MultiMath: Using Numeric Keypads to Utilize Limited Computer Resources for Education

Heather Underwood, Clint Tseng, Charlotte Robinson, Sunil Garg, Meera Lakshmanan, Richard Anderson, Joyojeet Pal

University of Washington, Department of Computer Science and Engineering

{hmu2, cxlt, solstinc, skgarg}@cs.washington.edu,

meeragargi@gmail.com, anderson@cs.washington.edu, joyojeet@u.washington.edu

ABSTRACT

As the need for access to technology in developing regions increases rapidly, the supply of personal computers in these areas fails to meet the demand. In the context of education and the presence of computers in under-funded schools, the computer-to-child ratio limits equal access to educational material and deprives marginalized children of valuable digital literacy skills. In this paper we expand on prior shared computing research to demonstrate that ten-key numeric keypads are usable as primary input devices and provide the benefits of increased engagement and collaborative learning while offering an inexpensive and versatile educational tool for shared computing scenarios.

Keywords

Shared Computing, Educational Software, Multiple Input Devices, Single Display Groupware

1. INTRODUCTION

For most disadvantaged youth in the developing world, the first and often only source of access to technology is through institutions that offer shared computing facilities. The presence of classroom computers in developing countries is on the rise, even in some of the poorest parts of the world. Government and community funded urban schools in developing nations are included in this technological trend, but only to a limited degree. Often in these schools there are only one or two computers for the students and teachers to share. These computers are primarily used for educational purposes in addition to some gaming. The current model for educational software typically consists of a narrative or short audio story followed by a series of questions. Prior observations in these schools have shown that up to nine or ten children will share a single computer to complete this type of coursework, inevitably causing some students to be left out, a dominant child taking complete control, and many children never interacting with the software or hardware at all [5]. Research has shown that, despite clear evidence of computer sharing being the dominant means of access among disadvantaged children, there is almost no hardware or software designed explicitly to accommodate such usage scenarios [5].

MultiMath uses multiple numeric keypads as input devices for a basic arithmetic game and divides a single computer screen into sections corresponding to each student. This setup — individual USB keypads and corresponding split screen display — provides equal access to the technology, allows students to access personalized and adaptively calibrated content, and lets students participate at their own skill level while maintaining a sense of competition between the other students.

2. RELATED WORK

The concept of single display groupware (SDG) is a not a new idea, and researchers have previously explored the potential benefits of collaboration through multiple input devices [2]. Our research follows the SDG model and provides an easily extensible foundation for adding more educational content over time.

Prior research on using multiple mice has demonstrated the benefits of providing each student with their own input device [5]. The overall engagement of the students with the material was higher when each child had their own mouse. We observed similar results in preliminary trials with the keypads. The chaotic talking and physical contact significantly decreased when each child had their own device, and the perceived learning was higher in this scenario as well.

There has also been research done using a split screen model [3] where the screen was split into two halves and the children worked in teams of two. The results of this study showed that by giving each child their own input device, the common scenario of one dominant child controlling the mouse or keyboard was reduced and collaboration among the teams increased. Research has also shown that children pay almost no attention outside of their section of screen [3], which we found also applies when the screen was split into four sections rather than two.

Research with on-screen keyboards has demonstrated the possibility of text entry using a mouse [4]. However, by using a physical keypad, as in MultiMath, we save valuable screen real estate and hypothesize that a physical keypad will allow for faster input.

3. IMPLEMENTATION

MultiMath is built on Microsoft's .NET framework as a desktop application for the Windows operating system. Windows already supports multiple input devices, but the input data is processed as a single stream, thus all of the mice control the same cursor and all of the keyboard data is displayed as if only one keyboard were being used. In order to obtain and process data from one of multiple input devices, we identify events such as key presses or mouse clicks and correlate them with a specific device ID. We can use this information, which is provided by the Windows RawInput API, to pair users' personal keypads with the input data from that keypad and tailor the corresponding screen section to react appropriately.▲

The MultiMath software is designed as a competitive game that tests students on basic arithmetic operations. The students are initially presented with a screen split into four sections colored blue, green, yellow, and pink. There are identical progress bars along the side of each participant's section of the screen, which indicate each student's current progress in the race. The multiple progress bars and split screen keep students focused on their work while allowing them to stay involved in the competitive aspect of the game. The split screen setup also allows each student to work at their own skill level and allows us to employ adaptive questioning in the form of difficulty scaling to simultaneously challenge and encourage students.

As a low-cost input device — roughly four dollars apiece — the USB keypads can be deployed cheaply and easily on any computer with USB input capabilities. In addition, the keypads provide a versatile platform for various input types, as they can support numeric input as well as directional input, multiple choice questions, and key mapping for text entry.

In this iteration of MultiMath, we have created a spelling game called MultiSpell. This game displays nine letters on the screen and a picture, under which is a series of blanks where the name of the object in the picture will be filled in. The students use the keys 1-9 to select the corresponding letter on the screen to fill in the blanks and spell the word. MultiSpell demonstrates the flexibility and ease with which the USB keypads can be expanded to support numerous input types and curriculums.

In carrying forth the past findings from various iterations of multiple input interactions, MultiMath pursues three courses. First, we maintain the racing aspect to ensure that the engagement gains from multiple inputs persist. Second, we use adaptive questioning to create competitiveness and reduce the impacts of lost attention by concurrent players who are progressing at different speeds. Third, we build upon the shared screen model to both demonstrate the usability of multiple windows and exploit the potential for 'personal screen real estate' for young children.▲

4. PRELIMINARY FIELD TRIALS

We recently conducted preliminary field trials of MultiMath at four schools in Bangalore, India. These schools were government funded and the students were entirely from a low-income demographic. Although we do not have enough data from these preliminary trials to make statistically significant conclusions, our study provided positive results and motivation for further testing. Our field tests broadly addressed the following questions:

1. Can students understand and quickly grasp the numeric keypad as an input device?
2. How is learning and engagement affected by competition, collaboration, or a combination of the two?
3. How usable is the screen when split into four sections?

4.1 Trials

We tested MultiMath with groups of four students primarily from fourth and fifth grade using same and mixed gender groups. These students all spoke the local language, Kannada. We used two laptop computers to run two simultaneous groups. The children were encouraged to seat themselves, given past findings which indicate that patterns of screen and input dominance emerge in the ways the "central position" seating works out within a group [5]. After the translator briefly explained the game to the children and pointed out the enter and backspace keys on the keypad, the children were allowed to play and interpret the game as they saw fit. Initially, each child had their own keypad and the screen was divided into four sections, which were color coded to the keypads. During the second round of the game, the children were divided into two teams of two and each team shared a keypad. In the final round, all four children shared a single keypad. Upon completing these three rounds of the game with each group, we asked the children a series of questions regarding which round they preferred and why, as well as the perceived educational value of the game.▲

4.2 Observations

Results from our field trials suggest that the difficulty of the math questions was appropriate for fourth grade students, but possibly too easy for higher grades. We believe that with an improved adaptive questioning scheme, the difficulty of the questions will be appropriate for any level.

We also recorded significant differences in the physical positioning and collaboration when children had their own keypads versus having a single keypad to share. Children were more focused when they had a personal keypad and there was less shoving and yelling than there was with a single shared keypad. In the scenario with two keypads and two teams of two students, there was collaboration in some cases and dominance in others. However, students and teachers indicated that they preferred the collaboration with competition setup over individual keypads because stronger students could encourage struggling students and no one would be left behind. The students also enjoyed this scenario because they could work together and work through the problems as a team.

Some of our results indicated that children would get too involved in the racing aspect of the game and not focus as much on getting the correct answer to the problem. We believe that with continued use, students would realize that it is to their benefit to solve the problems correctly if they want to win the race.

Overall, the children responded well to the new device and had little trouble understanding the meanings of the keys. The split screen setup did not draw children's attention away from their own section of the screen, similar to the results found by Moed and Otto. In fact, the students were so focused on their own screen section that some children failed to notice their progression along the top of the screen, thus motivating our decision to implement individual progress bars on each screen section.

Our high-level observations support our hypotheses that multiple keypads and a four-section split screen display are a usable and beneficial solution in shared computing environments.

5. FUTURE WORK

At some schools, we were able to speak with the teachers and educators to solicit their feedback on MultiMath. One of the main concerns the teachers voiced was that the slowest student may become stuck and consequently be distracted or give up on completing the game. This concern motivated our improvement to the adaptive questioning scheme in order to more effectively slow down smarter students and give slower students a greater chance of keeping up. We are also working on implementing hints to help struggling students avoid getting stuck on a single problem while other students progress.

Another useful suggestion we received was to create two versions of the game: one for evaluation and one for practice. The current version of MultiMath focuses mainly on drilling the students on skills they already know, rather than walking students through how to do certain kinds of math problems and helping them understand the concepts. By creating a practice version and an evaluation version, students would have the opportunity to learn in a low stress, non-competitive environment before using their acquired skills in the racing format. This practice-and-evaluation structure echoes current teaching methods and would offer a familiar progression for the students. In both modes, we will still be able to utilize multiple inputs and the split screen environment to maximize the number of students who are able to interact with the computer at once.

One of the strongest suggestions was to implement an English learning game in a similar format. The teachers' emphasis on learning English as an opportunity to raise students out of their impoverished communities was just as strong if not stronger than the desire to gain valuable technological skills to achieve the same goal. We have begun developing MultiSpell to address basic spelling and recognition of English words. By combining English learning and the use of technology in the developing world, our software can give marginalized students a chance to integrate into mainstream culture.

6. CONCLUSION

The preliminary field trials, although small in scope, have demonstrated that MultiMath is a usable educational tool for disadvantaged children needing to share computers due to resource constraints. By using low-cost hardware and modularized software, MultiMath provides the basis for an extensible educational software platform that can easily adapt to existing curriculum in diverse environments. With continued research and more extensive field tests, we hope to deploy MultiMath systems in developing world schools as a high quality educational tool capable of promoting social integration and personal advancement through increased exposure to academic material and technology.

7. REFERENCES

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