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ROLES, CULTURE, AND COMPUTER-SUPPORTED COLLABORATIVE WORK ON PLANET OIT

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Abstract

The Geology Explorer is a multi-user geologic simulation created by North Dakota State University's World Wide Web Instructional Committee (WWWIC). This paper briefly describes the recent developments to the Geology Explorer Planet Oit software, both pedagogically and organizationally. The difference between group and individual goals is described, and how educational and cultural theories contributed to their creation. The results of a recent pilot study are reported, and research directions indicated by those results are outlined.

Key Words

Role-based collaborative interactive learning environments, advanced learning technologies, culture and learning, immersive virtual environments and authentic scenario learning

1. Introduction

Immersive virtual environments (IVEs) are poised to enter the pantheon of mainstream research on computers and advanced technology for education. There are a number of reasons for this. IVEs have become more prevalent in the research community and this familiarity has led to a degree of acceptance. Technology has progressed to the point where fielding these systems outside the laboratory has become more feasible. But perhaps most importantly, theories of learning and enculturation in virtual environments have begun to mature and to cross disciplines in ways that better help to explain the processes of learning within IVEs.

This paper describes an experiment conducted in an IVE for education, the Geology Explorer. The Geology Explorer is a multi-user geologic simulation created by North Dakota State University's World Wide Web Instructional Committee (WWWIC). In the Geology Explorer, students act in role-based authentic scenarios within a virtual cultural context to explore the mythical Planet Oit. Students explore geologic concepts, such as rock and mineral identification and landform creation, and, through these experiences, learn various disciplinary approaches to the geological sciences.

Until recently, cooperation between online explorers was limited to informal groups of students working in close physical proximity. Advances in the Geology Explorer software have resulted in an expanded learning potential for students by developing a framework for group interaction and cooperation. Students now are able to form groups, chat with others online, leave notes for offline participants, and engage in various important organizational tasks that formerly were available only through close proximity or out-of-band communication, such as e-mail. Now, students can interact with one another within the virtual space, using roles to create a virtual learning culture heuristically separate from the classroom.

A recent pilot study gave an indication of how effective group learning can be: 347 geology students were given the opportunity to visit the virtual Planet Oit as part of their coursework in a freshman-level class. Most of the students were instructed to explore the planet in the usual mode: as individuals informally encouraged to collaborate and cooperate as the opportunity arose. A smaller group was invited to volunteer for a structured pilot study employing techniques found in the arena of computer-supported collaborative work. The results of this study, reported below, indicate that students in structured interaction groups achieve better success in more complex and difficult tasks, and are more likely to complete all the activities. We explain these

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preliminary results in terms of recent theorizing on role formation in enculturative contexts.

2. Background: IVEs for Education

2.1 WWWIC Projects

North Dakota State University's World Wide Web Instructional Committee is engaged in developing a range of virtual environments for education spanning a variety of disciplines, from earth science to anthropology and from business to biology. All these projects share a strategy, a set of assumptions, an approach to assessment, and an emerging tool set, which allow each to leverage from the insights and advances of the others.

WWWIC projects typically build simulations on a MOO ("MUD, Object-Oriented," where "MUD" stands for "Multi-User Domain"). MUDs are text-based electronic meeting places where players build societies and fantasy environments and interact within them [1]. Technically, a MUD is a multi-user database and messaging system. The basic components are "rooms" with "exits," "objects," and "players." MUDs support the object management and interplayer messaging that is required for multiplayer games, and at the same time provide a programming language for writing the simulation and customizing the MUD. One of the major shortcomings of MUDs, however, is their low-tech communication system: text. Because of this, WWWIC games usually supply a graphical user interface layered on top of the networked multi-user database and messaging system that MUDs provide.

Each project has distinct properties in common. They are role based and goal oriented; they are immersive authentic scenario simulations intended to promote learning-by-doing; they are spatially oriented, exploratory, and highly interactive; they are multi-user and game-like; and they employ software agents as tutors.

WWWIC projects employ *authentic scenario learning*. Authentic scenario learning has developed into a major pedagogical strategy for proactive learning projects [2, 3]. For IVEs, authenticity has two major components. First, at the system scenario level, "authentic" means not duplication but reflection of the dynamics of practical contexts [4]. In this way, it matters not that Planet Oit of the Geology Explorer is fictional. Rather, the IVE context, where context is task, social interaction, and virtual environment, is reflective of geology practice.

Second, "authentic" at the individual *learning* level means agreement on the part of the student to participate in the simulation scenario by means of a role (the concept of a role is described in Section 3.4 below). This is a style of learning in direct contrast to traditional classroom learning. It requires the student to act a part and to suspend disbelief in the unreality of the virtual context [5]. For some students, this nontraditional approach to learning at first can be disconcerting. Nonetheless, by assuming roles, students partake in a simulation that provides meaningful experiences at multiple levels.

More than mere goal-oriented "doing" of a task, role-based simulation learning is learning-by-performance. Rather than simply teaching goal-based behaviour and tactical task-oriented skills and methods, the role-based approach communicates a general strategic manner of practice.

The educational IVE systems currently at our disposal are the Geology Explorer [6], the Virtual Cell [7], Dollar Bay [8], and the ProgrammingLand MOOseum of Computer Science [9]. Other systems, under development but not currently ready, include the Virtual Archeaologist [10] and the Blackwood simulation. These are IVEs of the "desktop VR" variety, where students join an immersive simulation using a personal computer and then explore the "virtual space" in a goal-directed manner, assuming a role and learning the content by actively participating in the problem-solving context. These have been rigorously tested in the college environment and have shown to be both engaging for students and highly effective [11] in a range of controlled studies conducted over several years.

2.2 Software Agents and Intelligent Tutoring

Agents, and especially intelligent, adaptive software agents, are a necessity in the kinds of self-paced anytime/anywhere environments we propose. At NDSU we have developed a taxonomy of atmosphere, infrastructure, and tutoring agents [12].

Atmosphere agents lend colour to simulations. They do not directly affect game play but provide animation and interest without causing distraction.

Infrastructure agents provide services for game play. They are necessary to the simulation in some way, and are often the basis of the simulation.

Tutoring agents observe student actions and intervene at strategic points. There are a variety of strategies employed: simple rule-based triggering, diagnostic interventions prompted by student errors [12], and case-based interventions that rely on a library of past cases and classifications of student tasks and errors [13].

The overall goal is focused on developing and employing intelligent agents within multi-user distributed simulations to help provide effective learning experiences. From the perspective of intelligent tutoring systems, the agents of interest must fundamentally support models of the knowledge of a domain expert and an instructor. However, it is desirable that the agents have a number of additional capabilities as well, including awareness and understanding of other agents in the simulation. Some of the desirable intelligent agent capabilities are as follows:

1. Intelligent interaction among agents, including both collaboration and competition to achieve goals. This requires tracking (monitoring) the actions of other agents, assessing their goals and reactive behaviours, and inferring their states and plans over time. In general, the plans need not be rigidly prescribed, but can instead dynamically respond to changes over time.
2. Mechanisms for analyzing successful decisions, in order to recognize relevant features and to support the explaining of their reasoning to learners. This may involve such things as episodic memory for recalling previous decisions and the circumstances under which

they were made as well as a structured decision analysis capability for determining which features are relevant.

3. The ability to monitor, recognize, and anticipate when the student reaches an impasse situation, in which progress towards successful completion of task is stymied.
4. Explanation facilities, including answering questions about why tasks should be performed in a certain way, and the ability to "walk through" or demonstrate how to perform tasks.

All systems of multiple software agents, including those created for pedagogical purposes, must be provided with the ability to communicate with their peers through the exchanging of messages, usually expressed in an Agent Communication Language (ACL). Typically an ACL will provide for the communication of such things as constraints, negations, rules, and quantified expressions. There are a variety of approaches to providing an ACL, and there are also dependencies on communication and interoperation standards such as CORBA and OLE [14]. There are key issues involving the semantics of specifying such things as preconditions, postconditions, and satisfiability; network transport mechanisms, security, and authentication [15].

There are several alternative means of designing and developing agent architecture, and they differ in their appropriateness for pedagogical applications. One type of approach employs direct interagent communication mechanisms, and all agents handle their own coordination activities. For example, in the contract-net approach [16], agents distribute requests for proposals to other agents, who respond with bids to the originators, who may award contracts for services. Specification-sharing approaches involve agents advertising their capabilities and needs, which are then employed by other agents. A competing approach organizes the agents into federated systems, generalizing the concept of a mediator [17]. A federated system uses facilitators to perform intermediate brokering functions and transfer of messages, eliminating direct agent-to-agent communication.

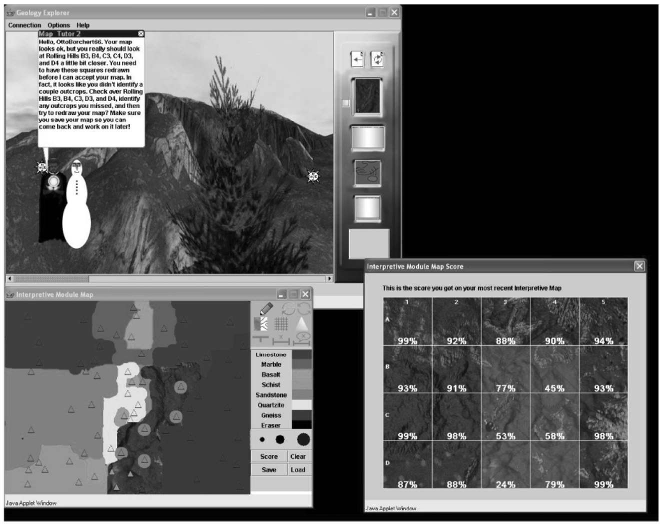
2.3 Geology Explorer

Geologists are engaged in the study of the materials of which the earth is made, "the processes that act on these materials, the products formed, and the history of the planet" [18]. Students can best learn geology by learning the process of geologic investigation, including taking samples, petrographic analysis of thin sections, whole rock chemical analysis for major and trace elements, microprobe analysis of mineral grains, and so on, and by evaluating the data obtained in a theoretical context.

However, in the real world, students may not have access to all the equipment necessary for such a complete investigation, nor to the locations for collecting interesting samples. The Geology Explorer affords an environment in which expensive analytical tools can be built and any location can be visited, virtually. A student will be able to take a sample of a garnet-biotite schist, view a thin section of it, make microprobe analyses of coexisting garnet and biotite, and collect radiogenic isotope analyses, all while perhaps collaborating with a peer from a different country.

The geologic interpretation module is based on a detailed deciphering of the geologic history of an unexplored region of Planet Oit. Because students will have already achieved several goals involving rock and mineral identification before being assigned the interpretive module, they will have the necessary background to undertake further studies.

Although apparently simple, the geology of the region holds enough ambiguity to provide training for novice geologists. It is clear that the mafic dike cross-cuts the sedimentary and metamorphic units, but features such as way-upness and the age relation between the dike intrusion and the regional tilting must be determined by careful investigation of various data types. See Fig. 1 below for a view of the prototype 3-D model constructed for the region.



Hello, OttoBorchert66. Your map looks ok, but you really should look at Rolling Hills B3, B4, C3, C4, D3, and D4 a little bit closer. You need to have these squares redrawn before I can accept your map. In fact, it looks like you didn't identify a couple outcrops. Check over Rolling Hills B3, B4, C3, D3, and D4, identify any outcrops you missed, and then try to redraw your map? Make sure you save your map so you can come back and work on it later!

This is the score you got on your most recent Interpretive Map

	1	2	3	4	5
A	99%	92%	88%	90%	94%
B	93%	91%	77%	45%	93%
C	99%	98%	53%	58%	98%
D	87%	88%	24%	79%	99%

Figure 1. A student's geologic map (lower left) is automatically scored (lower right).

Upon entering the region, the student is asked to map the outcrops. This requires spatially navigating the region, sampling, testing, and identifying rock types as a geologist would in the field. Some of the samples may need to be taken back to the "lab" for thin sectioning and investigation under the "microscope." (In practice these would be digital images of thin sections.) As identification proceeds, the student creates a draft geologic map by locating potentially significant geologic contacts. When all these intermediate goals have been met, the student is asked to put the rock units in time-stratigraphic order. In fact, without complete information (such as, perhaps, paleomagnetic data combined with age determination of the dike), there may be more than one plausible answer. This mimics the real-world practice of geologists holding multiple working hypotheses on maps in progress [19].

The Geology Explorer is a MOO virtual world where learners assume the role of a geologist on an expedition to explore the geology of a mythical planet [20–23]. Learners participate in field-oriented expedition planning, sample collection, and "hands-on" scientific problem solving.

To play the game, students are transported to the planet's surface and acquire a standard set of field instruments. They are issued an electronic log book to record their findings and, most importantly, are assigned a sequence of exploratory goals. Students make their field observations, conduct small experiments, take note of the environment, and generally act like geologists as they work towards their goals. A scoring system has been developed, so students can compete with each other and with themselves.

Planet Oit is available online at http://oit.ndsu.edu/.

3. Context: Culture and Learning

3.1 Culture Theory

We examine preliminary results of the Geology Explorer as an educational tool by using models of culture dynamics and recent theorizing on role formation and performance in enculturative contexts [24].

The Geology Explorer, as mentioned above, is an IVE. From the perspective of anthropology, the study of learning in an IVE is the study of culture and learning. Two paradigms dominate culture theory in anthropology: interpretive/symbolic anthropology and cultural materialism. They are not incommensurate paradigms, but reflect the degree to which anthropology is reflexive, reacting and adapting to its own knowledge about disciplinary progress [25]. Arguably, the difference between these two paradigms is theory foci. The former (interpretive/symbolic) is focused on the individual and processes of/guidelines for meaning and behaviour. The latter (cultural materialism) is focused on the group and concerned with the structures, functions, and processes of a shared system. In other words, anthropologists study a culture and ask, "What is this system and how does it work" (cultural materialism) and, "What is it like to live it?" (interpretive/symbolic anthropology).

3.2 Constructivist Interpretive Approach

For the purposes of IVE interpretivist study, we model virtual culture as guidelines for meaning and behaviour socially shared by a group. These guidelines and meanings are not transmitted from the group to the individual in unchangeable form. Rather, individuals are engaged in a dialectical process with their cultural environment. This environment includes social interactions as well as interactions with material objects and nonmaterial experiences. Today, most learning constructivist research projects use this approach [26–28]. The basic premise of constructivist learning theory is that individuals piece together their own understanding by reference to their own comprehension of materials and to their own individual experience, a process involving, among other factors, qualitative transformation of individual understanding. In other words, constructivist approaches to education hold that true learning occurs when learners construct their own meanings about a given topic.

In the Geology Explorer, research emphasis is on individual accumulative experience and knowledge, and the processes of individual development through role performance. Role performance learning is driven by individual experiences and "other-dependent learning" in both the virtual and real worlds. Other-dependent learning involves "conditions of informally guided discovery" [29]. "Others" in the IVE environment include the tutoring agents (described in Section 2.2) whose virtual behaviour takes the form of "powerful hints and occasional correction" that is critical to other-dependent learning. Similar learning theory is found among business management theoreticians, who emphasize the role of people who are "third-party brokers" and "go-betweens" [30].

In the Geology Explorer, the engagement of learners with others within the virtual world produces reflexive cognitive performative encounters. Performance is the execution of action, whether symbolic or material action. Performative encounters are social interplay that produce effects either on the performer or on the other social actors [31]. At the textual discourse level, reflexive performative behaviour occurs when students are self-conscious of their language interaction and use, and perceive their role as one "to display for others" a certain grasp of other or specialized concepts and language.

This performative aspect of the student engagement in the IVE allows the researcher to move beyond simplistic analysis of whether or not a student's work is correct or incorrect. The performative aspect involves a self-conscious proactive shifting of language-style presentation on the part of the student and is indicative of change in learning levels [32]. For the virtual learner, performative social interaction develops and changes as the student progresses through levels of understanding and learning. These various developments are salient where the student displays increasing levels of communicative competence. Typical proactive changes in presentation include, among others, a shift to increasingly formalized and/or specialized language, arrangement of logical parameters and delimiters to control the context within which the message is couched, and preventative language that anticipates the potential critique/response of others to the content of the specialized message. This type of performative encounter has been observed in other learning situations, such as mathematics classes [33].

3.3 Systems Approach

For the purposes of IVE systems study, we model virtual culture as an open adaptive system characterized by multilineal multidimensional relationships among infrastructural, structural, and superstructural subsystems made dynamic through individual agency and social interaction. Some contemporary learning science projects employ the adaptive systems approach, but it is rarer than interpretive constructivist projects [34; esp. chaps. 1, 6–9].

Systems study involves determining how structures affect learning; how functions are performed by a variety of processes and structures; and how interaction processes are organized within system components and between the virtual system and the classroom system. The infrastructural components include, for example, the IVE technology and virtual environment as engaged from the student's point of view, the associated knowledge required to use that technology, and the economy of the students' engagement in the IVE, including the use of time, virtual labour (movement, logging, task engagement), and supporting materials and software agents that act as resources for the students.

The structural subsystem of the IVE includes, among other organizing forms, the social organization of the student to other students and software agents within the IVE, both those preset by the IVE developers and those created in the IVE by the students, and the social identities by which students identify themselves and others.

The superstructural subsystem includes the demanded list of tasks to be performed by the student and the reasoning behind those tasks, the rules for interactions with both software agents and other students, the built-in hierarchy of power and control over the students' activities as well as power relations within collaborative groups, the self-imposed etiquette developed by the students in their social interactions, the scientific philosophies that drive the disciplinary domain represented in the IVE, and other ideational aspects.

Systems study allows the researcher to focus both on the student learning and on the cohesiveness of the IVE system itself. For learning research, the systems approach involves comparative pattern analysis, with data organized in terms of systems components, and student behaviour described in terms of system and subsystem relationships. For critical assessment of IVE cohesiveness, systems study reveals certain strengths and weaknesses in programming and design.

3.4 Roles

A *role* is the dynamic aspect of a social identity. By dynamic, we mean roles are manifested symbolically through human agency. Among other behaviours, roles involve putting the duties of social identities into effect through practice. This is performance.

Another way to put this is that a role is the activity guided by rules associated with a status. Statuses are symbolic spaces located within cultural systems. Statuses are part of social organization in groups and usually are associated with varying levels of prestige.

In the Geology Explorer, students perform the role of "exploring geologist." But this performance is not as straightforward as it appears. Roles are reflexive; because they are dynamic, they are open to improvisation, to self-assessment, to shades and degrees of variation as created and practised by an individual. As students adapt to the IVE and gain increasing comfort with their status as "exploring geologist," they informally may begin to redefine the role of "exploring geologist" into a hierarchy of "exploring geologist*s*" in turn associated with a hierarchy of prestige.

For example, there will be the beginning student who enters Geology Explorer for the first time. This student's knowledge of the role of exploring geologist within the IVE may be both limited and generalized. This new-to-the-IVE "exploring geologist" will be interested in learning the basics of the IVE and what is expected of her or his role; in other words, the student will be focused on learning the IVE tools and a specific tactical approach to their role.

In contrast, a second student who has been in the Geology Explorer several times may no longer be concerned with figuring out how to move about or communicate with others within the IVE. This second student, who already has mastered that type of activity, may associate such beginning behaviour with low or entry-level prestige. Instead, this not-new-to-the-IVE student may begin to focus on developing a strategic approach to complete the overall set of problems assigned. In so doing, this student will have become a more advanced "exploring geologist" than the first-time user. In the social organization of the IVE, she or he may have self-assigned a higher prestige to her or his role than that which this student now associates with the brand-new user.

This is one way that IVEs teach more than how-to knowledge. By relying on the dynamic and reflexive nature of role performance, IVEs provide students with the virtual cultural space that allows students to construct for themselves a path that leads to a more robust understanding of the performance of their role. They gain not only a utilitarian tactical approach to a specific problem, but a strategic approach to a class of problems.

Student performance requires ever-increasing knowledge and ability to successfully practice, interpret, and advance the role associated with geologists. In this sense, role is studied as an individual dynamic (interpretivist approach).

Roles also have a component place in the virtual system (materialist approach). Specifically, knowledge and ability are gained, in part, through role engagement with enculturative conditions.

3.5 Enculturation

Enculturation primarily refers to the culture system. It classically refers to the processes by which cultural ideas and behaviours are passed from one generation to the next. It is one process by which humans adapt to their cultural environment and learn to fulfill the function of their statuses (social identities) through the learning and performing of associated role behaviour (rights, duties, and obligations). In contemporary anthropological usage, enculturation generally refers to the learning of a culture in terms of behaviour and symbolic content, including belief systems [35]. Enculturation combines both experiential and propositional knowledge. It is an adaptive intrinsically social process that uses material context and content and symbolic context and content to bridge the gap between cognizance of new ideas and practice relying on those ideas.

Enculturation is sometimes given as a synonym for the sociologist's term "socialization." The difference in these terms is beyond the scope of this article, but it is important to note that we use the term "enculturation" because we are emphasizing not just a conditioning process but an adaptation process. It is the ability of the individual to *adapt* to a new cultural system by assuming a new role that drives the IVE virtual environment. This choice is conscious on the part of the students, whether or not they recognize all the ways in which the virtual system has been organized to filter their attention directly to geology practices through enculturative conditions.

Enculturative conditions are those mutual internalities and externalities common across a group that symbolically and materially influence and filter the potential learning experiences of the individual. In the Geology Explorer, for example, enculturative conditions include, among others, the structural contents of the IVE itself, the structured and unstructured dynamic interactions among students and others, and the material and physical interaction of students with the system.

The Geology Explorer has been engineered to provide enculturative conditions that powerfully focus the students' attention on learning geology practices. Unlike life in the classroom, there is little to distract the student from geology. Within the IVE, students can either become "exploring geologists," as is intended by the developers, or they can be "tourists" who are simply looking around the IVE. Even as tourists, they are exposed to ideas directly relevant to geology. In other words, even in fairly passive interaction with the IVE, students are constrained to deal with geology.

We find that the catalyst that transforms the virtual world into a cultural learning experience is role performance within virtual enculturative conditions. Because the virtual reality is embedded within everyday reality, the student's understanding of the virtual problem is transferable to real-world problems, using the same classes of psychological and social processes that are associated with individual learning through problem exposure [36], unceremonious social coaching [29], and innovation diffusion within a cultural system [37].

3.6 Advancement of Theory

We advance two theoretical stances within the field of culture and learning theory: (1) IVE cultures are not simply prototypes or mimicry of "real world" culture. Through social interaction among learners inside the IVE, the IVE becomes a culture system just as "real" as cultures of the classroom. As such, it is available for critical study of learning structures and processes at both the individual and the system level. (2) IVE culture can be designed for learning sciences experimentation. We can develop hypotheses and engineer changes in the IVE culture to test hypotheses.

Virtual worlds are places where opportunities for learning constantly are presented. The issue for virtual world developers is to invent the spaces and dynamic vehicles for interaction in ways that are both engaging and authentic.

4. Group Learning in the Geology Explorer

4.1 Approaches

The organization of student learning can be categorized for heuristic purposes into three primary categories: individualized learning, competitive learning, and cooperative or collaborative learning. An individualized learning approach encourages students not to work in groups; each individual is responsible for his or her own success irrespective of the other students. In a competitive approach, students are placed in a situation where each individual can do well only if his or her classmates do poorly. Finally, in a cooperative environment, students are positively correlated, in that the success of one results in the success of the many [38].

4.2 Individual Approach

In the Geology Explorer, the original, individualized goal structure has students go through two separate modules, with each module having five and three subgoals, respectively. The first module gives the student a primary goal of finding and successfully identifying a particular rock or mineral. Upon positively identifying the assigned rock or mineral, the student receives 100 points. If they identify some other random outcrop on the planet, 25 points are awarded. Each student is required to score 500 points for this module, resulting in a maximum of five primary subgoals. Identification provides an important first step in enculturation. All geologists are required to be able to identify a variety of rocks and minerals throughout their careers. By providing this crucial initial scaffolding step, students are able to begin to construct the knowledge that will be used extensively in both the real and virtual cultures.

The Geology Explorer was built with an individualized approach in mind. Students travel the planet, completing a series of goals. Their success is independent of other student's success. In this scenario, students still create their own impromptu groups, providing informal other-dependent learning. The goal of the new group interface is to formalize this structure and enhance the goal hierarchy with research from the learning sciences related to group learning [38–40].

Upon completing the identification task, students are required to complete an interpretive geologic map of an area of land known as the Rolling Hills. This task is subdivided into visiting the Rolling Hills, identifying one type of each outcrop needed to successfully create the key for the map, and drawing the map to a desired specification level that is automatically scored against a "school solution" provided by practicing geologists (Fig. 1). In order to reach this specification level, students must engage the geoscience toolkit. Map building is a cultural expectation of geology practice and requires students to perform as geologists.

4.3 Collaborative Approach

In the new group-centric collaborative goal paradigm, students are placed into groups of two and advance through a series of group goals similar in form to the individualized goals. First, the group is required to score 800 points, with each member needing to contribute at least 300 points to the total. Rather than each individual needing to find different outcrops, they both search for the same primary rock or mineral. Also, they can only identify each random other outcrop once.

The interpretive task is subdivided similarly. Both students need to be present to visit the Rolling Hills, they must work together to find each of the outcrops needed for the key of the map, and each individual must draw at least a third of the map.

These constraints match the four principles for effective group learning: positive interdependence, individual accountability, equal participation, and simultaneous interaction [39]. Students need each other in order to complete the goal (positive interdependence), each can see what the other is doing (individual accountability), and each does approximately the same amount of work (equal participation). Students also are required to be online at the same time to complete the goals (simultaneous interaction).

4.4 Collaborative Approach Experiment

In the fall of 2004, an experiment was performed to determine the effectiveness of the newly created collaborative group interface for the Geology Explorer. A group of 347 introductory geology students was divided into two sections. The first played the Geology Explorer using the original individualized approach to the learning material. The second used the group-centric set of goals. Completion rates were compared between the two groups of students. The results are enumerated in Table 1.

Table 1
Geology Explorer Goal Completion Rates, Fall 2004

	Individualized	Cooperative
Identification Task	278/309 (90%)	38/38 (100%)
Visit Rolling Hills	276/309 (89.3%)	34/38 (89.4%)
Identify Outcrops	253/309 (81.8%)	30/38 (78.9%)
Create Map	204/309 (66.0%)	28/38 (73.6%)

The data indicate that students are more likely to complete the more difficult tasks (the identification task and the geologic map creation, row 1 and row 4 of Table 1) while in a group. These are not definitive results, as the treatment groups are not of equal size, and other variables might come into play. However, these are promising results that bear further study.

Future experiments are planned to compare subjective comparisons on motivations and empirical comparisons of communication and actual learning levels between the two groups.

The data indicate that students in the group activity tended to chat more than their individualized counterparts. A more detailed semantic analysis is in progress that will determine their level of understanding based on communicative competence. However, we can begin to study the interaction. Table 2 shows a comparison of the number of words typed by the individualized students versus the students in the group activity. “Text balloons” refers to the common method of inter-peer communication shown as the white balloon in Fig. 1. The group interface provides a method for group members to talk only to each other; the level of this form of communication is listed in the second row of Table 2.

Table 2
Geology Explorer Number of Words Typed, Fall 2004

	Individualized	Cooperative
Identification Task	278/309 (90%)	38/38 (100%)
Visit Rolling Hills	276/309 (89.3%)	34/38 (89.4%)
Identify Outcrops	253/309 (81.8%)	30/38 (78.9%)
Create Map	204/309 (66.0%)	28/38 (73.6%)

Finally, upon completing the experience, students were allowed to comment on how they felt about the game play. Their responses provide positive news and directions for further research.

Almost half of the cooperative students felt the game was confusing and had bad directions. Progression in the performance of a new role is tracked through evidence of increasing levels of communicative competence, among other measurements. For example, early stages in a new culture are characterized by a confusion of how to exist and interact in that culture. In terms of the IVE, this begins with initial student engagement of the system. They must adapt to combine their individual role of “a student learning a new system” with the role of “an exploring geologist” in the IVE. Future study would include a time-spread collection of data on ease-of-use.

Three students also felt it was boring. Collaborative work creates the dynamic conditions possible for reflexive critical thinking; boredom may indicate a recent phase that began with frustration from the new environment and ended with complete immersion familiarity. Familiarity allows critical space for thought about limits and the desire to develop. Future study would include a time-spread collection of data on familiarity of IVE culture pattern.

Finally, two students felt it was difficult to coordinate the group and did not like the group work at all. Collaborative work is social interaction. As such, it requires students to harness all they know about both the IVE and the classroom cultures to organize the group and motivate its work. Their ability to do so is tied to the system conditions of the virtual culture and the individual response to those conditions. Future study would include testing how to incorporate leadership training opportunities within the geology exploration context.

5. Conclusion

Changes to the Geology Explorer software provided both organizational and pedagogical benefits. The use of roles within virtual enculturative conditions combined with collaborative virtual social interaction among students appears to have the potential to enhance students’ ability to complete difficult tasks and learn both tactical and strategic approaches to problems.

We continue to seek better ways in which to enhance and employ immersive virtual environments in the schools. There clearly is evidence supporting this approach. We find that when students are engaged actively with the systems, interested in their performances, and are even having fun, they seek to learn more. If we make learning absorbing and enjoyable, achievement will follow.

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