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ABSTRACT

Rich educational environments encourage students to construct their own knowledge, to solve problems collaboratively, and to heighten their interest and motivation to continue to learn. This paper presents the findings of a qualitative study that investigated the formation of collaborative problem solving through social interaction during a large-scale space science simulation exemplifying an innovative educational design. Results from this study suggest that this nontraditional educational approach is conducive to collaborative problem solving, involves students in small and large group experiences, and actively engages students in learning. Contains 18 references. (WRM)

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Collaborative Problem Solving in a Large-Scale Space Science Simulation

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Collaborative Problem Solving in a Large-Scale Space Science Simulation

Rich educational environments encourage students to construct their own knowledge, to solve problems collaboratively, and to heighten their interest and motivation to continue to learn. The learning process is further strengthened when problems are embedded in a realistic context (Jones, Rasmussen, & Moffitt, 1997; Newmann, Marks, & Gamoran, 1995; Nicolopoulou & Cole, 1993).

The embedded nature of a problem is one of the key elements of problem-based learning. More fully defined, problem-based learning is a curriculum "that simultaneously develops both problem solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem-solvers confronted with an ill-structured problem that mirrors real-world problems" (Finkle & Torp, 1995, p. 1). The benefits to this type of learning include engagement in learning due to cognitive dissonance, relevance to real-world scenarios, opportunities for critical thinking, and metacognitive growth (Beardsley, 1992; Sizer, 1992).

Collaborative learning requires students to become involved at both an individual and interactive level. The fact that student understanding is actively constructed through individual and social processes is one of the fundamental assumptions upon which the National Science Education Standards are built (National Science Education Standards, 1996). Students must often rely on the collaborative strategies of communication and information sharing to solve complex, ill-structured problems. Cognitive development can be enhanced through collaboration and social interaction building upon personal and interpersonal strategies of communication, negotiation and compromise (Bearison, 1982;

Forman & Larreamendy-Joerns, 1995; Hare, 1992; Kafai & Harel, 1991; Rutherford & Ahlgren, 1989).

This paper presents the findings of a qualitative study that investigated the formation of collaborative problem solving through social interaction during a large-scale space science simulation exemplifying an innovative educational design.

Moonbase America

Recently an innovative high school science project took place in a suburb of Akron, Ohio. The high school enrolled 750 students, grades 9-12 with a racial composition of 87% White, 10% Black, and 2% Asian. Of these students 86% were college bound.

In order to gain entrance into the project the students were required to submit a formal application. Specific criteria needed to be met. Along with basic information forms, the students needed recommendation letters from both a teacher and a member of the community. The students had to select two areas to research from a list of 15 specialty areas. Each research topic had questions to answer requiring the students to gather and analyze information, then report their findings in either a written report or constructed model.

Any student who completed all the entrance requirements was included in the project. Grade point average was not a consideration. Ninety-six 8 –12 grade students were admitted into the project. They were evenly distributed across grades and gender with a total of 52 boys and 44 girls. Once admitted, the students became a part of the Moonbase America experience and were assigned to one of fifteen specialty area team based on preferences stated on their entrance applications. The students stayed with the same team for the duration of the school year. The specialty area teams included; Command Controllers, Government Officers, Press Officers, Research Specialist, Medical Officers, Education Specialists, Food Specialists, Commissary/Recreation Officers, Energy/Waste Management, Fish Hatchery Crew, Hydroponics Crew, Air/Water Control Specialists, Maintenance and Security Officers, Computer Specialists, and Communications/Scheduling Officers.

In the year prior to the simulation, intensive course work and preparation equipped the students with the knowledge and skills necessary to design, build, and otherwise plan for survival and scientific operations during the Moonbase America simulation. Selected topics in geosciences, communications, and advanced technology were included in the curriculum. Prior to the simulation, the students also created a governance and security system. This plan helped to insure that everyday living and scientific work could be carried out in an orderly and efficient manner. The scope of the Moonbase America curriculum included not only science and technology but also such areas as history and government, vocational business, physical education, speech and communication, library sciences, and restaurant management.

The culmination of the yearlong curriculum was a live-in simulation of a moon-based space station. For six days, 96 students from grades 8-12 lived and worked as a community cut off from the world they knew. The students had to use their knowledge and skills to survive and succeed in the restrictive environment they had helped build. The simulation became the Moonbase America's "final exam."

The Simulation

The focus of this research study was limited to the large-scale simulation where the students lived, worked, controlled, and maintained their environment without adult intervention for six continuous days and nights. The Moonbase environment was built from wood and consisted of one 50-ft. geodesic dome, connected in a spider-like manner to nine smaller offshoot pods. Inside, students spent six days and nights sleeping, eating, studying and working. Their mission was to discover what life would be like in a similar world on a lunar outpost. To make the simulation more realistic, the students' only contact with the outside world came via telephones, video cameras and computers. They relied upon themselves to form a government, confront conflicts and resolve problems (Birkos, 1992; Simonis & Staudt, 1992).

During the simulation 84 of the participants lived inside the Moonbase facility and twelve students were stationed at the ground control in the high school nearby. Within the Moonbase domes, the students' activities included a variety of scientific experiments as well as food preparation, waste management, climate control, and recreation. Much of their time was spent communicating with each other and with the outside world. Literally thousands of complex interactions occurred during the simulation.

Communication was central to the success of the assigned tasks and daily survival. The students' primary means of communication was an interconnected network of telephones established for many purposes, including fax machines, modem communications, and emergency use. Computers were initially used for information sharing and data collecting, and later served to enable extra communication between the several groups of students. The ham radio became the most stable and reliable piece of equipment used during the simulation.

Video communication was another critical component in the Moonbase America operation. Cameras were mounted throughout the domes allowing teachers and parents to monitor the students' activities at all time. Several cameras were specifically mounted to allow video communication between dome residents and the ground crew in the high school.

The large-scale simulation component of Moonbase America was an elaborate and dynamic experience. The fifteen specialty area teams attempted to carry out their assigned tasks while confronting the realities of life. During the simulation, problems (both spontaneous and induced) needed to be addressed and solved. Complex social interactions occurred between the students. No single student had enough knowledge or authority to independently solve the problems. The students had to construct collaborative methods in approaching these issues.

The project was designed with an appreciation for the fact that venturing into the frontiers of space goes beyond the capacity of any single individual. Without the collaborative efforts of many individuals, space exploration would be impossible. Moonbase America became as much a social as it was a scientific enterprise.

<u>The Study</u>

The Moonbase America coursework and simulation were completed before the research study was conducted. For this reason the investigation was retrospective in nature much like an archeological dig. Data could be gathered only from what remained of the project. Predetermined perimeters could not be imposed. Although this was a limitation to the investigation, rich information documenting the experience had been accumulated. Journals were kept by 96 students for each of the six days of the simulation. Ongoing video footage captured the students' activities during the course of the simulation. Six, one-hour satellite programs had been videotaped and transmitted each day of the simulation. Finally, at the completion of the Moonbase experience the National Invention Center of Akron, Ohio produced a videotape of students reflecting their experiences in the Moonbase America simulation.

The research study attempted to determine if there was any evidence of collaborative problem solving during the Moonbase America simulation. In this study, collaborative problem solving was defined as the process of joint decision making among students seeking resolution to a problem. During the process it was assumed that: 1) the necessary information for solving many problems was scattered among different people, 2) acceptance of decisions by the individuals involved was often as important as the quality of the decision itself, and 3) participation in the generation of solutions facilitated favorable group responses (Simonis, 1977).

The research was designed to 1) discover if there were significant critical incidents that presented evidence of collaborative problem solving in the Moonbase simulation, and 2) determine how the evidence related to collaborative problem solving with respect to individual students, pairs of students, and groups of students.

Sources of data

The 96 students who participated in the Moonbase simulation were the subjects of the study. Data were drawn from the 96 student journals, student-generated videotape, and videotaped interviews. The data were analyzed across the six days and nights of the simulation.

There were two sources of data; student logs and video tapes. The student logs served as the primary source of data. All 96 students were required to keep a daily computer log during the six-day simulation. The quantity of daily log entries produced by 96 students during 6 days of simulation experience was 576. The log entries ranged in size from several sentences to multiple pages. No structure was imposed on the students; therefore, the nature of the logs varied.

Over 100 hours of videotape was accumulated during the six days. The video was originally accumulated for three separate purposes.

1. Six, hour-long videos were constructed by the Moonbase students during the simulation and were used for satellite broadcasts. Although the students planned and scripted each of these videos, much of the actual content was extemporaneous.
2. Ninety hours of less structured video tape was collected by both remote cameras and student initiated video taping during the six days. This was the bulk of the video. Of the 90 hours, approximately ten hours related to the critical incidents under investigation.
3. At the completion of the simulation, professional video recordings were made which contained vignettes of several Moonbase students reflecting on their experiences.

Since no predetermined parameters were placed on the collected data, latitude and adaptability were required in the research design. It was important that the methodologies provide flexibility and at the same time afford the degree of structure necessary to manage the complexity. For this reason the study was qualitative in nature and employed Glaser and Strauss' (1967) grounded theory: the discovery of theory from data. Conceptual categories were generated from emergent evidence derived from the data. Content analysis and categorization (Goetz & LeCompte, 1984; Marshall & Rossman, 1989) also aided in the research process that passed through two phases of qualitative analysis. The first phase identified critical incidents, while the second analyzed the critical incidents with respect to the elements of collaborative problem solving.

Critical Incidents

To investigate the issue of critical incidents in the collaborative problem solving process, a pool of incidents were identified that met the following operational criteria; 1) at least two individuals were involved in the problem, 2) at least five hours passed before the problem was resolved, and 3) the resolution of the problem involved multiple steps.

The source of data for this phase of the analysis was the student journal entries. All 96 students kept word-processed journals for each of the six days of the simulation. Using computer-based text analysis and a qualitative method of categorization, these data were reduced into critical incident categories.

The student logs were queried with a free form text analysis tool named Metamorph. Metamorph is a computer software program designed to work with large quantities of unstructured text. Metamorph allowed the researcher to enter collaborative problem solving concept words and interact with the data output. The researcher was able to see the emergence of critical incident themes using this process. The foreshadowed view of the critical incidents was carried into the next phase of analysis. The student logs were read and coded in printed text form. The qualitative methodology of categorization was used to reduce the data into meaningful and manageable critical incident clusters.

Categorization allowed the researcher to divide "observed phenomena into units...to indicate how units are like and unlike each other" (Goetz & LeCompte, 1984, p. 43). The categorization methodology was used to identify critical problem-solving incidents which met the specified criteria of the operational definition.

Certain events repeatedly surfaced within the student logs. Cross journal agreement guided the analysis. These events were marked and coded in the student log text-based "book." Eight incidents were identified by the researcher that met the required criteria stated above. In order to manage the data that were marked and coded, the researcher used a digital form of the student logs to “cut and paste” portions of the journals that related to each critical incident. Eight separate files were created and prepared for judging. Each file was titled with the name of the critical incident and included the excerpts from each student that referred to the critical incident. Information on each student included specialty area team, a discreet student code, the date of entry, and the exact log excerpt.

From the pool of eight incidents, a team of three judges (an educational research specialist, a science education professor, and the designer of Moonbase America - a high school science teacher) selected the two most provocative problem-solving incidents. While ranking the condensed student files, the judges were directed to consider 1) the number of people involved and the level of interaction between these people, 2) the amount of information needed to solve the problem, 3) whether any technology was used, and 4) whether there was any evidence of personal and/or group growth.

The two most provocative problem-solving events were selected by taking the two highest ranking incidents across the three judges. The incidents that were selected were the *fish fungus incident* and the *moon walk incident* (description below). These incidents became the content from which evidence of collaborative problem solving was found.

During the second phase of analysis, video and journal entries served as the source of data. The qualitative methodology of content analysis was used to tag the journal entries and the notes taken from the video analysis. Content analysis "is a technique for making inferences by objectively and systematically identifying specified characteristics of messages" (Goetz & LeCompte, 1984, p. 98).

The content analysis for this investigation was accomplished by sorting the data into three groupings: 1) individual student actions, 2) interaction between pairs or dyads of students, and 3) interactions between triads or larger groups of students. In order to manage this task the computer was again employed. Using the files which had been created for each critical incident, student entries were sorted into discreet file groupings of individual, dyad, and group behavior. It was from this information that the conceptual categories of collaborative problem solving emerged. Generalized relationships among the categories were drawn suggesting a typology of collaborative problem solving. This method closely followed Glaser and Strauss' (1967) methodology of the discovery of grounded theory. "Whether or not there is a previous speculative theory, discovery gives us a theory that "fits or works" in a substantive or formal area (though testing, clarification, or reformulation is still necessary), since the theory has been derived from data, not deduced from logical assumptions." (p. 30)

Collaborative Problem Solving during Moonbase America

The qualitative analysis of student interaction during Moonbase America led to the discovery of two collaborative problem-solving incidents. Each met the requirements of a critical incident and each was judged as provocative by a team of education experts. The descriptions and analysis of the *fish fungus* and *moonwalk* incidents were gathered by piecing information together from the 96 student journals. A comparison between the two incidents is made at the end of this section.

Description of Fish Fungus Incident

The fish fungus incident occurred the first day of the simulation. In the fish hatchery dome, four 2250-liter tanks were filled with 2000 Tilapia fish. The fish were being grown as a source of food to eat during the simulation. It was the responsibility of the fish hatchery team to monitor the fish.

Prior to the simulation, the teachers intentionally filled one of the four fish tanks with pond water that would cause this tank to become contaminated. The students on the fish hatchery team noticed that one of the fish in the pond water tank was swimming vertically and became suspicious. The students removed the fish from the tank and began to run some scientific experiments. While testing the fish, one of the female fish hatchery specialists spilled a chemical on her hand and felt a burning sensation. The injured girl was taken to the medical specialty area team within the dome to be treated. The medical team flushed the burn for five minutes, but the pain was not relieved. Jointly, the students on the medical team decided to call outside paramedics to take the girl with the burn to the hospital.

Complete, partial, and misinterpreted information concerning the fish incident spread quickly through the domes. For this reason, the government team called a community meeting to communicate what had actually occurred with the fish and the specialist who had burned her hand.

During the government meeting the paramedics arrived at the simulation site to take the burned girl to the hospital. When the paramedics entered the domes, however, they set off a security alarm. The students inside the domes could not tell from the sound of the alarm if there was a fire or a security problem. The government team instructed the students to evacuate the domes. The evacuation was accomplished quickly and orderly.

Analysis of Fish Fungus Incident

Of the ninety-six students who participated in the Moonbase simulation 41 referred to the fish fungus incident. Fourteen of the 15 specialty area teams were represented. From the 41 student entries, six individual student actions were identified, nine interactions between pairs or dyads of students were found, and 31 incidents of interactions between triads or larger groups of students existed. A cross tabulation of the 41 student log entries was charted by gender and grade level. Of the 41 students represented, there were 22 males and 19 females. Although each grade level had varying proportions of responders, the total distribution of boys (42%) and girls (43%) was approximately the same.

Description of Moon Walk Incident

The moonwalk incident occurred over a period of four days. Prior to the simulation, two students from the research team were selected to be moonwalkers; one was an 11th grade girl (the leader) and one was an 8th grade boy. Their assignment was to spend approximately one hour nightly conducting research experiments outside the domes. In order to walk on the "moon" surface, the moonwalkers were required to wear space suits. These space suits had been designed and created for the two students by Cornell University. During the moonwalks, the students moved around the lunar surface (the school grounds) using a land rover (a foil covered jeep). Ham radio and video transmissions were the communication devices used during the moonwalks.

Local and national television and press reporters were on hand to capture the nightly moonwalk activities. The media attention was a scheduled event that brought a "star" quality to the moonwalker job.

On the first night of the simulation, after a rain delay, the 11th grade girl and the 8th grade boy went on their planned moonwalk. The communication between these two students was weak and many tasks were not accomplished. The 8th grade boy did not sleep at all after the first night's walk. By the next day he was highly stressed and appeared to be dysfunctional. Because of the boy's condition, the research team decided to select another moonwalker for the second walk. This job was offered to another 8th grade boy who declined. The job was presented to and accepted by an 11th grade girl on the research team. The new moonwalker happened to be the best friend of the lead moonwalker, the first-mentioned 11th grade girl.

The next two nights the girls went out on moonwalks. The original 8th grade boy stayed inside the domes. His job was to man the communication station and direct the moonwalkers via ham radio and remote video. The communication between the two female moonwalkers and the 8th grade boy was weak. The girls would call for guidance and often there was no reply. Negative attitudes and emotional intensity increased as attempts to communicate continued. The two girls began to rely more on each other and less on the direction from inside the domes.

The girls were able to communicate with each other. There was a high level of trust between them that enabled joint problem solving during the moonwalks. They performed their tasks well and felt successful in their research attempt.

Analysis of Moon Walk Incident

The moon walk incident was referred to by 26 of the students. Eight of the 15 specialty area teams were represented. Multiple journal entries occurred most often within the research specialty area team, which was the moonwalkers' team. From the 26 student entries, 14 individual student actions were identified, 10 interactions between pairs or dyads of students were found, and 21 incidents of interactions between triads or larger groups of students were found. A cross tabulation of the 26 students was charted by gender and grade level. Of the 26 students responding to the problem, there were 16 males and 10 females. Each grade level had varying proportions of male and female representation. The distribution of respondents had a slightly higher representation of boys (31%) than girls (28%).

Comparison of the Fish Fungus and Moon Walk Incident

By comparing the domains and categories of the *fish fungus* incident with the *moonwalk* incident an interesting phenomena surfaced. The *fish fungus* incident occurred rapidly and affected the entire simulated community. It presented a threat to all the residents and the students' behaviors were focused on team concerns. Individual domains were of less importance.

The *moonwalk* incident, on the other hand, occurred over many days and affected only selected students. Team behavior was important, but individual concerns surfaced.

The success of the *moonwalk* did not threaten the outcome of the simulation. Instead, personal worth was attached to this event and individual domains became important.

Although the nature of each critical incident was different, there were problem solving categories shared by both. The shared categories were: 1) joint decision making--the process of agreeing upon a plan of action, 2) collaborative team work--implementing the plan of action agreed upon, 3) cooperation across teams, 4) confidence in group performance, and 5) utilization of team member expertise. These five categories characterize collaborative problem solving. Thus, the results of this study suggest strongly that these categories have potential to become the basis of a typology of collaborative problem-solving behavior.

Conclusion

Moonbase America is an example of a large-scale simulation designed with the purpose of immersing students into real-life science encounters requiring hands-on activities, higher-order thinking, and collaborative problem solving. Specialty area teams were assigned, tasks were designated, outcome parameters were established, and the six-day simulation began. This research study was conducted to determine if there was evidence of collaborative problem solving in the Moonbase simulation.

The results from this study suggest that this non-traditional educational approach is conducive to collaborative problem solving, involves students in small and large group experiences, and actively engages students in learning.

One of the purposes of creating simulated environments is to promote "true-to-life" experiences while reducing real-life risks. In large-scale simulations problems arise in unexpected ways and creative solutions often need to be constructed. The knowledge gained from these experiences can transfer to real-life situations. To prepare students for 21st century careers, educators are designing learning strategies to support the development of flexible, creative people with analytic and creative problem solving skills. Large-scale simulations appear to be a vehicle to achieve these goals.

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