Research on Role-based Learning Technologies

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Abstract: One of the goals of science education is to familiarize students with an intellectual framework based on established scientific principles and general approaches that can later be used to solve science-based problems. Science is also content-based, and students must master the content of a discipline in order to succeed. The challenge for science educators is to develop educational tools and methods that deliver the principles but at the same time teach the important content material, but in a *meaningful* way. This paper describes research based on experimental virtual role-based environments built to explore the following beliefs:

(1) educational technology should capitalize on the natural human propensity for role-playing;
(2) students will be willing to assume roles if the environment makes it easy to do, and if the environment reinforces role-playing through careful crafting of explicit tutorial components; and
(3) that educational software should be engaging, entertaining, attractive, immersive, interactive, and flexible: in short, game-like.

The experiences provided to the student within these virtual worlds can be both meaningful and authentic, although some trade-offs are required to make them fun, challenging, and occasionally unpredictable.

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Abstract

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1. Introduction

The NDSU World Wide Web Instructional Committee (WWWIC; McClean et al., 1999; Slator et al., 1999b) is engaged in several virtual/visual research and development projects: the Geology Explorer (Schwert et al., 1999), the Virtual Cell (White et al., 1999), and the ProgrammingLand MOOseum of Computer Science (Slator and Hill, 1999). Each has shared and individual goals. Shared goals include the mission to teach science structure and process: the scientific method, scientific problem solving, diagnosis, hypothesis formation and testing, and experimental design. The individual goals are to teach the content of specific scientific disciplines: Geology, Cell Biology, Computer Science.

In addition, WWWIC is applying what has been learned in Science education to new domains: history, microeconomics, and anthropology. Further, WWWIC has active research projects in three highly related areas: 1) qualitative assessment of student learning, 2) tools for building virtual educational environments, and 3) intelligent software tutoring agents (Slator, 1999).

The WWWIC program for designing and developing educational media implements a coherent strategy for all its efforts: to deploy teaching systems that share critical assumptions and technologies (e.g. LambdaMOO; Curtis 1992, 1997), in order to leverage from each other's efforts. In particular, systems are designed to employ consistent elements across disciplines and, as a consequence, foster the potential for intersecting development plans and common tools for that development. Our simulations are implemented by building objects and interfaces onto a MOO ("MUD, Object-Oriented", where MUD stands for "Multi-User Domain"). MUDs are typically text-based electronic meeting places where players build societies and fantasy environments, and interact with each other. Technically, a MUD is a networked multi-user database and messaging system. The basic components are "rooms" with "exits", "containers" and "players". MUDs support the object management and inter-player messaging that is required for multi-player games, and at the same time provide a programming language for writing the simulations and customizing the environments.

2. Role-based Environments

The theory of role-based environments (Slator and Chaput, 1996), is both simple to explain and complex to implement. An apprentice watches their master, learning techniques and practicing their craft; they observe the master's actions and internalize them (Brown et al., 1989; McGee et al., 1998). When confronted with a problem, the apprentice asks, "what would the master do in this situation?" And then the apprentice models the expertise of the master in the pursuit of their goals. This is a common experience shared by silversmiths, doctors, Ph.D. candidates, and anyone else enculturating themselves into what they want to be. When John Houseman says, in the *Paper Chase* that "We are not teaching you the law, we are teaching you to think like a lawyer," this is what he means. Similarly, there is little argument that immersive foreign language learning is most effective; to learn French, go to France. At some point, it is widely reported, you begin to "think in French", and that is what you want.

Our idea is to put students into authentic situations that will challenge them to think through problems and act like scientific problem solvers. Students in our role-based environments are presented with a series of high-level goals, which are designed to promote science reasoning. For example, "locate a kimberlite deposit" is designed to raise inquiries like "what is kimberlite?", "what properties does it have?", "what experiments relating to these properties will confirm an identification?", "what instruments are needed for these experiments?", and "how are these instruments used?". These questions exemplify science reasoning in terms we are attempting to promote: the "doing" of hypothesis formation and experimentation, and the acquisition of conceptual knowledge in a problem-solving context.

3. Developing Role-based Environments

Developing such systems is difficult, expensive, and inherently collaborative, and requires three components: 1) content expertise by subject matter experts and the associated (non-standard) pedagogical design; 2) software design, development, and project management; and 3) fundamental Computer Science research in the areas of distributed systems, software agents and intelligent tutoring, and virtual environments. In practice this means implementing authentic simulated environments where students can learn-by-doing. This entails implementing a vast range of interacting locations, artifacts, and instruments to support 1) authentic problem solving situations, 2) research questions and content-relevant goals, and 3) online help and tutorial advice in context.

4. Major WWWIC Team Efforts

Space does not permit full description of the WWWIC projects. This paper describes only two: the Geology Explorer and the Virtual Cell.

4.1 Example: the Geology Explorer

The Geology Explorer project (Saini-Eidukat et al., 1999; Slator et al., 1999a), implements a virtual world where learners assume the role of a geologist on an expedition to explore the geology of a mythical planet. Learners participate in field-oriented expedition planning, sample collection, and "hands on" scientific problem solving. The Geology Explorer world, Planet Oit, is simulated on an Object Oriented Multi-user Domain. A text-based version of Geology Explorer was tested in an introductory geology class during the Summer 1998. Results of that test were used to prepare for a much larger test during the next semester. A graphical user interface to the Geology Explorer is under development.

To play the game, students are transported to the planet's surface and acquire a standard set of field instruments. Students are issued an "electronic log book" to record their findings and, most importantly, are assigned a sequence of exploratory goals. These goals are intended to motivate the students to view their surroundings with a critical eye, as a geologist would. Goals are assigned from a principled set, in order to leverage the role-based elements of the game. The students make their field observations, conduct small experiments, take note of the environment, and generally act like geologists as they work towards their goal of, say, locating a kimberlite or a graphite deposit. A scoring system has been developed, so students can compete with each other and with themselves. The Geology Explorer prototype can be visited at http://oit.cs.ndsu.nodak.edu/.

4.2 Example: the Virtual Cell

The Virtual Cell (VCell) is an interactive, 3-dimensional visualization of a eukaryotic cell. VCell has been prototyped using the Virtual Reality Modeling Language (VRML), and is available via the Internet. To the student, the Virtual Cell looks like an enormous navigable space populated with 3D organelles. In this environment, experimental goals in the form of question-based assignments promote diagnostic reasoning and problem-solving in an authentic visualized context.

The initial point of entry for the Virtual Cell is a VRML-based laboratory. Here the learner encounters a scientific mentor (a software agent), and receives specific assignments. In this laboratory, the student performs simple experiments and learns the basic physical and chemical features of the cell and its components. More notably, our laboratory procedures are crafted such that they necessitate a voyage into the Virtual Cell where experimental Science meets virtual reality. As the student progresses, they revisit the laboratory to receive more assignments. Periodically, the student will bring cellular samples back to the virtual lab for experimentation. The Virtual Cell prototype can be visited at http:/ /vcell.ndsu.edu/.

5. Background: Authentic Assessment

All WWWIC projects are based on the idea of authentic assessment (Bell, Bareiss, and Beckwith, 1994), within authentic contexts, where the goal is to determine the benefit students derive from their "learn by doing" experience using our virtual environments (Duffy and Jonassen, 1992; Edelson et al., 1996; Lave and Wenger, 1991; Reid, 1994). Our scenario-based assessment protocol is a qualitative one that seeks to measure how student thinking has improved.

When learners join the synthetic environment they are assigned goals, selected by content matter experts to be appropriate to the learner's experience. Goals are assigned point values, and learners accumulate objectively measured scores as they achieve their goals. The goals are taken from a principled set, where easier goals are followed by more advanced ones. Similarly, certain goals in a set are required while others are optional. In this way, we can insure that highly important concepts are thoroughly covered while allowing the maximum flexibility to the learner. Subject matter experts identify teaching objectives in more-or-less traditional ways, while learner outcomes are assessed in terms of the performance of specific and authentic tasks. This is the particular strength of learn-by-doing immersive environments, that a learner's success in achieving their goals provides an automatic measure of their progress.

In addition to these outcome-based measures, all students are asked to answer open-ended scenario-based questions before and after the experiment. These scenario questions are word problems that present the student with a situation that a scientist might confront (the complete set of Planet Oit scenarios can be viewed at http:// www.cs.ndsu.nodak.edu/ ~slator/ html/ PLANET/ assess-scen.html). Students respond to the question with a narrative answer, which is evaluated according to an established protocol.

6. Next Steps

The Blackwood Project (http:// lions. cs. ndsu. nodak. edu/ ~blackwood/), is the first attempt at the "next generation" of role-based virtual environments for education where the pedagogical simulation will support cross disciplinary content and a choice of varied and specific roles to promote player interaction and potential collaborations. Blackwood combines microeconomics with Western history and implements a virtual reconstruction of a 19th Century Western town populated with intelligent software agents to simulate an economic environment representative of the times.

The Virtual Polynesia project will develop an educational software system for presenting, in an intellectually engaging and stimulating way, a humanities perspective on human culture. The system will be used to teach and present research methods and critical analysis for the often-overlooked humanities tradition within cultural anthropology. Most funding for anthropology comes from social science sources, hence the humanities aspect of anthropology has become neglected. Yet it is that very dimension of anthropology that is crucial today for understanding globalization and the interaction of diverse groups.

Our goal is to give students a tool for understanding other peoples by teaching ethnographic techniques and methodology through an interactive, on-line, game environment for stimulating learning about human culture and social behavior. Specifically, the application will teach ethnography techniques to focus on (1) global awareness, (2) cultural diversity and interaction, (3) decision-making in a cultural environment, and (4) anthropology in general.

7. Conclusion

Role-based instruction allows the student to participate in the practices of a discipline within a naturalistic context. These environments allow the students access to techniques in the context in which they actually work; such techniques, as noted by Lave and Wegner (1991), embody the practices of the culture. Our goal is to extend this pedagogical approach from Science to the domain of socio-cultural systems.

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Acknowledgements

WWWIC research is supported by the National Science Foundation under grants DUE-9752548, EAR-9809761, DUE-9981094, and EAI-0086142, and US. Department of Education FIPSE Program. We also acknowledge the large team of dedicated undergraduate and graduate students who have helped to make these projects possible.