Collaborative Problem Solving Processes in a Scenario-Based Multi-User Environment

Shannon Kennedy-Clark, Kate Thompson, Centre for Computer Supported Learning and Cognition, University of Sydney, Sydney, Australia,
Email: shannon.kennedy-clark@sydney.edu.au, kate.thompson@sydney.edu.au
Debbie Richards, Computing Department, Macquarie University, Sydney, Australia,
deborah.richards@mq.edu.au

Abstract: This paper presents the results of a study aimed at gaining an understanding of the process that groups use to solve scientific inquiry problems in a scenario-based multi-user virtual environment. In this study, 12 university students worked in pairs to complete either a structured or unstructured problem in a virtual environment. The pairs were recorded using screen-capture software. The data was coded using a modified decision function coding scheme. The results of the study indicate that participants in the unstructured activity were less likely to arrive at an outcome. Moreover, participants spent more time implementing navigation goals than implementing inquiry-based goals. Overall, the results indicate that scaffolding that supports orientation processes should be incorporated into collaborative problem solving activities in a virtual environment.

Introduction

This paper presents the findings of a study on collaborative problem solving in a scenario-based Multi-User Virtual Environment (MUVE). Scenario-based MUVEs such as *Quest Atlantis* and *River City* have been shown to both motivate and engage students (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Dede, Clarke, Ketelhut, Nelson, & Bowman, 2005) yet little is known about how students collaboratively solve problems within these environments. While these environments present learners with collaborative elements of group work, such as shared goals, distribution of tasks, different roles and planning, these roles are not intuitive and students often need to have direction in managing group performance.

Virtual Singapura was the scenario-based MUVE used in this study. A MUVE, such as *Virtual Singapura*, can afford students the opportunity to visualize and engage with an inquiry-based problem in a setting that is motivating and engaging. As with most computer games, a scenario-based MUVE is underpinned by a narrative that forms the basis of the learning. *Virtual Singapura* is set in 19th century Singapore and is based on historical information about several disease epidemics during that period. In this study, the students worked in teams in order to solve the problem of what is causing the illnesses and to develop appropriate inquiry skills such as defining the scope of the problem; identification of research variables; establishing and testing hypotheses and presentation of findings.

Language and social interactions are considered to be the building blocks of social order and conversation analysis is the study of the structure and formal properties of language in consideration of its social use (Coulon, 1995). The study focused on how users collaboratively attempted to solve an inquiry-based science problem in a virtual environment. The purpose of the trial was to gain an understanding of how users collaborated to solve a structured problem compared to those given an unstructured problem. The study used a modified version of the Decision Function Coding Scheme (DFCS) (Poole & Holmes, 1995) to code the conversations of dyads in both groups. The DFCS was used to provide detailed information about the processes that participants undertook to navigate around the virtual world in order to complete the given activities. The study was aimed at identifying what the participants focused on during the task and to identify barriers to the completion of the activities.

Analysis of Collaborative Decision Making Processes

The paper analysed the verbal conversation data collected with pertinent interaction data as part of a suite of simultaneous audio, visual and screen recordings. In this study, participants interacted with a complex environment where there were multiple routes to reach the solution. Through this initial analysis of the conversation between members of the dyads, we begin to gain insights into how these decision-making processes could influence a dyad's learning outcomes.

Participants

12 participants (8 undergraduate and 4 post graduate students) were recruited for the study. Five of the participants were male and seven were female. The undergraduate students were completing a compulsory unit on the use of computers in education. The postgraduate students were all completing higher research degrees in education. None of the participants had a background in science or had used *Virtual Singapura* previously.

Materials

The trial used *Virtual Singapura* as the problem solving platform. There were two versions of the problem solving activity that were based on reducing cholera. One version was a structured or guided activity (Groups 1, 3 and 5) that led participants through the virtual world and directed participants to data collection locations within the virtual environment. Participants in the guided condition were provided with a hypothesis upon which to base their data collection in order to reduce the incidence of cholera. The second version was an unstructured problem solving activity (Groups 2, 4, and 6). Participants in this condition were not provided with a hypothesis and were not provided with instruction on where to collect data. Both sets of activities required that participants made a recommendation on the basis of their data collection and analysis. Both the structured and unstructured conditions were provided with a set of introductory materials on how to collect information and use the tools within the virtual world. No additional verbal or audio material (e.g. an introductory DVD) was provided to the participants. The materials had been revised as a result of several previous trials in order to improve the clarity of the instructions and the activities.

Data Collection

The study was conducted between August and September 2010. The participants in the study were expected to complete an in-world problem solving activity during a one hour session. The participants were randomly assigned to a partner and were then given either a structured or unstructured activity. The participants were recorded using *Camstasia* screen capture software. *Camtasia* recorded the participants' in world actions (e.g. moving the mouse, changing screens, clicking on objects), a head-shot video of the pair and their audio communication.

Data Analysis

A broad analysis of this data can express whether students are evaluating or defining a problem, agreeing or disagreeing or orienting the group's process and the data can be coded to see how students collaborate when trying to solve or engage with the problem domain. The value of this, as Sawyer (2006) indicates, is that to date, very few studies have examined how collective group dynamics can impact upon a learning experience. Moreover, this rich and observable source of data represented by sounds, words and expressions can show turn-taking and subtleties of how communication and shared understanding while focusing on the activity is achieved in far greater depth than a post-intervention questionnaire or post-test (Mazur, 2004).

Video, audio and screen capture technology were used to record the students while they interacted with the virtual environments in their teams and individually. The video and screen shots were analyzed to provide detail to the verbal items. Firstly, verbal utterances and participant turn-taking were analyzed to see how students engaged with each other during the activity and to see if there were discernable differences between the structured and unstructured condition. Secondly, the screen capture software captured pertinent information about what aspect of the environment the learners were focusing on (Mazur & Lio, 2004).

Table 1: Modified coding scheme for collaborative decision making.

Code	Category	Definition
1	Problem definition	Statements that define or state the causes behind a problem Statements that evaluate problem analysis
2	Orientation	Statements that attempt to orient or guide the group's processes Statements that evaluate or reflect upon the group's progress or processes
	Solution development	
3a	Solution analysis	Statements that concern criteria for the decision making process A direct reference to the solution must be given
3b	Solution suggestions	Suggestion of alternatives
3c	Solution elaboration	Statements that provide detail or elaborate on a previously stated alternative
3d	Solution evaluation	Statements that evaluate alternatives and give reasons, explicit or implicit for the evaluations and therefore include a valuation
3e	Solution Confirmation	Statements that ask for final group confirmation of the decision Statements that concern decisions linked to immediate results
4	Non task	Statements that do not have anything to do with the decision task
5	Agreement	Agreement – response to a question or statement e.g. yeah or yes
6	Disagreement	Disagreement – response to a question or statement e.g. nah or no
7	Implementation	Undertaking agreed upon action

The six recordings were transcribed. Each turn was considered as a unit to be coded. The transcriptions were coded according to the coding scheme provided in Table 1. A modified version of the DFCS from Poole and Holmes (1995) was adopted for the analysis of the collaborative problem solving. We selected the DFCS as it allowed for problem definition, orientation and solution development. However, we modified the coding system to include a category for implementation of a decision. Given that in this type of collaborative learning environment, the decisions were made and implemented straight away, in contrast to other environments to which the coding scheme has been applied (Reimann, Frerejean, & Thompson, 2009) in which the decisions were made in order to coordinate longer-term team work, this was felt to be an important addition to the type of patterns that were being observed. This addition reflects initial attempts to coordinate both conversational data and data from the video screen shots that were recorded. The resulting coding system has seven main categories and five subcategories. When coding the data according to the DFCS system, 7 represented implementation of a goal, in this case the implementation of a goal was often not a verbal utterance, but was reflected in an on screen action, such as teleporting or collecting data. In most of the other cases, the codes related to verbal utterances. Overall success in the problem was, in this instance, seen as arriving at a conclusion as to whether or not building new wells would stop people from getting cholera. It was expected that participants engage in several decisions in order to come to this conclusion. The data was coded separately by two members of the research team, the pair then discussed the coding, reaching final agreement rates ranging from k = 82 – 94%, which is a satisfactory level of agreement (Banerjee, Capozzoli, McSweeney, & Sinha, 1999).

Results

The results are not presented in full in this paper; instead an overview of the results relating to the research question will be presented. The six recordings were transcribed and were combined with the corresponding video and screen shot data to provide a detailed account of what the groups were saying and doing while they were using the virtual world. It should be noted here that not all of the groups were successful in arriving at an outcome. The structured Groups 1 and 5 ran out of time, but were engaged in the activity in that they remained on task. Groups 3 (structured) and 6 (unstructured) completed the activity and arrived at a conclusion. However, Groups 2 and 4, which were unstructured groups, had difficulties navigating in the world. Table 2 provides an example of the coded raw data for Groups 1 and 2. The data were taken from around 9 minutes into the activity as participants had all moved beyond the initial interaction with the virtual world.

Table 2: Raw data from transcribed conversations.

DFCS	Time	Item	Speaker	Verbal	Action on screen and video
Group 1 (Structured)					
1		69	w	can I do this thing or that thing	
3b		70	b	I think we use this thing, there is e-coli in the water	Clicking on well in China Town
3e	9.00	71	w	I'm sure it works	W pulls face and sighs
2		72	w	hrrrrrrr	
2		73	b	maybe not	Samples not changing, w pulls face
2		74	w	this is ahhhhhhh	
2		75	b	c'mon	
Group 2 (Unstructured)					
1		24	c	how do we get out	whispered
5		25	j	oh yeah	both laughing
2	9.0	26	c	here we go	move to experimental condition
7		27	c	there we go	foyer teleport to new wells

After the data were coded, percentages of each code were calculated in order to see if there were similarities between the groups. It was evident from this analysis that the majority of the items were to orient or reflect upon a group's process. The results indicated that in groups that were structured there was a higher incidence of orienting the group's processes. For example in Group 1, 67% (n= 67) of the items were coded as orientation processes (code 2) while in Group 2, only 37% (n=20) of the coded items were orientation processes.

As in other studies (for example Beatty and Nunan (2004)), participants' perceptions of the technology were important. Evidently many of the groups had difficulties locating places, people and data collection tools while in the world. This led to varying levels of frustration (see Table 2) and confusion. For example, Group 5 spent nearly five minutes trying to find the hospital and locate the doctor to interview, and when asked in a follow-up survey several weeks later about what they remembered of their in-world activity, one member of a dyad indicated that not finding the doctor was the most memorable part of the experience. Moreover, most of the participants focused on making decisions that related to navigating through the world, such as moving from one location to another rather than actually engaging with the inquiry problem. For example, Group 4 did not engage with the problem at all, they did implement decisions, but they were navigational rather than inquiry-based. This reflects issues raised in earlier work that participants had difficulties in engaging with the problem due to the complexity of the environment and raises a series of design issues on how best to structure for learning in a scenario-based MUVE (Kennedy-Clark, 2010). Overall, while there was convergence on a desired goal state, there was little convergence on a shared understanding of the problem (Roschelle, 1992).

Table 3: Comparison of goal implementation between groups 2 and 6.

Group 2	Group 6
2 38 g you click on (laughing)*	1 144 n now we need another sample (looks at notes)
2 39 c ok, so that's the	2 145 s uhummmmm
2 40 g yeah, the [phraser] thing	5 146 n okay
7 41 c (right click on patient)	5 147 s okay
	7 148 n four and two, okay, that's two, I think that's all (counts objects in wells)
	5 149 s yeah, okay

* Actions shown in brackets

Table 4: Example of disagreement followed by orientation.

Group 3				
12	1	32	b	hospital admissions
	2	33	g	changing seasons
	2	34	b	is that the hospital (moves mouse)*
	6	35	g	nah
13	6	36	b	no
	6	37	g	no
	2	38	b	At the map
	5	39	g	yeah (moves mouse to map)

In terms of implementing a desired goal (code 7) the unstructured Groups 2 (n = 18, 33%) and 6 (n = 61, 26%) implemented more decisions. However, examination of the groups revealed that different strategies were used. Group 2 consisted of two undergraduate students that had the least number of coded items (n=54) and they failed to arrive at a conclusion in the time given; however, Group 6 consisted of two postgraduate research students that had the highest number of coded items (n=219). This indicates that the implementation of decisions does not necessarily result in effective collaboration as Group 2 spent their in-world time focusing on navigation with large amounts of time between items and actions (Table 3), while Group 6 moved quickly through the world and established a pattern of deciding upon a goal state and implementing the goal.

The results also indicated that as Baker et al. (2001) found, participants did not express high levels of disagreement. Disagreement levels ranged between 0 – 2%, only Group 3 had a higher level of disagreement at 6% (n=6). However, when reviewing their patterns of disagreement, each disagreement was followed by an orientation process and led to further investigation (see Table 4). While disagreement may not be a pivotal factor in achieving a goal, confidence in expressing an opinion and in being part of a collaborative experience are factors that contribute to a successful collaborative learning experience.

Discussion

This study used a DFCS to analyze when, and if, participants converge on agreement of a course of action and when, and if, they implement their goal. The results of the study did show that all groups converged on goals and implemented desired activities, but that most of the goals focused on navigation rather than inquiry-based activities. This study was the third in a series of studies that examined the nature of the information and instruction required for participants to effectively interact with the given problem rather than focus on navigation around the space. Kleinermann, De Troyer, Creelle and Pellens (2007) noted the importance of navigation to enhance the usability of virtual environments (VEs), particularly in the context of the Web or for VEs reaching a large audience. To provide scaffolded navigation, Kleinermann et al. (2007) provided a tour guide and stored navigation paths that could be reused. However, we observed that not only were our participants "lost in cyberspace", they also lacked a fundamental understanding of the domain and the nature of the problem. Our previous work which builds on human role playing games (Richards, 2006) found that "actors" must be appropriately primed to understand the context and immersed in the problem situation prior to entry into the game world. For example, in a training simulation in the border security domain using the first person shooter *Unreal Tournament* game engine, participants in our usability studies would often ask where their gun was so that they could shoot the passenger. To overcome this misunderstanding which interfered with successful engagement and learning in the training task we spent the first 15 minutes setting the scene and discussing with the participant what behaviors are normally exhibited by an immigrations officer and what the role typically involved. Similarly, in *Virtual Singapura*, students also need sufficient background of the scenario in order to be able to focus on the problem. To address this issue, in the next iteration of this study, scenes from a movie and several texts on cholera will be included in order for students to anchor their data collection to a tangible problem.

This study has also shown that groups that orient their processes and explore alternatives before implementing a goal tend to be more successful at collaboratively solving problems than groups that do not use similar strategies. This indicates that when using a MUVE, students should receive explicit scaffolding in how to make decisions as they engage in an activity and this instruction should be complementary to the instruction on how to navigate through the world. Furthermore, this scaffolding should include steps in decision making that involve disagreement.

Conclusions

Scenario-based MUVEs may provide learners with a highly visual environment complete with interactive and authentic objects, but learners are not able to collaborate effectively to solve problems unless they have the prior instruction in how to use decision making strategies. Further to this, the results of this study suggest that students need to have prior knowledge of the scenario in order to be able to anchor their collaboration. This study has shown that while the participants did collaborate to achieve goals, the majority of the goals were focused on navigation rather than inquiry-based problem solving, which may indicate why learning outcomes in scenario-based MUVES are not as high as expected. Of course these findings are limited as this study involved a small sample size and a one-off interaction with the environment. The next iteration of this research study will involve priming the participants before the virtual activities and may provide a more detailed picture of collaborative problem solving in a scenario-based MUVE. Overall, collaborative skills and an understanding of the environment may equip students with sufficient background knowledge to enable deeper learning within the virtual environment.

References

Banerjee, M. B., Capozzoli, M., McSweeney, L., & Sinha, D. (1999). Beyond Kappa: A Review of Interrater Agreement Measures. *The Canadian Journal of Statistics, 27*(1), 3-23.

Barab, S. A., Thomas, M., Dodge, T., Carteaux, R., & Tuzun, H. (2005). Making Learning Fun: Quest Atlantis, A Game Without Guns. *Educational Technology, Research and Development, 53*(1), 86 -107.

Coulon, A. (1995). *Ethnomethodology* (J. C. a. J. Katz, Trans.). Thousand Oaks: Sage Publications.

Dede, C., Clarke, J., Ketelhut, D. J., Nelson, B., & Bowman, C. (2005). *Fostering Motivation, Learning and Transfer in Multi-User Virtual Environments*. Paper presented at the American Educational Research Association. from http://muve.gse.harvard.edu/rivercityproject/research-publications.htm#2005.

Kennedy-Clark, S. (2010). *Pre-service Teachers' Perspectives on using Scenario-Based MUVEs in Science Education.* Paper presented at the Curriculum, Technology & Transformations for an Unknown Future. Ascilite 2010, Sydney, 497-507.

Kleinermann, F., De Troyer, O., Creelle, C., & Pellens, B. (2007). *Adding Semantic Annotations, Navigation Paths and Tour Guides for Existing Virtual Environments.* Paper presented at the 13th International Conference on Virtual Systems & Multimedia, Brisbane, 50-62.

Mazur, J. (2004). Conversation Analysis for Educational Technologists: Theoretical and Methodological issues for Researching the Structures, Processes and Meaning of On-line Talk. In D. Jonassen (Ed.), *Handbook of Research for Educational Communications and Technology*. New York: MacMillian.

Mazur, J., & Lio, C. (2004). *Learner Articulation in an Immersive Visualization Environment.* Paper presented at the Conference on Human Factors in Computing Systems, Vienna, Austria.

Poole, M. S., & Holmes, M. E. (1995). Decision Development in Computer/Assisted Group Decision Making. *Human Communication Research, 22*(1), 90-127.

Reimann, P., Frerejean, J., & Thompson, K. (2009). *Using Process Mining to Identify Models of Group Decision Making in Chat Data.* Paper presented at the Computer Supported Collaborative Learning Practices, CSCL 2009, Rhodes, Greece.

Richards, D. (2006). *Is Interactivity Actually Important?* Paper presented at the 3rd Australasian Conference on Interactive Entertainment (IE'2006) Murdoch University, Perth, 59-66.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *The Journal of the Learning Sciences, 2*(3), 235-276.

Sawyer, K. (2006). Analyzing Collaborative Discourse. In K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 187-204). Cambridge: Cambridge University Press.

Acknowledgments

The authors would like to acknowledge Singapore Learning Sciences Laboratory and Nanyang Technological University for their ongoing support in the use of *Virtual Singapura*.