developed [21, 22] has been extended to interoperate with the Active Worlds virtual world server world as part of the pilot VS-1 project. The use of agents with goal nets has been initially tested in the VS-1 world in relatively simple yet functional ways, such as increasing the range of queries and informational responses a synthetic character may “understand,” helping students navigate in the virtual landscape, and answering various forms of questions students commonly ask virtual characters, such as: Who are you? Are you sick? Where am I? Where should I go next after I explore this area?

Research efforts in a new version of Virtual Singapura—which we call VS-2—are focusing on how to use different agent’s functions, such as location awareness (where), situation awareness (what happened), context awareness (how) [19], and social collaboration in order to support student learning in the virtual
environment [24]. Also, authoring tools such as a “scenario designer” and an “agent factory” are being developed to support the generation of agents in VS-2 [20, 23]. These agent development tools are intended to be easy to use by non-programmers and will be integrated into the VS-2 world so that researchers and teachers (rather than programmers) can create agents and build scenario-based goal nets according to research or curriculum needs. In addition, a new function will be added that will allow the chat conversations of student teams and students’ activities to be recorded for knowledge mining, dynamic inference, and action selection, which will greatly enhance the research data that will be obtained in the project and in turn provide information to inform the iterative enhancement of agents in future studies.

As a component of the new phase of research, the VS-2 project is working on integrating metacognitive and conceptual scaffolding by intelligent pedagogical agents into the virtual experience. For example, a student might be uncertain about what to do at some point when using the program and could approach a synthetic character (i.e., such as the doctor in the Tan Tock Seng hospital) for advice. At this point, the synthetic character would activate an intelligent pedagogical goal net and adaptively ask the learner a metacognitive strategy question such as “Has your group set your goals for today?” To a “no” reply, a scripted response could be “Your group and you might want to discuss what your goals are for today as they will help you know what to do” or to a “yes” response “That is a smart way to work. What do you think you need to find out now?” The proposed research would further develop the chain of responses the intelligent agents would provide based on an analysis of the interactions between the students’ avatars and intelligent pedagogical agents in the pilot research. In addition, research involving intelligent pedagogical agents will explore ways they might scaffold students’ conceptual thinking about subject content knowledge by functioning as an information resource about these concepts as well providing context specific explanations relative to a particular setting in the virtual world. In summary, the agent augmentation research that is being conducted in this project has the potential to greatly enhance interactivity that is possible in a multi-user virtual learning environment. It is hoped that this interactivity will help scaffold and support learning of challenging knowledge and inquiry skills in ways that are difficult to do in even “real world” learning environments, which will be the focus of research described in the next section.

6. Agent and Learning Research

There will be two main types of research that are being planned once the technical development of the agents is completed: (a) small scale experimental studies of students interacting with the agents to explore various aspects of natural language processing, realism of agent responses, and adaptive ways agents might provide scaffolding for self-regulated learning and metacognitive strategies, and (b) classroom-based research. The project will employ a mix of schools in Singapore and Australia, with some schools having a profile of students classified as academically achieving at a lower to middle level and the other schools with a higher overall academic achievement ranking. This research design will allow the assessment of the potential of multi-user virtual environments such as VS-2 to help the “less academically energized” students first develop interests in school activities, and also to help them learn important scientific perspectives such as science inquiry. Data about the students’ progress will be obtained by using screen capture software, and by audio and videotaping student conversations and actions in the classroom. Rubrics will be developed to code the transcripts of the audio and video data, and the computer log files in terms of the types of interactions the learners have with the agents, the types of activities they are involved with in the virtual world, and the types of collaborative interactions they have with each other as team members.

In addition to process data, pretest and summative data will be collected that will use items similar to current tests administered in Singapore and Australia teachers in their classes and to other standardized tests (e.g., Cambridge “O” level items). Alternative assessments of learning will be employed in the project, such as verbal protocols of individual student problem solving solutions or articulations of inquiry approaches, knowledge transfer tests of conceptual understanding, and rubric scored portfolio artifacts of student learning such as their VS-2 online exercises, notes, and log files. Items derived from international assessments such as the Programme for International Student Assessment (PISA) will also be used. By collecting this range of data, this project hopes to determine if students using an intelligent agent-augmented MUVE can learn important conceptual knowledge and skills in the physical and social sciences. In addition, interviews will be conducted with selected students and the participating teachers to explore perceptions about learning in an immersive virtual environment, and for pre-service and experimental class teachers, perceptions about the role of the teacher in virtual environments such as those being developed in this project.

In the major studies to be conducted in this project, it is hypothesized that students in the experimental classes who use the curriculum modules developed in the project will perform at a higher level on the open-ended alternative problem solving assessments and the PISA items that require greater conceptual understanding and knowledge transfer than students in the comparison
classes. Student and teacher pre and post interviews and surveys will also be conducted to explore perceptions and experiences about learning and teaching with intelligent agent-augmented multi-user virtual worlds.

7. Conclusion

This paper has outlined the rationale and major development and research components of an ongoing international research project that seeks to explore ways that agent augmented multi-user virtual environments might be designed to effect significant learning outcomes. Projects such as this must have not only strong technical components but also solid grounding in learning theory and research as well as rigorous assessment methodologies. We hope that the next phase of development and research we are involved with will build upon our earlier provisional success as well as provide a viable model for conducting trans-disciplinary research into how intelligent agent technologies might augment eLearning experiences of students.

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9. References

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