Multiple Mice for Computers in Education in Developing Countries

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Abstract—**A distinct feature observed in computer use in schools or rural kiosks in developing countries is the high student-to-computer ratio. It is not unusual to see more than five children crowding around a single display, as schools are rarely funded to afford one PC per child in a classroom. One child controls the mouse, while others are passive onlookers, without operational control of the computer. Learning benefits appear to accrue primarily to the child with the mouse, with the other children missing out.**

The obvious technical solution is to provide each child with a mouse and cursor on screen, thus effectively multiplying the amount of interaction per student per PC for the cost of a few extra mice. To our surprise, both the concept and the implementation appear to be unique to date, for the specific application to computers in education in resource-strapped communities, with previous work restricting studies to two mice, or for largely non-educational applications.

We have developed software that allows multiple coloured cursors to co-exist on the monitor, along with two sample games with some educational content. Initial trials with both single-mouse and multiple-mice scenarios suggest that children are more engaged when in control of a mouse, and that more mice increases overall engagement. Our results suggest new areas of research in pedagogy for computers in education.

Index Terms—**Educational Technology, Developing Countries, Single Display Groupware, Multiple Input Devices**

I. INTRODUCTION

COMPUTERS are rapidly entering schools in developing countries. Computers-in-education projects range from small, isolated, computer kiosks in rural villages to large-scale, high-end, computer installations in wealthier urban schools. Almost always, due to economic constraints, there are not enough computers to support the large numbers of students, leading to highly skewed student-to-computer ratios in the classroom. This is particularly notable in rural schools, where

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it is not unusual to see even ten children crowded around the same computer (see Figure 1, for example).

In a previous study [17], we looked at 18 rural primary schools in four states in India. These schools ran computer classes for the students, with content in the form of educational CDs. Without a single exception, we found that computers were used in this mode, where simultaneous sharing occurred. Student-to-computer ratios ranged from two-to-one, to ten-to-one. (There were situations where a single PC was being used as a teaching aid to an entire class, in which case the ratios could be as high as thirty or forty to one). By sampling some characteristics subjectively rated by teachers, it was seen that there was a tendency for the brightest or the richest child of a group to take the center position and control the mouse. Often in rural schools, there are large age differences within the same class, as some children drop out and rejoin after some years, and others may be left behind from the previous years. So, often the dominant child who takes over the mouse is simply the oldest one. The other children were seen pointing, gesturing, and vying for control of the mouse (see Figure 2), but ultimately without any direct control of the PC. Often, they lost interest and shifted their attention elsewhere.

Figure 1. Nine girls sharing one PC

Research in learning shows that engagement or involvement is an important component of effective learning [26]. Thus, all students without access to the mouse are likely to be receiving less educational value than the child controlling the mouse. Worse, since the mouse-controlling child is typically the oldest

or brightest child, it seems possible that the disparity in learning between students is exacerbated.

Figure 2. Four boys sharing one computer. Note that two children have their hands close to the mouse, in the hope that they would also get a chance to use it. The fourth is just too far from the action

In this paper, we propose, implement, and test a technical solution to this problem by providing each child with his or her own mouse and corresponding cursors. Thus, each child can have direct control of the software, which we also believe requires re-writing, as software written for single users is inadequate.

Despite the simplicity of the idea, to our knowledge, this solution is novel and unique in the domain of computers-in-education in developing countries. In particular, while there is some work that looks at PC-based education with two and three mice [8][9][10][11][20][23], no prior work anticipates as many as ten simultaneous users. Similarly, while there is research in software that potentially allows multiple-mouse input for collaborative office work, none addresses the potential for its application to education in resource-constrained environments.

The economic benefits are clear. While some speculate that a $100 laptop per child might bring digital technology to poor schools [13], at ~$5, a mouse can effectively multiply the value of a PC for minimal cost. Even at a cost of $500 per PC, five mice would allow five children to interact with PCs at a per-student cost of ~$105 – and this using PCs that may already be present in many poor schools.

It is possible that the advantages go beyond economics. Prior work with collaboration in education suggests that a collaborative environment would make for more effective learning experience [4][12][23]. In this context, it may be that a one-to-many ratio of PCs to students is actually desirable in an educational context, provided that every student has some control over what is happening on screen.

The paper is organized as follows: In Section II, we give a brief overview of computers-in-education projects in developing countries. Section III describes the technical implementation of our multiple-mouse work. We performed studies with children which suggest that educational software for multiple mice is worth further exploration. Qualitative results are presented in Section IV; related work is discussed in Section V; and possible avenues for future work are outlined in Section VI.

II. COMPUTERS IN EDUCATION IN DEVELOPING NATIONS

Computer-aided learning has existed in various forms for some time, starting from early experiments which ranged from basic computer-assisted instruction, to more recent ones with robotics for science education [15], facilitated distance learning [27], and so on (for a comprehensive historical overview, see [16]).

The use of computers in education is now an established area of work in India and other developing nations. Reasons for using computer-aided learning range from supplementing teacher shortages, to familiarizing underprivileged children with technology [18].

In India, many computers-in-education projects feature educational content in the form of multimedia CD-ROMs, such as in [1]. These are audio-visual lessons on maths, science and languages. Lessons usually end with simple activities, such as multiple-choice quizzes. The multiple choice quizzes are quite standard in format. Because of the engaging game-like nature of the multiple choice activities, the children enjoy this part of the computer experience the most, and often rush through the 'lesson' part to get to it. All children around a computer try to follow and answer the questions, but the child with the mouse is the one who actually chooses from amongst the options on screen. We observed widespread usage and popularity of such an interaction modality, and so, for the applications built in this research, we are looking at such interaction schemes.

The other kinds of applications in computer classrooms include computer training on applications such as Microsoft Word and Excel, general computer fundamentals, Internet, drawing, and programming.

III. IMPLEMENTATION

A. Enabling Multiple Mice

Our aim was to provide a separate mouse to each student who is in front of a computer, as well as a separate on-screen cursor corresponding to each mouse. This kind of an application, which supports a group of people around a single display, by enabling input by each individual, has been termed *Single Display Groupware* (SDG) [22]. Early efforts to implement multiple input devices include Bier's MMM[1] and Hourcade's MID[6].

Windows supports multiple mice, but does not support multiple cursors the way we envision. It is possible to easily plug in more mice, by simply plugging USB mice into open USB ports. However, in this case, all of the mice control the same cursor, with the sum of the mouse motions being used to control the single cursor. Obviously, multiple children controlling mice this way would result only in chaos.

Our goal was to provide *multiple cursors*, as well as multiple mice (see Figure 3). Windows architecture is separated into two broad areas, the kernel mode (drivers and operating system) and the user mode (applications). When we plug in a mouse, a vertical stack of drivers loads in kernel mode – the lowest level interacts with the actual electronics of the USB bus, and this links all the way up to the high level mouse class driver, which includes code for controlling "plug and play," and other features. The mouse driver communicates to the Win32 API, which is in user mode. Mouse information packets are sent up the stack. These contain button state, delta *x*-, and *y*-values, and most importantly a unique ID for each mouse.

The implicit assumption that nobody will use multiple mice has lead to the fact that this ID variable is ignored by the standard Windows shell. In fact, programming documentation cites that it is "not used," and when the Win32 API system processes the mouse packet to generate a mouse event that programmers use, the OS eliminates the ID identifier. Hence, neither the application programmer nor the cursor-drawing subsystem can distinguish between multiple mice which are sending events. Since the mouse packets send delta values (representing motion relative to last known point), this ends up causing the same single Windows cursor to move.

One approach is to write a filter mouse driver [28]. This would plug into the driver stack above the mouse driver. All mouse information packets would pass through it, with the ID retained. It would then be possible to send a call to higher levels (user mode) and identify which mouse is sending what position data. The drawback in this method is that kernel-mode programming and driver optimization – both notoriously complex – are involved.

Fortunately, the RawInput API (in Windows XP) allows for direct access to ID-rich mouse data in user mode, thus allowing independent identification and use of the mice. Tse and Greenberg [24] have written a well-designed toolkit (the SDG Toolkit) for prototyping SDG applications, built on this API. With this, the RawInput data and calls are packaged in a .NET-compatible event manager, which makes it easy to come up with applications supporting multiple mice. The toolkit allows everyday programmers to use modified mouse-event packets which contain mouse ID identifiers (called SdgMouseEvents). The toolkit allows for drawing separate customizable cursors on screen, by creating transparency-enabled movable windows per cursor. The standard Windows cursor is suppressed to give developers full control over mouse drawing.

There appear to be no problems with latency in clicking, even with up to fifteen mice.

Technically, the main limitation of the toolkit is that the multiple cursors only show within Windows of applications developed on the toolkit, and we cannot use them in normal Windows usage or with other standard applications. Moreover, the RawInput API, and hence the SDG toolkit currently only work with Windows XP. This is a minor issue, as it is unclear in any case, how multiple cursors would work with standard applications, such as a browser or word processor, which have been written for single-cursor use only.

Building on this toolkit, we developed two additional features that we believe would be used frequently in an educational application with multiple mice. We built button controls that are aware of multiple mice and react differently based on who clicks, as the standard .NET controls cannot support multiple mice. Additionally, we allowed for the possibility to colour each cursor differently, to allow children to easily identify their own cursor.

B. Software Developed

We built sample educational applications in C# for use with school children. The first is a simple game consisting of a grid of white tiles, intended to familiarize children with mouse actions (movement, clicking, and double-clicking). Each user has his own cursor controlled by his own mouse. Cursors are distinguished by being in different colours. Clicking on a tile by a user results in the capture of the tile, by changing the tile colour to the user's cursor colour. Clicking on a coloured tile makes it white again. Hence by double-clicking on a tile which has an opponent's colour, a user can capture the opponent's tile. A timer can be started and whoever captures the maximum tiles in the timer period is the winner.

Another competitive application allowed a simple quiz format with arbitrary multiple-choice entries. A grid of sixteen randomly selected alphabets is shown (See Figure 3). One of these alphabets is spoken out by a voice recording, and the children compete to be the first to click on the letter corresponding to the spoken alphabet. All children can play simultaneously, and the first to click wins the round.
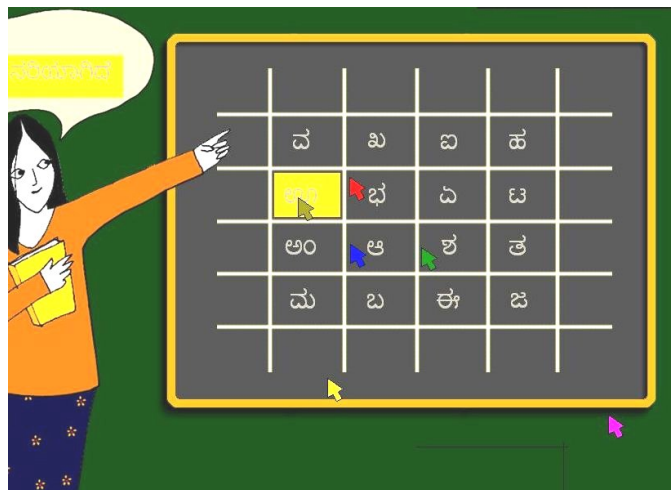

Figure 3. A screenshot of the Alphabet game (in Kannada). Note the multiple cursors in different colors.

In order to give feedback, when the correct alphabet button is pressed, it changes colour to the same colour of the user who clicked on it first. A success message also blinks in the same colour and an audio file is played: "That's correct." The score

is displayed in a bar-graph display, with colour-coded columns representing the users' scores. When a user crosses the win threshold, a congratulatory message and voice recording is played. To show the ease with which other "flash-card" type games can be implemented, the game works in any of three languages – English, Hindi and Kannada.

There is a button for cycling through the languages, and also a separate quit button (as the default close button in Windows cannot work with multiple mice enabled). These buttons are currently such that they can be activated by any of the cursors.

IV. PRELIMINARY FIELD TRIALS

We conducted some preliminary field trials to get a sense for the overall value of multiple mice for educational settings in India. Previous work with multiple mice in education has focused on the collaborative, two-child scenario [8][9][10][11][20][21][22][23]. Our goal was to determine whether multiple mice were viable in situations where there are many more children, as is frequently the case in developing-world classrooms, and whether children would remain engaged even with competitive games.

While we have not yet performed enough trials to draw strong conclusions that are statistically significant, our preliminary trials do allow us to get a qualitative understanding of how multiple mice might fare in education. In particular, the broad questions that our study answers are as follows:

1. Can children understand and use the multiple-mouse paradigm when the number of mice is as many as five?
2. How do children interact with each other with respect to multiple mice? How do they share or not share?
3. Does the multiple mouse paradigm increase interest and engagement?

A. Trials

A total of three trials were conducted. The first two trials were with students located in urban slums in the city of Bangalore, India. These were all Kannada-speaking children. *Trial A* was at a community center of an NGO that supports slum women who work as domestic help, and has after-school activities for their children. This center had two computers, and the children have had some exposure to using computers and hence were aware of how to use a mouse. The group included both boys and girls. *Trial B* was in a similar center in another slum, but this group was made up entirely of girls.

Trial C was held at a residential school which is run by a private foundation. This foundation admits students from families which are below the poverty line, but gives them access to a well-funded and high-quality education. Here we have a rare setting in India, where there is a 1:1 ratio of computers to students during computer classes. All of the students are, therefore, accustomed to manipulating their own mice. All of the children spoke English. The group included boys and girls.

All three groups included a mix of ages, as shown below in Table 1. Trials were video-taped for later scrutiny.

Table 1. Test group characteristics.

	Setting	Description	N	Age
A	NGO Community-centers in urban slums	Basic proficiency in using a mouse, due to some past usage	7	8-12 yrs
B			10	8-11 yrs (girls only)
C	Residential School – rural	Regular PC users. Normally 1:1 ratio	6	5-7 yrs

Set-up and Procedure: We used a single computer (laptop) in each case. At first, the children were shown the alphabet game, with only a single mouse and cursor. They were left to play with it for twenty minutes. This ensured that the children were familiar with the idea of the game, and more importantly, allowed us to observe students' behaviour in the single-mouse scenario. We paid attention to who took up the mouse first, how they interacted with the other children, and how levels of engagement rose or fell.

After twenty minutes, a USB hub and four more mice were plugged in and distributed to the children. After twenty minutes with five mice on the alphabet game, the children were introduced to the tile-capturing game. After ten more minutes, the formal observation was ended, but students were allowed to continue as they chose (free play). At the end, students were also verbally interviewed in an open-ended format that sought their overall impressions.

B. Observations

All three trials demonstrated that children immediately take to a multiple-mouse set-up, and engagement increases, not only for the children with a mouse, but for those left without one. Almost all the children said that they would prefer a multiple-mouse scenario for all their work.

Single-mouse observations: Overall, the single-mouse phase saw a single, dominant child taking control of the mouse, although there was some movement of the mouse among children. The child with the mouse always appeared most actively engaged, while others tended to lose interest, particularly as time went on. Most of these observations confirm previous observations found with the two-child-one-mouse scenario; here, we extend them to multiple-children and one-mouse. Some specific observations:

- *Even with a dominant child, all children engage:* The oldest child immediately took over the mouse in Trial A and B. In Trial C the child who was directly in front of the computer took the mouse; no one moved position. In all cases, initially, the children were excited and everyone was crowding around the monitor. There was a lot of enthusiasm, and the children played with a lot of laughing, shouting and gesturing. This phase of the trials echoed

other classrooms we have observed, as well as the studies with two mice [11][23], in which children who were not given mice, animatedly pointed at the screen and gave directions to the mouse-controlling child (See Figure 4).

- *Engagement decreases with time for students without a mouse:* Within five to ten minutes in all trials, the children in the periphery began to appear bored, and shifted their attention to other things (such as the video camera). In some cases, children got up and simply walked away. Previous work with two children and one mouse also reports that a child without access to a mouse showed increased off-task behavior [11][23].

- *Sharing patterns differ between boys and girls:* In Trial A, the mouse was with the same boy all along, who was the eldest. In Trial B, with all girl students, the girls made conscious efforts to share the mouse, and an older child made sure that all the children had their turns. Trial C was with much younger children, who in the regular computer class always had their own mouse; there was some inconsistent mouse-sharing. In this case, the eldest child was a shy girl (7 years old), who was happy to stand by the side and let the others play. The gender issue is an important factor and has been noted as a factor affecting achievement in past two-mouse trials[8][9].

- *Children want to engage; they want their own mouse:* In all three trials, there were many points where one could notice multiple hands on the single mouse. Some children did this passively, without attempting to direct the mouse motion. Others were more forceful and would eventually gain control of the mouse. One child was heard to say, "Nobody's letting me play," and another commented, "he's doing it all wrong!"

Figure 4. One of the field trials, in the single mouse phase. Note the pointing and gesturing being done by the children without the mouse.

Multiple-mice observations: Upon being given four more mice and cursors, the children immediately adapted to the new model (see Figure 5):

- *Children immediately understand the idea of multiple mice and cursors:* Most interestingly, none of the children in any of the trials were particularly surprised by the addition of more mice; they treated the extra mice as an obvious feature.

- *Children are not confused by multiple cursors on screen:* Once a child discovered which colour cursor was his, there was never any confusion at all in spite of having so many cursors on screen. One girl remarked, delightedly, "I'm green, I'm green, I'm green!" In another instance, at the end of a game, another child exclaimed, "She won, she's blue."

- *Children with mice remain engaged throughout:* No child with a mouse ever wanted to give it up willingly, and none with a mouse ever appeared bored, as in the single-mouse phase. In Trial C, one boy without a mouse, who had expressed boredom in the single mouse (repeatedly demanding, "let's change the game!"), stopped asking for changes when he got his own mouse, and kept on playing the same game with enthusiasm until the end of the multiple mouse phase, 30 minutes later, without a single complaint. Somewhat un-intuitively, the multiple-mouse scenario often meant less noise, as complaints and directives to the dominant children decreased in number. We also noticed that the number of times a child looked away tended to decrease, and there were no instances when a child walked away while owning control of a mouse (in contrast to the single-mouse scenario when this was frequent, due to pressure for others demanding the mouse). We gauge engagement by looking for decreased off task behavior such as looking away, talking to others, etc. [11]

Figure 5. Each child with a separate mouse and cursor.

- *Overall engagement increases, even for children without a mouse!* With five mice, we never had a trial where there were enough mice for all children. Nevertheless, there appeared to be increased interest among non-mouse-holding children when the number of mice was increased.

We speculate that this was because there were more opportunities for each of them to take part, as mouse exchange was more frequent. In Trials A and C, the spontaneous, unprompted discovery was made independently by two boys, that the laptop's built in track-pad is also a valid input device. These boys both used this to re-engage, bending over from *behind* the laptop and taking part in the game (see Figure 6).

Figure 6. An older child, not a part of the initial test group, finds out that the trackpad is an additional input and begins to play using it.

Other observations:

- *In interviews, student reactions were very much in favour of multiple mice:* With one exception, all the students said that they preferred the multiple-mouse mode. Typical reasons included "Now, we don't have to fight for the mouse"; "Everyone can share"; "Having more mice gives everyone has a chance". This indicating that the greater number of mice does not hamper the overall experience, which is similar to the two-mice case[9][11][21][23].

- *One child did not like multiple mice because of its competitiveness:* One girl did not prefer multiple mice, reporting that the games became too competitive and she did not enjoy that.

- *There can be considerable difference in game-playing competence, especially with large variance in age:* In Trial A, the oldest child had a pronounced advantage in playing the game, and won the game repeatedly.

- *Joint decision-making about what game to play next was chaotic:* In various trials, children debated whether to play the alphabet game in Hindi or English and argued whether to play the tile game or the alphabet game. In all cases, the decision-making process was confused as most children figured out how to change games and languages, and the software was such that all children with a mouse had the power to make the change.

- *Children rapidly pick up finer points of UI and game control:* Although not part of the official study, the students were indirectly exposed to mechanisms for how to change games during changes in the test phases. The students immediately absorbed these UI commands and utilized them in the free play time at the end. This is in line with previously studies documenting the rapid speed with which children absorb computer skills [13].

V. RELATED WORK

There have been some studies on children in educational settings collaborating around a computer, but the landmark work was Inkpen's studies with pairs of children, who were to solve a set of puzzles [8][9][10]. Two children had a mouse each, though there was just one cursor whose control could be toggled. Pairs were found to solve significantly more puzzles than children playing alone. Inkpen and collaborators have explored other settings, later on enabling separate cursors [11][20], but never with more than two children per PC.

Bederson, Stewart, et al., have looked at experiments using collaborative storytelling software [22][23], with an aim to encourage and teach collaboration. The same software was used by Stanton and Neale [21], who studied the social interaction of the collaborations. These studies had children working together with independent cursor on a visual drawing and storytelling package, but again, scenarios were limited to two children per PC. The applications studied were meant to enhance collaboration in classroom settings, and in most cases the educational goal was to teach collaboration itself among students.

Zanella, Tse, and Greenberg have looked at some more general UI implications for Single Display Groupware [25][29]. Brignull, et al., have built a community shared workspace [5] which incorporates multiple inputs with large displays, with an emphasis on practical, but non-learning applications such as sharing information and social interaction.

Overall, previous work that involves more than one mouse for children and education focuses on the two-mouse, two-child case, with some work restricted to a single cursor. Generally, this work also sees collaboration itself as the goal of learning, and does not consider general-purpose education as a possibility for multi-mouse interaction. These applications do not seem to have caught on in a significant way in the environments for which they were designed.

A lot of the previous work with multiple mice appears to be struggling for a raison d'etre. The applications are not compelling and authors seem to struggle with the potential value of their work. In the only previous body of work in which more than two mice were used with children (but, still restricted to three) [3], the application features a colour-matching task, in which three children are expected to independently modify red, green, and blue (RGB) values to match a single given colour. The author writes,

"Working in small collaborative groups teaches students skills needed in later life to interact with their peers in college or on the job" [4].

In contrast, the work presented in this paper is motivated by a different need in developing-world schools, where the ratio of children to computers is typically very high. Although this situation has existed for as long as there have been PCs in developing countries, and while the potential solution has been present with the first multiple-mouse trials, to the best of our knowledge, this work represents the first instance when multiple mice (more than two, in particular) has been proposed for educational settings in the developing world, for general-purpose education.

VI. CONCLUSION AND FUTURE WORK

Multiple mice for education deserves much more exploration, particularly, but not limited to, developing-world classrooms, where financial resources may be scarce, and the addition of a few mice is far easier than a PC per child.

Our initial trials provide qualitative evidence that children rapidly and effortlessly adapt to multiple mice and multiple cursors on screen. Trials with five mice showed no visible degradation in the ability of children to interact with the PC. Children also show considerable more engagement when the *opportunity* for having access to a mouse increases, above and beyond actual access to a mouse. Sharing patterns with several children and five mice confirm patterns reported by previous work with two children and one or two mice.

Just as computer games are felt to be more fun when playing against human opponents (versus playing against computer opponents), our results suggest that students are more engaged with software when they are learning with other students. In future work, we hope to build more educational applications and verify these hypotheses more conclusively, over longer term experiments, specifically in terms of more tangible learning outcomes.

There are also a range of interesting possibilities at the more pedagogical and user-interface-design levels, which might be relevant for future work

- *Individualised Pacing of Instruction and Gameplay:* We noted earlier, that in one case, the oldest child was repeatedly winning. It seems that even though individual control and engagement is being provided to all students, it cannot overpower an inherent disparity in capabilities. A solution we can propose is creating mechanisms to match pace with each child individually, and designing games accordingly. This can be thought of like a computer-adaptive-testing system that adapts to the paces of each of multiple simultaneous users.
- *Joint Decision Making:* We noted that there was a lot of chaos and debate when deciding to switch between the games. Educational software with multiple mice would need joint decision making mechanisms for such actions which are shared and affect everyone.
- *Collaborative Applications:* In this current work, we have looked at a purely competitive scenario in our case, while almost all of the past work we have examined focuses on

collaborative learning. For further work, we are keen to explore and expand on such collaborative scenarios in our target settings.

We believe that this is just a beginning. Multiple mice in educational settings in developing countries, can be a simple but very effective way of instantly multiplying the value of a shared computer in a school. The inherent simplicity in implementation and scaling is something we believe will go a long a way in addressing the resource crunch that faces education in developing nations.

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