Toys to Teach – Mathematics as a Collaborative Climbing Exercise

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Abstract

Whereas traditional research on collaborative educational systems has primarily focused on how to define better modes of digital interaction, this approach is found lacking when applied to developing collaborative systems for elementary school aged children. It is creatively and collaboratively restrictive to filter the enthusiastic interactions of these excited 12-year-old children through progressively more complicated GUIs. Current E-GEMS research examines design factors of educational systems that recognize and facilitate the social context of the classroom and hopes to encourage, rather than restrict, peer-to-peer social discussion and interaction. By correlating observed interactions in the digital domain with those in the social domain, we hope to shed light on design factors of collaborative systems that can be an integral and exciting part of a child's mathematical education. The vessel of our current research is the two-player collaborative mathematical exercise PrimeClimb, developed at E-GEMS. This paper describes the study conducted with PrimeClimb and documents the methodology of data capture and analysis used in the study – methods borrowed from ethnography, education research and sociology.

Keywords: *educational technology, collaborative learning, peer to peer discussion, computer support for collaborative learning*

1 Introduction

Since 1992, the E-GEMS lab at the University of British Columbia has been a playground for an interdisciplinary force of researchers in Education and Computer Science, professional game developers, school teachers and thousands of children. E-GEMS research focuses on using educational games as toys to teach children mathematical concepts [Klawe 1999]. Our results have demonstrated that games can be very effective in increasing both motivation and achievement in mathematical learning for girls and boys, playing apart and especially together [Inkpen 1995; McGrenere 1996].

The foundation of E-GEMS research includes commercially available games as well as professional games developed in the lab. Our games are iteratively designed to explore vital factors that promote player communication, accountability and thought about the underlying mathematical principles through the motivation of single and multi-player adventures. Our stories are weaved non-gender specifically and instead encourage the players to find their own identities through tackling the challenges in the games. Screenshots of past E-GEMS games are at the end.

PrimeClimb (Figure 1), in which a pair of children attempt to climb to the top of a mountain of numbers together, is the newest addition to the E-GEMS playground. In order to reach the top of each mountain, students must collaboratively avoid falling – a feat only accomplished by recognizing shared common factors between the numbers on which they stand. There is a tool – the magnifying glass – that can be used to shed light on the factors of any number. Magnifying glasses are hint-giving resources that are limited and shared amongst the two players. Our observation sessions were used to provide feedback in developing the current design factors of the magnifying glass.

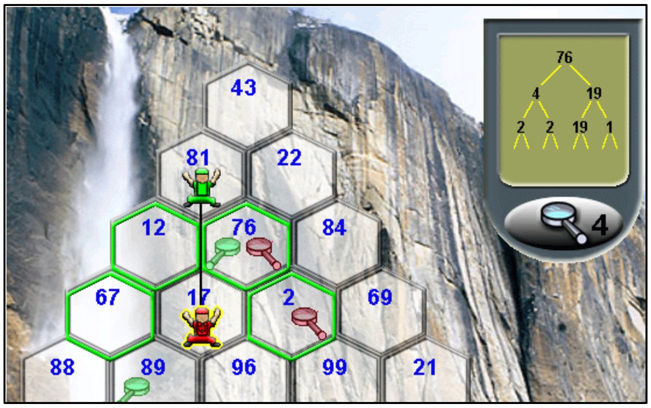

Figure 1 – PrimeClimb Screenshot

2 Research Setup

With PrimeClimb, we are primarily interested in analyzing design factors of hint-giving tools that promote collaboration in educational systems. Toward this end we have conducted a study in a local elementary school with two versions of the game to analyze the pedagogical effects of limiting a valuable shared resource - the number of magnifying glasses given to the players per level. The two versions used are in shown in Table 1.

	Tool Allocation	Sample Size
Version A	Limited	22 children
Version B	Relatively unrestricted	22 children

Table 1 - Sample Allocation

Version A allowed 6 possible uses of the magnifying glass per level – a number found to be rather restrictive in our prototype sessions. Version B had increasing allowances of the magnifying glass as the mountains became larger – the number given is approximately one magnifying glass per every 4 numbers on the mountain – quite an abundant supply. Both versions of the game were played for 20 minutes by 11 pairs of grade 7 children (7 pairs of boys, 4 pairs of girls). In total 44 children were observed over the period of an entire week.

3 Methodology

The sessions of the study proceeded as follows: the pairs of children were first given a pre-questionnaire to access their mathematic factorization skills and general attitudes toward collaboration in math and computer games. They then played PrimeClimb together for 20 minutes and the session ended with a post-questionnaire that reassessed their math skills and attitudes. Each play session was computer-logged and video-recorded. In order to correlate the digital events in the computer log with social discussion and interactions, an absolute clock was displayed on the game screen at all times. Each video captured a player's upper body along with their game screen; thus two tapes were produced from each session (Figure 2, the image has been blurred to preserve the subject's identity).

Captured audio transcripts have been successfully used to correlate social discussion and digital events in ethnography [Suchman 2000] and math education research [Pirie 1996]. We hope to use our captured video data to match social interactions with the PrimeClimb game events. By plotting both sets of events on the same absolute timeline (which is made easier through the displayed game clock on the bottom left corner of Figure 2), patterns between the digital and social worlds can be analyzed. The mixed video data captures the sessions more completely than audio transcripts and will allow us to supplement the social discussion with non-verbal physical interactions, such as the exchange of glances or gesture encouragement.

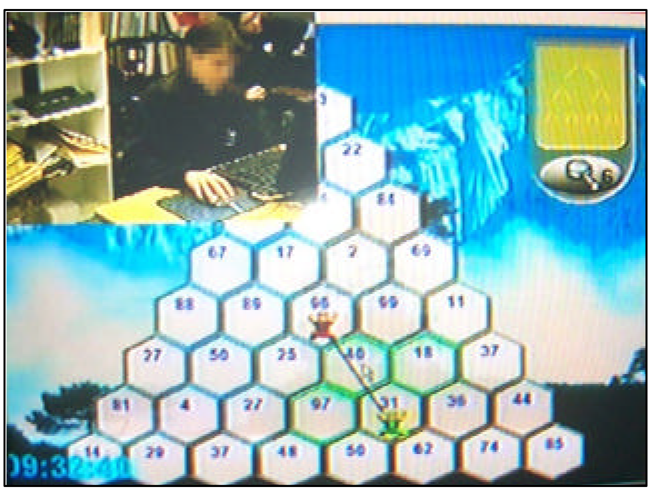

Figure 2 – Mixed Video Capture

4 Discussion

The data from the study sessions have been completely captured – including more than 20 hours of mixed video tape and all the pre and post questionnaires. The detailed analysis of the data is underway. Through our field observations we have already seen encouraging trends, three of which are elaborated upon below.

Firstly, we have seen that in the version of the game that has the more restrictive number of tool usages, the hint-giving tool played a much larger role in discussions about climbing strategy. For example, in this version of the game the players reminded each other of the presence of the tool and the number of tool uses remaining much more frequently than the version of the game with the much less restrictive tool allocation.

Secondly, different categories of social interactions of children playing PrimeClimb are becoming clearer. As in past research from mathematics education, the categorization of peer-to-peer discussion in a mathematical context should take place first and foremost before the analysis of the pedagogical values of those categories can be carried out [Pirie 1998]. A few possible patterns of interactions in the context of PrimeClimb have emerged that include: a player explaining to the other player why a move is not allowed using mathematical language, a player explaining the reason for a failed move using mathematical knowledge and a player strategizing and logically planning a series of moves and explaining this strategy to their partner. An example of the latter is when a player states that she is on a prime number and encourages her partner to move as high as possible. Just as the categorization of peer-to-peer discussion in the classroom context has been subject to detailed analysis in mathematical education [Pirie 1998], we hope to apply this categorization and subsequent analysis of peer-to-peer discussion about math in the context of this computer supported collaborative environment.

Finally, we have noted that all the children had very little difficulty grasping the interface to the game – a result of multiple prototype sessions that have shaped the game interface. This means PrimeClimb could serve as a stable foundation upon which other research questions about collaboration can be launched. We noticed that girls and boys tended in general to employ different strategies in progressing through the game. Whereas some girls leaned more towards careful team-based planning and some boys were much more competitively collaborative and trigger-happy, the game accommodated all ranges of playing styles. It has been argued that designing games especially for girls is not a viable route because of the risk of marginalizing them – instead games should be non-gender specifically designed to allow children to find their own identity in the context of the challenge [Cassell 2002]. PrimeClimb seems to have succeeded in this respect.

5 Conclusion

The data collection part of the PrimeClimb study has been completed and the data analysis has begun with promising signs. Our ultimate vision is to build collaborative educational systems that fit seamlessly into and facilitate the social context of the classroom – this study has so far shown that ethnography and math education research have methodologies that can provide valuable insights.

6 Acknowledgements

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Figure 3 – Super Tangrams Screenshot [Sedighian 1997]

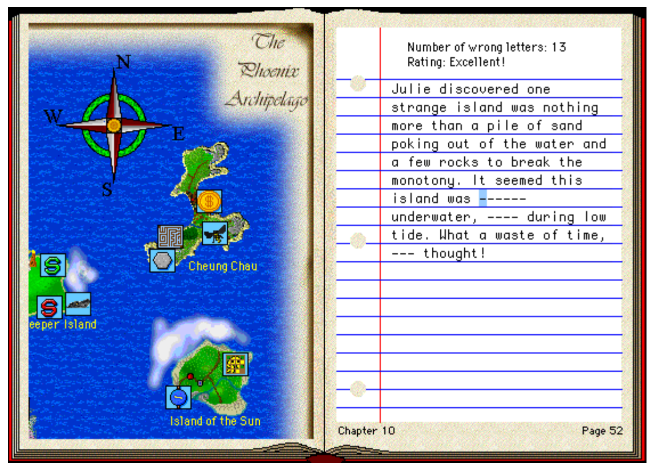

Figure 4 – Phoenix Quest Screenshot 1 [Klawe 1996]

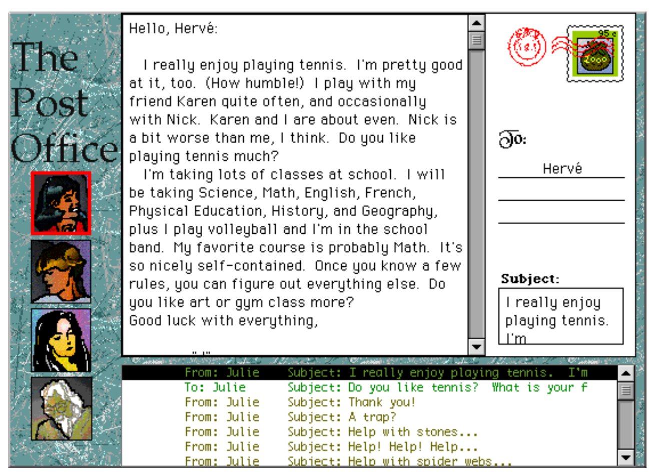

Figure 5 – Phoenix Quest Screenshot 2 [Klawe 1996]