Mischief: Supporting Remote Teaching in Developing Regions

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ABSTRACT
Mischief is a system to support traditional classroom practices between a remote instructor and a group of collocated students. Meant for developing regions, each student in the classroom is given a mouse and these are connected to a single machine and shared display. We present observations of teaching practices in rural Chinese classrooms that led to Mischief's design. Mischief's user interface, with which scores of collocated students can interact simultaneously, supports anonymous responses, communicates focus of attention, and maintains the role of the instructor. Mischief is an extensible platform in which Microsoft PowerPoint slides, used commonly in developing regions, are made interactive. We setup a controlled environment where Mischief was used by classrooms of children with a remote math instructor. The results from the study provided insight into the usability and capacity of the system to support traditional classroom interactions. These observations were also the impetus for a redesign of several components of Mischief and are also presented. These findings contribute both a novel system for synchronous distance education in an affordable manner and design insights for creators of related systems.

Author Keywords
Classroom technology, developing regions, distance learning, children, CSCW, user interface.

ACM Classification Keywords
H5.2. Info interfaces and presentation: User Interfaces.

INTRODUCTION
Education is a crucial factor in any discourse on economic development and consequently there is much interest in the role of Information and Communication Technologies (ICTs) in education for developing countries. However, merely placing computers in schools is not a proven solution. Education in developing countries suffers from numerous problems such as insufficient funds and basic infrastructure [11]. One key problem is the shortage of competent and motivated instructors, especially in rural areas [11]. Even when rural instructors are available, they often lack subject expertise, are overworked, and have high rates of absenteeism [29].

Many possible solutions for educating rural children remotely have been proposed including broadcasting educational television and radio, sending pre-recorded lectures via DVD [29], and real-time (synchronous) distance education [28]. Integrating computers in the classroom is another commonly proposed approach because it is scalable, measurable, and can be subject to quality standards. However, multiple factors, such as a lack of appropriately designed content and prohibitively expensive hardware have contributed to these experiments falling short of their claims. While there are large-scale initiatives underway to provide computers for children in developing countries (e.g. OLPC [22]), others argue about the utility of this approach [23].

We are examining a distance education approach where technology is used to facilitate classroom interactions with a remote instructor. The emphasis here is on facilitating social interaction in an affordable, extensible, and engaging manner rather than providing software applications for students to interact with.

This paper first presents related academic and commercial work then examines classroom cultures in rural China and the observed challenges of distance education there. The paper then describes Mischief (videos at [21]), an inexpensive and scalable system to provide shared, synchronous, classroom-wide interaction. Mischief (the collective noun used for 'mice') is inspired by earlier multi-mouse research [24, 15, 27] which has shown educational benefits for small groups interacting around a shared computer with multiple mice. Mischief extends this idea by giving a mouse to each child in a classroom and provides remote instructors with the means to communicate with

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students both individually and as a whole (see Figure 1). Using Mischief, large numbers of students can interact with a remote instructor simultaneously, modeling traditional classroom interactions.

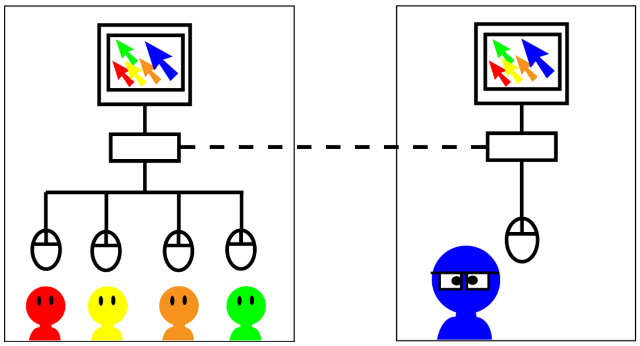

Figure 1. The Mischief system. Left: multiple, collocated students use a shared display. Each student is represented by a small colored cursor. Right: a remote instructor sees identical content on her screen and is represented by a larger cursor.

Observations of students using the Mischief system showed that even novice computer users were able to easily learn the system and identified with their cursor as a representation of themselves. When used during remote teaching sessions, the students were engaged with the system in spite of the absence of a physical teacher. Additionally, the instructors in our field studies were able to learn the functionality of the system, teach and review mathematical topics, and felt they could garner the status of the classroom as a whole in spite of being remote. The paper concludes with design improvements made to the system that could help designers of similar systems.

RELATED WORK

Remote Collaboration

Many remote collaboration and telepresentation systems have been developed in both research and industry (e.g. [30, 2, 18]). The dominant focus of these systems is to support distributed corporate meetings and presentations [33]. Common features of these systems include: application-sharing, shared annotation, telepointers, floor control, whiteboards, and voting. Other key factors in designing these systems include simplicity of use [33], enhanced social interactions [17, 19], and contextualization [30]. These systems largely rely on each participant having a desktop computer and are not optimized for a classroom environment with many collocated students. This work showed that remote presenters need sufficient feedback in order to stay engaged and "motivated" [16], or they may perceive a "lack of interest" or "get offended" [17].

Distance Education

Distance education broadly represents any teaching or learning activities that take place with people who are geographically distributed [9]. In Western interpretations, modern distance education tends to focus on scenarios where all participants (students and instructors) are distributed. In contrast, the notion of distance education used in this paper is a group of collocated children in a rural environment taught in real-time by an urban instructor.

In many developing countries, adults leave the countryside for work and any educated instructors leave rural towns to find work and send back remittances. This is especially common in China, where an increasingly uneven distribution of skilled instructors exists [5]. This begs the design of remote teaching systems to connect urban instructors with rural children.

As summarized in [31], educating geographically dispersed students in the developing world has been attempted for many years using correspondence courses, telephone, fax, and video-mediated communication. Research has further shown that students in distributed learning environments can perform as well or even better than students in traditional classrooms [10]. Broadcasting educational content (e.g. using radio, TV) is a viable option for distance education. However it lacks the ability to focus on individual students and is limited in terms of student interactivity. Further, it can bore younger students who may require more stimulation or interaction to stay engaged.

Tutored Video Instruction (TVI) [10] works by allowing collocated students to discuss the video of an instructor's lecture. The study showed that TVI enables students to outperform collocated students. Applying this concept to developing regions, the Digital StudyHall project [29] enables urban instructors to record high-quality lectures to be played back in rural classrooms and mediated by local instructors. This method lacks direct, synchronous interaction with a qualified instructor. To address this, some countries have invested in bidirectional audio-video systems for educational use; however these systems are expensive and restricted to higher education (e.g. [28]).

Audience Response Systems

Other research and commercial work referred to as Audience Response Systems (ARS) have explored classroom technologies that enable individual students to provide free-form feedback [3] and submit answers to multiple-choice and true/false questions [3, 7, 13, 32] to collocated instructors using relatively high-end equipment such as PDAs, Tablet PCs, and proprietary hardware. They found that the ability to individually respond can improve student participation and retention of concepts presented in class.

Single Display Groupware

Single Display Groupware (SDG) [27] refers to the practice of multiple collocated users each using an input device (e.g. mice) with a single display. As applied to children and education, the SDG model has been shown to be beneficial in both industrialized [5, 15, 26] and developing countries [24]. In particular, multiple mice have been shown to lead to higher engagement, better task performance, and a positive impact on collaboration and motivation [15]. However, this research has only focused on small-group SDG (e.g. 3-5 students), and has not been applied to whole-class interaction (e.g. 20-80 students), nor have they studied the case of an instructor being an active participant.

The present work is unique in that it introduces a technically and financially scalable system based on SDG for use with whole-class interaction on a single display in order to enable remote instructors to teach synchronously. The system's design is based on the observed classroom practices presented in the subsequent section.

RURAL CLASSROOM CULTURES

We first wanted to understand classroom culture in rural regions of developing countries. In particular, we were interested in social interaction norms and current distance education approaches.

Observation Subjects

Observations were conducted in several Chinese schools and the results were corroborated by researchers in India who work closely with schools there. We visited 5 schools in 2 Chinese provinces: 1 urban (7th-11th grade), 3 semi-rural (1st-3rd and 4th-6th grade), and 1 rural (1st-3rd). Among these, we observed 10 classroom sessions of grade 2-10 and interviewed 20 instructors. Each class had 50 to 80 students for a total of approximately 600 students.

Traditional Classroom Practices

We identified seven classroom practices that guided Mischief's design. Many are familiar teaching practices while others are more pronounced in the aforementioned cultures.

Blackboard

Blackboards were often used in the traditional manner (i.e. writing and co-referencing) for instructor-class interaction. In addition, blackboards were sometimes used as a public display where students could write answer upon. Figure 2 shows an instance where four students were asked to "come up to the board" to write down their answers to a question. Instructors used these instances as an opportunity to publically provide positive and negative reinforcement.

Figure 2. Using the blackboard as a means of public display and evaluation.

Individual and group identity

We observed that both personal and group identity was important in the classroom. At times, instructors addressed the children by name and had them perform individual activities. Other times, students were placed in groups for activities and these groups were given identifying names and assigned representatives to relay answers from the group. In both cases, the teacher aimed to ensure each child was individually encouraged to be an active participant.

Individual attention

Individual attention was used to help the children feel that they were being attended to in spite of large class sizes. Instructors used pointing gestures or eye contact to transfer attention to individual students in the class or to ask them to respond to a question (see Figure 3).

Figure 3. An instructor pointing at a student and making eye contact to grant individual attention.

Positive public reinforcement

Instructors often provided positive public reinforcement to students in the class using compliments or having the class applaud individual students by clapping or chanting rhythmically. Once, an instructor rewarded a child by applying a sticker directly to her forehead so that the other children would notice it. The instructor felt that the reinforcement was more valuable when it was visible to the student's peers.

Raising hands

Children raised their hands to answer questions, volunteer for activities, and vote – but never to ask questions. There was very little solitary hand-raising in response to real (rather than rhetorical) questions. Hand-raising was used much more in unison (see the next subsection and Figure 4).

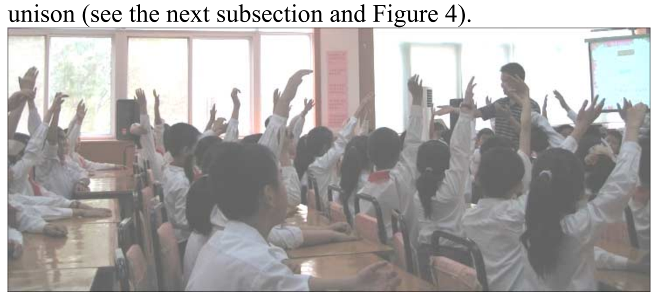

Figure 4. An example of unison response where students physically answer a question in the affirmative.

Unison response

Instructors encouraged unison responses to help maintain engagement and set a rhythm, particularly in large classes. This was often done with quick, rhetorical questions like "That's what we saw earlier, right?" or "Is everybody with me?" or asking many students the same question to give each child a chance to say the same answer. These questions elicited vocal and physical unison responses and created a unique pace in the classroom (see Figure 4).

Gauging class status
We observed that the instructors continually, quickly, and almost imperceptibly ascertain a high-level status of the class as a whole in three ways: visually, audibly, and spatially. Visually, he scans the class to see outliers or unexpected behavior such as poor posture or students distracting others (see Figure 5). Audibly, he listens for children's voices, papers rustling, a lack of sounds (implying they are working quietly or perhaps confused), or chairs moving. Spatially, he recognizes and recalls certain areas in the class as problematic or particularly receptive.

Figure 5. An instructor visually, audibly, and spatially observing class status.

Instructors using Computers

In the urban school we visited, we walked around the school and saw two classes in session using computers. Both were using PowerPoint almost exclusively. One was a computer lab setting where each student was creating multimedia presentations (rare outside China's wealthy, urban schools); the second was an instructor delivering teaching content via Microsoft PowerPoint [20] using a digital projector. When asking about this practice, we learned of the prevalence of PowerPoint in developing regions, including those outside China.

Distance Education Practices

We next wanted to gain an understanding of how distance education is currently being applied in China. We visited the Tsinghua Distance Education Center [28] at Tsinghua University, China's premiere technical institution, where we found high-end equipment used for cross-university, synchronous instruction. This required highly specialized audio-video equipment for both parties. Due to these requirements, less-wealthy schools that are fortunate enough to get any help from the program are relegated to being sent material asynchronously.

We visited 3 rural distance education sessions where 56 instructors were viewing instructor-training material in three different ways. The first session involved 10 instructors in a computer lab viewing training material on two elevated computer monitors that showed the same content simultaneously. The second session saw 40 instructors in a semi-rural multi-purpose room equipped with a projector. In the third, 6 instructors viewed a lecture in a rural school's equipment room using a computer borrowed from the local Internet café.

In these sessions, instructors watched prerecorded lectures which were digitized, transmitted electronically, and shown using a large public display (Figure 6a) or on multiple elevated monitors (for visibility purposes) in a computer laboratory (Figure 6b). In both instances, the instructors appeared to be engaged in the activity; however, none of them asked any questions or started any discussions. There did not seem to be any advantage of using digitized video compared to sending DVDs via mail and displaying the content on TVs.

Figure 6. Left (a): elementary school instructors viewing instruction in a pre-recorded lecture from a top university. Right (b): instructors view instruction material on one of two elevated monitors in a computer lab.

Low-cost, synchronous distance education opportunity

Because of the current limitations of distance education, we wanted to explore the potential of using a remote instructor to interact with children in rural classrooms. We felt that technology could be used to facilitate observed classroom practices with a remote instructor instead of replacing them with video-mediated communication. The next section describes the design of the resulting system, *Mischief*.

MISCHIEF DESIGN

Mischief is a teaching system designed to use single-display groupware to enhance social awareness between collocated students and support classroom-wide interactions with a remote or collocated instructor. Mischief enables all students in the classroom to interact simultaneously with a large shared display by placing a mouse on each student's desk (see Figure 7). In effect, this creates a large-scale version of single-display groupware.

The distributed instructor communicates with students orally via a standard telephone network (or streamed using a digital network) and a speaker on the classroom side. If a digital network is available and bandwidth is sufficient, unidirectional or bidirectional video is streamed using webcams, though this is not required.

The remote instructor interacts with the Mischief application using a standard keyboard and mouse. Optionally, a bird's eye view of the classroom can be displayed on her second monitor or virtual window.

Figure 7. Using mice, students interact with the shared system while sitting at their desks. An adult facilitator is present.

The collocated students in the classroom see the Mischief application on a large shared display (e.g. via a digital projector) or multiple small displays, as observed in rural China. Optionally, the instructor's 'talking head' video can be shown on a separate screen. Students interact with the Mischief application using standard mice placed on each student's desk.

Each client displays identical data such that both sides (instructor and students) see the same information. Mischief requires a network connection to transfer data (mouse cursor positions and actions) between the Mischief clients. The intention is that Mischief could be used from Internet-equipped homes of instructors rather than specifically-designed teleconferencing rooms.

Mischief System Design

This section presents Mischief's user interface design, which is based on the concept of slides, familiar in presentation software such as PowerPoint. Each slide constitutes an *activity* and the instructor controls the software through buttons and keyboard shortcuts that appear on top of the activity content.

Cursors and identity

Each student is represented on-screen by a unique cursor (as in [12]) and has a corresponding unique audio sound. Cursors can be any size, shape or color. It is often desirable to have two distinct features to make it easy for the children to identify their own cursor. For example, in Figure 8, each cursor is represented by an animal and a color. The instructor's *supercursor* cursor is the standard arrow shape, but larger.

Before starting the class, the students each click an icon with their name on it so the system can match cursors with student names. The software can then control whether or not widgets respond according to role. Some widgets respond to input from the instructor's cursor while others only respond to input from students. Additionally, by tracking student identities, the software can record each student's achievement throughout the session.

When a student is activated, clicks answer choices, and at other strategic moments, their assigned sound is played. This is done to increase students' feelings of connectedness to their cursor, reinforce the unique identity of each student, and act as auditory feedback. Auditory feedback is important because visual feedback may not be appropriate given the large number of cursors on-screen. For example, if visual feedback is provided on a widget (e.g. a button being depressed), it is difficult to associate this feedback with the cursor that caused the action (i.e. to know which student clicked the button). Additionally, any localized visual feedback (e.g. on the user's cursor) may be occluded by other cursors. Auditory feedback can also help instructors recognize patterns of student interaction (e.g. hearing that the student with the bark-like sound always answers first), thereby improving awareness of the class.

The benefit of telepointers is well-supported in the research on distributed collaboration where they are noted to help mediate conversation, support gestures, and communicate focus of attention between remote parties [1, 12]. In Mischief, cursors are telepointers and help communicate attention and intention between instructor and students.

Student list

At any point, the instructor can toggle the *student list* (Figure 8) visible or invisible via an instructor-only button. The student list has three functions to help the teacher mimic behaviors we observed in traditional classrooms. First, it shows class progress in the current activity (e.g. answer choices). Second, the instructor can *activate* or *deactivate* each student's cursor by clicking their name, which toggles the visibility of that student's cursor and plays the student's sound when activated. Third, the instructor can give students public positive reinforcement by awarding them a *star* (a measure of achievement). This is performed by right-clicking that student's name in the student list.

Mouse gestures

As ARSs have shown the utility of anonymous responses from students, we knew Mischief must support this. *Mouse gestures* are used by student to make anonymous responses. A visual cue is given when the gesture mode is activated. At this time, the students answer the on-screen question using mouse gestures modeled after shaking one's head "Yes" or "No". To indicate "Yes" the students move their mouse up then down and repeating it a few times. To indicate "No" the students move their mice left then right repeatedly. During this time, their cursor is not rendered on-screen so other students cannot see the answer choices of their classmates.

Mouse gestures can be used to provide anonymous responses during Yes/No and traditional multiple-choice activities. First, the cursors must be deactivated. Then, students must position their invisible cursor in the desired answer choice's target area (in each corner of the screen as in Figure 9a). This results in a motion we call "petting the sheep" because the user must repeatedly lift and drag the mouse into a corner.

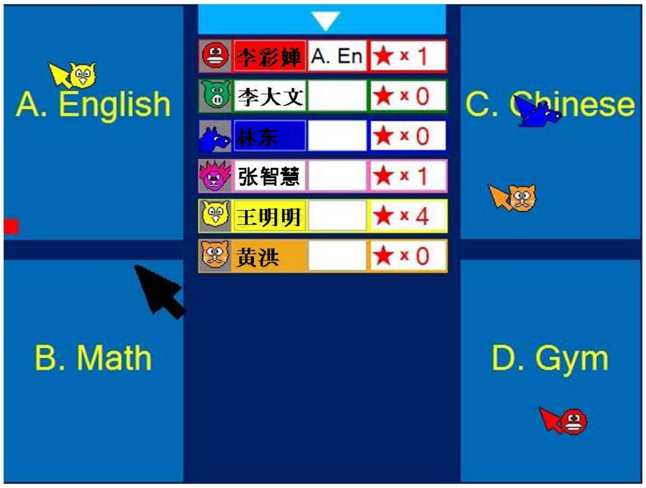

Figure 8. The student list toggled on, occluding the question of the active multiple-choice question. The instructor's cursor is the large black arrow and the students' are colored animals.

Raising hands

A student can raise her hand by right-clicking her mouse. While the button is down, a small visual flag appears next to that student's name in the *student list*. When called upon, the student speaks aloud and the audio is transmitted to the instructor through the webcam's microphone.

Activities

We developed six initial activities to explore use of Mischief. These activities are based on student workbooks given to us by Chinese instructors and on the practices we observed in the classrooms.

1. **Viewing a lecture slide**: non-interactive teaching content shown typically with the instructor's cursor acting as a telepointer to direct attention.
2. **Multiple-choice** (Figure 8): question and answer choices are presented on-screen and students click their choice. If desired, the activity can be anonymous and be answered using a mouse gesture (Figure 9a).
3. **Binary response**: a True/False or Yes/No activity answered using a mouse gesture.
4. **Short answer** (Figure 10): students simultaneously use a shared soft keyboard to enter their answer to a question. A single question can be post to all students or each individual student can be assigned their own. Each student is assigned an area of the screen where their keyboard output is displayed.
5. **Drag-and-drop**: enables individual student to drag objects around the screen or by requiring multiple students to drag an object simultaneously (Figure 9b).
6. **Drawing**: each cursor draws with their virtual pen.

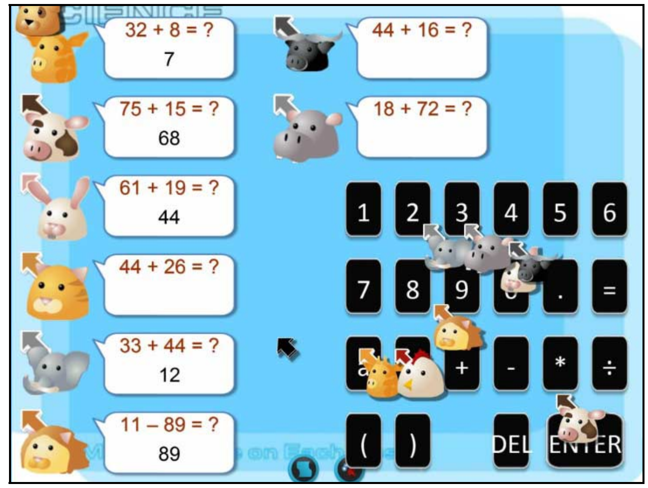

Figure 10. Short answer. Each student is assigned a personal output area with an enlarged version of their icon next to it (left side). The students simultaneously use the shared keypad.

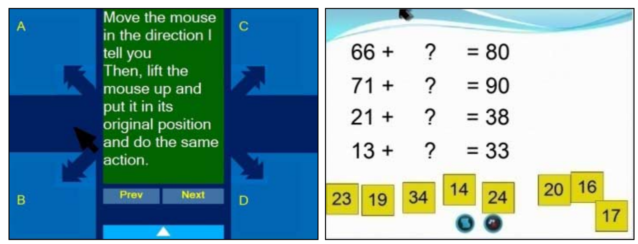

Figure 9. a) A multiple-choice training activity with visual indicators to show students which direction to drag their mouse, for anonymous responses. b) An example of using drag-and-drop to create an activity. The objects on the bottom must be dragged to their appropriate location.

Content creation

To make Mischief an extensible teaching platform, instructors themselves must be able to create educational content. Because many instructors already use PowerPoint and are familiar with its use, we designed Mischief to read and interpret PowerPoint files. This is commonly done with commercial Audience Response Systems (ARSs) such as [7] but is limited to bulleted lists that are rendered as answers of multiple-choice questions. In contrast, Mischief allows for complex activities using the fundamental Mischief actions described below.

To create one of the Mischief activities described above or to create custom activities, text, shapes, and objects are placed on the screen using normal PowerPoint features. Then, instructors 'tag' the shapes to describe that shape's Mischief behavior. Example tags include:

- "choice" (the shape is a multiple-choice answer choice)
- "keypad" (the shape is rendered as an interactive keypad as in Figure 10)
- "blank" (the shape is rendered as a short-answer blank, as in Figure 10)
- "drag" (the shape is drag-able)
- "scoreboard" (the shape is rendered as a list of the top students as dictated by the number of stars)

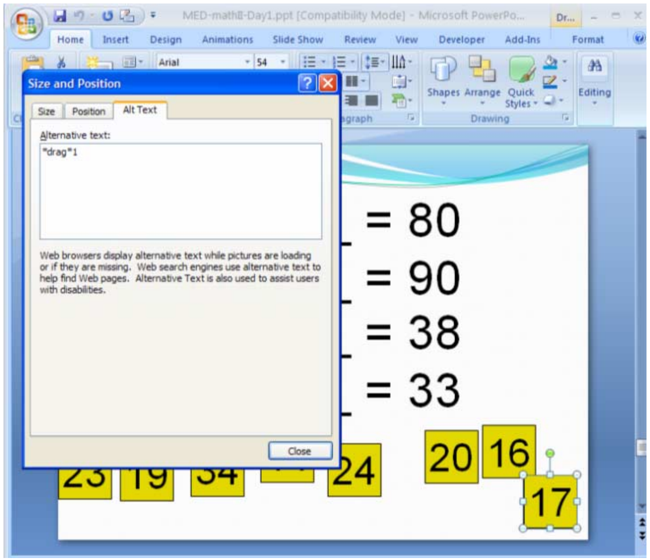

Figure 11. PowerPoint files are used to create interactive teaching content with basic computer skills. In our prototype, tags are entered into the "Alt Text" field of a shape. Here, a shape is tagged 'drag' to make it drag-able during class.

For example, Figure 11 shows a "drag" action assigned to the shape labeled "17" and specifies that only 1 student is required to drag it. When used during a class, students can click and drag the "17" shape to its appropriate location.

In this way, activities can vary widely or can use one of several PowerPoint templates (a concept which should already be familiar to instructors) that give instructors a shortcut to effectively designed slides (as in Figure 9a).

MISCHIEF DEPLOYMENT

We next describe our experiences using Mischief in a classroom and observations of how it was used to support classroom practices. These observations may help creators of related systems design user interaction elements.

User Study

We investigated use of the Mischief system in two different contexts. First, we had an instructor conduct four 30-minute *training sessions* where sample activities were used so the students could explore and learn the system. Second, she conducted a 40-minute *math class* that mirrored content that would have been presented in the regular math class. Mathematics was chosen as the subject because of its question-answer nature. The activities in the math class were chosen by the instructors and all content was presented in the students' native language. Each student also had a pencil and paper on their desk. The drag-and-drop and drawing activities were not used by the instructor.

We observed use of the system in China with a total of 58 children ranging from grade 4-8 in two classrooms and an actual math instructor. A remote teaching session was simulated by placing the instructor in a room adjacent to the class. In the classroom, two synchronized 19" monitors were used as the public displays (mirroring the practice we observed earlier) and a local adult facilitator was present. Audio and video transmission was provided using a webcam placed in each room. The instructor was able to detect who the speaker was and large movements on the screen but was not able to determine facial expressions due to low video quality. The Mischief system in use at that time supported 10 simultaneous mice so pairs of children were asked to share use of a mouse.

The training sessions allowed the instructor to have the students try several instances of each activity. The math class was prepared ahead of time, consisting of a mix of lecture and interactive exercises.

Usage Observations

The following subsections summarize the observations made from both classrooms we observed. Our goal was to examine how well Mischief supported interaction between the class and the instructor, particularly for the classroom activities we previously identified.

Blackboard

The instructor used a combination of her voice and her mouse to guide attention to content on-screen. Even when students' cursors were not activated they generally paid attention in case they were activated. Students often gave vocal instruction and hints to others who were activated if they themselves were not activated. Additionally, the students helped each other with use of the system when needed, which is particularly beneficial when the instructor is remote. The instructor commented on this, saying "When kids didn't know how to do things, they taught each other". We observed several instances where a child would control the mouse of another to help them.

Individual and group identity

Individual cursors in Mischief provided the students with a personal identity and voice which they seemed to genuinely associate with. Each student was allowed to choose an animal shape to uniquely identify their cursor and all students were able to remember which animal was theirs in a discussion following the study. The students enjoyed seeing their animal and they often took steps to ensure that their cursor was not occluded by other students' cursors.

The students also liked to hear "their" sound and some children would click an answer repeatedly to hear it often. This practice was distracting but auditory feedback proved useful because multiple students were able to click on the same button simultaneously and know when they clicked on it. Given the visual clutter on-screen, auditory feedback also alerted a student to the activation of their mouse.

Individual attention

The most common way the instructor gave individual attention to a student was to point to a student's cursor with her own. For example, when the instructor saw a student was choosing an incorrect answer in a multiple-choice activity, she would move her cursor to that user's cursor, simultaneously addressing them verbally (e.g. "yellow cat"). In this way, the instructor used the student's avatar for co-reference and attributed the motions of that avatar as an illustration of that student's decision-making process, a feature impossible with commercial ARS systems.

While each child's virtual actions were visible, the instructors found it difficult to get continuous and subtle feedback about each student's mood. One instructor commented, "In a real class I can see their facial expressions. With [Mischief], I can get a feeling of the total class status. I can know who is especially good or behind. But if a student got a question wrong, I can't know why they got it wrong. In a real class I could just ask 'What don't you understand?'"

One drawback with the current design was that the instructor could not refer to students by their names while the student list was closed because the student names were not visible at that time. Instead, the instructor referred to the students by their cursor description, such as "yellow cat".

Instructors also gave students individual attention by activating only that user's cursor while all other students' were deactivated, often during short answer activities. This action seemed to put peer pressure on the activated student because they now had to perform "on stage" in front of the other students. Normally rambunctious children quieted down when this happened, paralleling traditional classrooms. Once activated, that user's every action became visible to all others in the class (as in Figure 10), an activity not possible with ARS systems.

Positive public reinforcement

Stars were granted frequently, often accompanying verbal encouragement. Though stars were designed to be prizes given to notable students, they were distributed liberally (e.g. when an activity was complete and the instructor gave stars to all students who got the answer correct).

The stars were heavily coveted by students, which made public positive encouragement simple for the instructor. The visibility of these stars became an important factor; as indicated by one of the instructors, "In a real class I give verbal reinforcement. but with [Mischief], you can record it so I can see who is the best [across activities]." The importance was further illustrated by the instructor's desire to control them readily: "I should be able to take [the stars] away as well as give them."

Raising hands

The hand-raising feature was used heavily in Mischief. When the instructor was asking for a volunteer, a few students used it repeatedly to catch her attention (up to 174 times in 40 minutes). This speaks to the need for the instructor's attention to be salient. The hand-raising feature was useful in part because it is always available.

In at least one instance, the instructor asked the class to "raise their hands if they understood". Interestingly, all children used their virtual, not physical, hands in response. Although the students knew that the instructor could see them using the video, they may have felt that they could communicate better on the shared display.

Unison response

The instructors relied heavily on unison response while using the system. Unprompted by us the instructor asked many of the same rhetorical questions that elicit unison response in traditional classrooms. The students generally responded to these questions in two ways: verbal response and virtual hand-raising.

Gauging class status

To gauge class status as a whole, the instructors would reveal the student list. Done 20 times in the 40-minute math session, this became a metaphor for perusing the students and seemed to emulate an instructor's visual scan of a traditional classroom. Because the children and the instructor both had the same Mischief view, the children knew when the instructor brought up the student list and therefore, knew when her attention was on them (rather than on the class material). The effect was that, when the student list was visible, the students became quiet, paid attention, and awaited the instructor's action.

Mouse gestures

The instructors taught the children how to use mouse gestures by first practicing using activated cursors. During the training sessions, she gave them short tasks to ensure understanding of gestures. During the 4 training sessions, a 94.29% accuracy rate (140 instances) was recorded for Binary and 64.55% (110 instances) for Multiple-Choice.

Activities

The activities varied in their utility and applicability. When teaching new material, the instructor used non-anonymous multiple-choice and short-answer exercises where all students had the same problem. For small quizzes, she used anonymous multiple-choice or used short answer activities where each student had individual problems and could not copy answers from other students.

Though the teacher found the activities useful, she was unable to use Mischief in a dynamic manner. That is, during class, she could rely only upon static content she added to the PowerPoint beforehand. She could not generate exercises on-the-fly, reacting to the pace of the class.

Using binary choice as an individual activity seemed inefficient because it was easier to simply ask the children to raise their hands, virtually or physically, to answer the question. However, anonymous responses during multiple-choice was useful and the instructor voiced her concern that mouse gestures should be easier to perform.

When we designed the short answer activity, we were unsure how easy it would be for many students to use a soft keypad simultaneously. However, we found that students were not distracted by others clicking on the same keypad buttons and understood that their input was being displayed in their own section of the screen. Although slower than typing on a keyboard, the students were not frustrated. Indeed, they became quiet and focused, similar to when a student writes on a physical blackboard in front of a class.

MISCHIEF REDESIGN

Based on our user study results, we re-designed several aspects of Mischief to address problems and to more closely support traditional classroom practices.

Because Chinese classrooms can be so large, we redesigned the student list to support up to 256 simultaneous students. Because the teacher would sometimes forget the keyboard commands for the system, we added buttons to make the student list act as a menu (see Figure 12). Though this new student list occludes the slide contents, this is not problematic because making the student list visible is a method of showing the instructor's focus of attention.

Figure 12. The redesigned student list has menu buttons and capacity for 256 students by way of a scrollbar. The on-screen timer, requested by the instructor, is also shown.

The tendency for the instructor to often award stars inspired the idea of points that would make stars more special, like the red sticker on the child's forehead observed before. Students get a point for each correct answer in a session.

We simplified the anonymous responses of the system in two ways. Instead of gestures, which were difficult for children to perform, we use only combinations of mouse buttons. The legend (Figure 13) is on the screen, classroom wall, or on mouse pads given to all students.

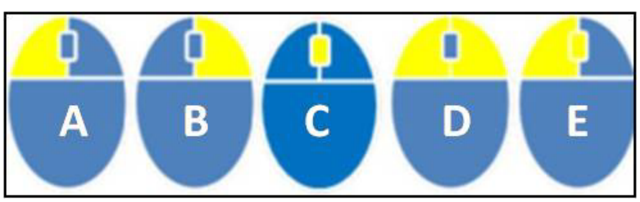

Figure 13. A legend, visible on-screen or elsewhere, shows a partial list of what buttons to press to answer a question.

Due to instructor feedback, we added a *timer* feature where a shape tagged "timer" would be rendered as a clock on-screen (Figure 12). When the clock is clicked, all cursors are activated and countdown begins. At zero, all cursors are deactivated. This is similar to commercial ARSs.

Because we observed that the instructor could not remember which cursor belonged to which student, the instructor is now able to toggle student names visible adjacent to their cursors. This could help build rapport between the two parties.

We wanted the teacher to be able to respond dynamically to the pace of the class. So, the instructor can load one of several pre-defined *generic* activities such as a slide with 20 short answer blanks and no question filled in. The instructor can then assign problems from a textbook that the students have physically in front of them, announce the problem verbally, or type the question into the slide directly.

CONCLUSION

This work has introduced a novel system that supports traditional classroom activities by providing synchronous interaction between each student in a class and a remote teacher. Seven impactful observations in rural schools that led to the design of Mischief were also presented.

Mischief provides this benefit while remaining low-cost compared to using one computer or PDA per child. It enables all children in the class to be active, thereby addressing the problem of engagement during remote teaching. Mischief lets the instructor give individual attention to students and to put students "on stage" for added pressure. These factors improve upon existing ARSs.

The process of designing and evaluating the Mischief user interface provided insights to designers of such systems. These include the simultaneous use of widgets, anonymous responses, mouse gestures, auditory feedback, an instructor-controlled student list, and other means of communicating focus of attention and clarifying the role of the teacher.

The aim to make Mischief a platform, rather than an application, is drawn from our observations in the field. This observation led to the use of PowerPoint as a flexible content development mechanism. This decision is one of many that derives directly from our user observations and is presented to aid future designers.

Illustrative videos of the system in action are at [21].

Future work

We are excited about the Mischief's potential and have learned a great deal about its use. Our first step is to conduct several short-term and longitudinal studies to evaluate the redesigned Mischief system.

From a pedagogical perspective, we are also interested in developing new activities and further empowering educational content designers to use Mischief as a platform.

Given the importance of instructors giving private, feedback to an individual student, we plan to provide a virtual means of doing so while using Mischief.

From a hardware perspective, we will experiment with using wireless mice and other low-cost peripherals such as keyboards.

We are developing a PowerPoint add-in so that instructors will not need to tag shapes manually. To design the add-in, we will study how teachers in developing countries currently aggregate teaching content.

The use of Mischief in classrooms with a collocated instructor is also interesting, as is using it to augment static educational video so that broadcasted content can be made affordably interactive in developing countries.

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