Examining Emergent Dominance Patterns in Multiple Input Based Educational Systems

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Past work with multiple input devices in low resource educational environments has largely been motivated by patterns of dominance that emerge when a large group of students is asked to share a single computer — inevitably, some students, at the cost of others, derive higher value out of the experience. Conversely, concern has been expressed about the lack of social learning and collaboration that results when students are given computers for individual usage. One means of addressing both concerns is to design multiple-input-based educational experiences to encourage collaboration among students. To explore this approach, we compared several different educational game setups in a controlled study with 192 primary school students in Bangalore, India. In the course of this study, we found that as collaboration was encouraged or enforced, patterns of dominance began to re-emerge, even though students each had direct interactivity with the computer. In this paper, we examine and discuss these patterns as they relate to intervention design and environment.

Shared computing, multiple input, single display groupware, developing regions, education, dominance, collaboration.

1. INTRODUCTION

Where computers are present in low resource classrooms in the developing world, there are often insufficient resources to individually support students. As a result, students often interact with a computer in groups of up to nine or ten. This situation can lead to significant and troubling patterns of dominance among the students, wherein the large majority of students in the group never interact with the computer or the educational software (Pawar 2006). To address this issue, several interfaces have been developed to support multiple input devices, one device for each student (Pawar 2006; Moraveji 2008).

Multiple input research stems from both single display groupware (Hourcade 2002; Stewart 1999) and shared computer use among children (Inkpen 1999). Recent work with multiple mice on a single computer has found that engagement and learning in certain conditions increased when each student was given an individual mouse to interact with digital learning material (Pawar 2006). Previous multiple mouse interfaces have largely focused on competition-based multiple choice designs, though some attempts have been made to incorporate text entry into the design to allow for more open-ended responses (Moraveji 2008; Amershi 2010).

Building on this research, we developed MultiLearn (figure 1), a multiple-input educational game for math, spelling, and other subjects (Garg 2009). As an alternative to the mouse, MultiLearn provides 10-key USB numeric keypads. Due to their near-universal compatibility, low cost, convenient size, and abundance of keys, these keypads provide an effective means of exploring input beyond the mouse, particularly for numeric and text input. MultiLearn supports multiple students at once by dividing the screen into individual sections. It also incorporates several educational design concepts: individual student performance is tracked over time, the difficulty of questions asked of each student is adjusted accordingly (made possible by the split screen), and teachers are provided with tools to create content and examine how each of their students is improving.

MultiLearn was initially a competitive educational game. Motivated by the significance of collaboration in computer-based learning for children (Bricker 2002; Moraveji 2008), we introduced several collaborative modes to reduce dominance patterns that could affect

***Figure 1:** MultiLearn setup: four keypads and split screen.*

student engagement and performance. In the past, some existing single-display groupware systems would encourage rather than enforce collaboration, by providing tools that combine to become more powerful when used by multiple students (e.g., Benford 2000), while other systems simply present students with a single, shared problem to solve (e.g., Scott 2003). To understand how effective these different modes of collaboration would be in a split screen context, we conducted a controlled evaluation with primary school classrooms in Bangalore, India. We found that as the collaborative modes were introduced, patterns of dominance began to re-emerge — the same patterns that multiple input devices were meant to solve.

STUDY DESIGN

Interface Conditions

Based on our initial goal of exploring collaboration and multiple input devices, we designed five versions of a math-based educational game for the MultiLearn platform. In all versions of the game, the system presented students with a series of single arithmetic questions (addition, subtraction, or multiplication), which students answered by entering a numeric value on a keypad. For the competitive game, each round ended once any student correctly answered 12 questions. Game rounds in the collaborative conditions ended once either team correctly answered 24 questions in total. Unless otherwise stated, each student had his/her own keypad to use. Question difficulty was also adapted to each student based on his/her individual performance. This skill rating of students was not preserved between conditions.

The experimental conditions supported four students at once, and differed as follows:

No collaboration (M4) — As a baseline as well as to introduce students to the concept of the game, we ran this purely competitive and individual mode.

Implicit collaboration (MI) — Students worked in two teams of two. Team members' individual scores summed to form the score for the team. The team nature of the game was stressed to the students, but they were not explicitly told to collaborate. Since a student could help if their teammate was stuck on a problem, but were not forced by design to do so, we considered this condition to offer implicit collaboration.

Explicit collaboration (ME) —Students were in teams of two, and each team earned a point only when both members correctly answered a question. To reinforce this behaviour, the first student to answer correctly was presented with an arrow pointing to his/her teammate's problem rather than the next question.

Physical collaboration (M2 and M2V) — Each team of students worked on a single question. In M2, the two students shared one keypad, which allowed us to study whether having students physically share a single point of input and problem would encourage constructive behaviour. In M2V, both teammates were given active keypads, both of which could be used to input the answer. We introduced this condition to see if it would affect the behaviour of the dominant student.

Methodology

The study took place in five public schools in low-income neighbourhoods of Bangalore, Karnataka, India, in August and September of 2009. We performed our tests in India to ensure that we worked in typical scenarios where computers were likely to be used as shared rather than individual devices. Students were randomly selected from classrooms in groups of four and asked to sit at the computer, whereupon the game would be explained to them in the local language.

Students were always presented with the competitive mode first to familiarize them with the game — the other modes were counterbalanced in order. As each game was explained and played, students were observed for engagement, collaboration, and dominance behaviours, such as using another student's keypad or asking questions of other students. In addition, the software automatically logged details about every game session so that we are able to reconstruct and analyze each game as it originally occurred. Once the mechanics of the game itself and each condition was explained to the students, we refrained from interacting with the students unless they were struggling to understand the input.

In addition, we asked teachers to rate the students in general class performance. We used this rating to help interpret collaborative and dominance patterns.

ANALYSIS AND DISCUSSION OF RESULTS

The data discussed here is from observations of 192 4th, 5th, and 6th grade students in Bangalore, with a total of 8976 responses recorded within the system. For exploratory and logistical reasons, MI was replaced midway through the study with M2V. As a result, data from those conditions is incomplete and we only include M4, ME, and M2 in the following analysis. All statistical analysis was done via repeated measures ANOVAs, with a Greenhouse-Geisser adjustment for non-spherical data. For posthoc pairwise comparisons, a Bonferroni adjustment was applied.

Design effects

The impact of the study conditions on behaviours related to dominance is summarized in Table 1. Due to logistical constraints, observations were coded in situ by two trained observers. Rules for rating were agreed upon beforehand for measuring the metrics, but otherwise no interrater control was instituted. Since the number of questions per round was not constant, we normalized the total number of instances of each observed behaviour based on the number of in-game questions. These figures were then multiplied by 100 for readability.

Use of Another Student's Keypad
The first metric, physical dominance, refers to the use of another student's keypad. In the case of M2, we defined this metric as the seizure of the input device and unwillingness to share despite requests from the teammate. This is the most clearly defined of our metrics in terms of dominance — in every instance where we observed this occurring, the student whose keypad was taken away disengaged immediately, not endeavouring to continue work on the problem or question the dominant student. In many cases, it led to the student gradually becoming less engaged over the course of the study, as they accepted the dominance of the other student. Statistical analysis shows that there is an effect of interface condition on instances of physical dominance ($F(1.42,55.5) = 34.3$, $p < .001$), and pairwise comparisons showed that significantly more instances occurred in ME mode than M4 or M2 ($p < .001$ for both comparisons).

The most likely cause for this difference is that, while the stronger student is encouraged to help the weaker one in the explicit collaboration mode (ME), the weaker student still has ultimate control over the input device, and thus the situation — this allows them to stall until they are satisfied with their answer. Dominant students would often lose patience, and attempt to physically rectify the situation. In M2, the weaker student was not empowered by their own input and question, so there was much less need and opportunity for the stronger student to steal input from a teammate.

Disengagement
The next metric measures the disengagement level of students. Disengagement was defined as students ceasing participation in the game, generally looking away from the screen and no longer answering questions, often until another student intervened. While disengagement may be the result of general disinterest in the game, all students were excited enough about the opportunity to participate in the study that this is an unlikely cause. Instead, disengagement in the paired conditions was likely the result of either the stronger student waiting on the other student to finish before being allowed to continue, or the weaker student waiting for the stronger student to help and possibly finish both of their problems. Both cases are again examples of poor dynamics and a potential imbalance, though the former, which occurred exclusively in ME mode, is less overtly negative than the latter.

Although the analysis on observed instances of disengagement behaviour is not statistically significant, the trend indicates that the team modes (ME and M2) produced more disengagement than the competitive mode (M4). This interpretation is supported by our qualitative observations: the most severe case of disengagement came in the modes where both teammates were solving a single problem (M2 and M2V), since the stronger student sometimes simply answered all questions before the weaker student could hope to make progress, resulting in the weaker student gradually losing interest in the game.

***Table 1:** Dominance metrics per group. For M4, ME and M2, N=40; only partial data for MI and M2V.*

Game Type	Physical dominance		Disengagement		Verbal abuse	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
M4	0.990	2.59	1.74	3.22	0.056	0.367
ME	5.25	4.73	2.95	4.72	1.35	1.88
M2	0	0	2.52	5.70	2.11	3.31
MI	0.878	2.00	0.991	1.55	0.245	0.521
M2V	1.95	2.57	3.87	3.48	1.52	3.48

***Table 2:** Dominance metrics by gender. N=167.*

Metric	Male		Female	
	Mean	*SD*	*Mean*	*SD*
Aggression	0.686	0.877	0.589	0.725
Deference	0.214	0.508	0.156	0.393

***Table 3:** Dominance metrics by class performance. N=167.*

Metric		Strong	Average	Weak
Aggression	*Mean*	0.884	0.571	0.500
	SD	0.868	0.739	0.622
Deference	*Mean*	0.192	0.143	0.250
	SD	0.430	0.430	0.623

Verbal Abuse
The verbal abuse metric measures the frequency with which one student scolded another. While not as direct as physically using another student's keypad, verbal abuse is still an indicator that one member of the team is working poorly with the other. There was a significant main effect of interface condition on observed instances of verbal abuse ($F(1.53,59.6) = 10.9$, $p < .001$). Pairwise comparisons showed that the conditions that used team scoring (M2 and ME) resulted in more instances of verbal abuse than the individual M4 condition (both comparisons $p < .001$). Informally, it appears that the frequency was higher in M2 than ME. The most common case of verbal abuse in M2 was when the weaker student was in possession of the keypad, either because it was convenient or because the students were taking turns, and answered a question incorrectly. It is possible that the occurrence of verbal abuse was lower in ME because of the previously mentioned effect of 'ownership' of a problem — in M2, a poor answer reflected upon both students, whereas in ME it was the other student's responsibility to supply the correct answer.

Gender and Class Performance

To understand how individual characteristics of the students themselves might relate to dominance patterns, we also conducted an exploratory analysis on dominance patterns and the gender and the teacher-rated proficiency of each student. This analysis is preliminary and will need to be further validated.

For each student, *aggression* and *deference* scores were calculated across all conditions based on raw observation notes (see Tables 2 and 3 for a breakdown of scores). For aggression, a student was rated 0 if no aggressive behaviour was noted, 1 if the student had verbally ordered a teammate around or dictated answers, and 2 if the student was physically using their teammate's input device on a consistent basis. Similarly, for deference, students were rated 0 if no deferent behaviour was exhibited, 1 for passive deference, most specifically waiting for a teammate's confirmation of each answer before submitting, or 2 if the student actively sought the other teammate to answer the question for them so that the team could move on. These two metrics are not directly linked, since simply being bullied by a teammate does not raise your deference rating, and vice-versa.

We found that male students had higher rankings in both aggression and deference. This is perhaps explainable by the observation that male students tended to be more competitive — they were more emotional about winning or losing the game, for instance. This difference largely explains both metrics — aggression, and thus dominance patterns, tended to appear more often with male students than female students due to their greater interest in competition and thus impatience with teammates. They were also more willing to defer to a stronger teammate and lose their involvement in the game as long as it meant that they would win in the end.

The breakdown by class performance also yields interesting results: more advanced students appear to be far more aggressive than the weaker students. There were some instances of students who were verbally and physically dominant who were actually weaker at math than their teammate, but those students were generally rare occurrences caused by pairing with abnormally timid yet strong students. Weaker students were more likely to defer to others, looking for help while playing. Extremely weak students would receive help even from the other team, as the students were generally aware of each others' skills.

CONCLUSION

Our results indicate an effect of game design on dominance: the stronger the design was intended to support collaborative activity, the stronger the dominance patterns that emerged. Introducing team play without otherwise supporting collaboration appeared to motivate very little in terms of reducing dominance. Conversely, forcing both students to work on the same problem caused severe single instances of dominance and subsequent disengagement of the weaker student.

We also found that gender and class performance were related to observed dominance patterns, and it is likely that pre-existing dynamics and relationships among the students could impact the results. We randomly assigned students to groups, but the collaborative and dominance dynamics could be entirely different had students been allowed to choose their own partners or be paired with their friends.

All the modes that we tested still had elements of competition along with the collaborative elements introduced. This competition could explain some of the motivation behind dominance, so purely collaborative designs should be explored in future work. Our observations and analysis also only focused on shorter-term negative aspects of dominance, and the study protocol was not designed to capture more intangible or longer-term collaborative benefits. For example, a weaker student may gradually pick up skills from the stronger student, or the dynamics between the two students could change over time.

This research has shed light on dominance as it pertains to multiple input systems in education, but, unfortunately, none of our designs were optimal for positive collaboration. A good design will need to achieve a balance between facilitating a collaborative dynamic, either physically or through the mechanics of the activity, and the potential for stronger students to feel limited by the skills of a weaker teammate.

ACKNOWLEDGEMENTS

We would like to thank the Azim Premji Foundation, Meera Lakshmanan, and the National Science Foundation for making this research possible.

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