Modeling Chinese Classrooms for Low-Cost Ubiquitous Interaction in the Classroom

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1. ABSTRACT

This paper presents a novel method of improving classroom technology access in developing regions for use in distance and co-located education. By placing a mouse on each student's desk in a classroom and connecting those mice to a single computer, the system affords simple anonymous and non-anonymous student interaction with a remote or co-located teacher. User interaction features and metaphors modeled directly from numerous classroom observations are presented. The results of user studies conducted in rural China and India indicate that the system is easy to learn for even novice students in developing regions. A discussion of the user study results found the system lends itself to a game-like classroom atmosphere where students can interact as a member of the group or as individuals and engagement is encouraging. A discussion closes the paper, indicating how the findings have implications beyond distance education and in teacher-mediated instruction and related classroom activities.

1.1 Author Keywords

Education technology, rural computing, distance learning, user interface, user study.

1.2 ACM Classification Keywords

H.5.2 [Information interfaces and presentation]: User Interfaces

2. INTRODUCTION AND MOTIVATION

Education is a crucial factor in any discourse on economic development and consequently there is much interest in the role of ICTs in education in developing countries [8, 34]. Evidently, the issue is not a simple as to be solved by placing computers in schools, as education pedagogy must be taken into account. Education in developing countries suffers from numerous problems such as a lack of funds and basic infrastructure, among other issues [16]. A key problem among these is the shortage of competent and motivated teachers [16], especially in rural areas due to urban migration. Among existing rural teachers there exist problems of absenteeism [28], overwork, and a lack of subject expertise.

It is widely recognized that a need exists to provide mass access to high quality teachers or learning content in developing communities. Many possible solutions have been proposed including broadcasting educational television [4] and radio [33] stations, sending pre-recorded lectures via DVD [45], and real-time distance education (DE) [42].

Introducing computers into such schools is commonly believed to be a plausible solution because it is scalable, measurable and susceptible to quality standards. However, a lack of appropriately-designed content and interaction techniques have made such experiments often fall short of their claims [21, 39] and computers are expensive.

In this paper, we introduce and discuss a Mouse on Each Desk (MED), a hardware and graphical user interface design combination that acts as a relatively inexpensive framework for shared, real-time classroom interaction with virtual content or with a remote teacher. MED is based on the idea of putting a mouse on each desk and attaching those mice to a single computer with extra-long cables. This allows a large number of students to interact with the teacher simultaneously (as in a real classroom) without crowding around a single computer.

The design of MED is presented in the domain of real-time distance education. This was done to recreate classroom behavior to such an extent so as to not require the teacher to be present. The result is a system that contains functionality that may also be useful for co-located teachers.

Initial evaluations of MED shows that even students from rural backgrounds who are novice computer users can learn to use the system quickly and identify with their cursor as a representation of themselves. The engagement of the students during a remotely-taught class was generally high and motivates a longitudinal study. This elevated engagement is an indicator of educational value in that it given appropriate content. The teachers in the studies were enthusiastic about the system after initial usage and basic system functionality was learned quickly.

2.1 Distance education

The uneven distribution of skilled teachers begs the design of remote teaching systems to connect urban teachers to rural children.

Broadcasting educational content is a viable option but is neither individually focused nor necessarily interactive. Efforts have been made to increase interactivity by having content mediated by local teachers such as in the Digital StudyHall (DSH) project [44, 45]. In DSH, high-quality lectures given by urban teachers are recorded and played in rural classrooms, mediated by local teachers based on the TVI model.

In these and related approaches, direct, real-time bi-directional interaction with a qualified teacher is still absent. Addressing this, some countries have invested in bi-directional audio-video systems for educational use, sometimes via satellite. These are almost always restricted to higher institutions (e.g. [30, 42]) due primarily to their high cost. The present work explores the notion that if real-time DE were inexpensive and designed to mimic traditional classes, it may be a viable model of improving rural education.

DE herein refers to scenarios where an instructor in a urban area teaches a more rural classroom filled with co-located children. This differs significantly from Western interpretations of DE where all participants in the class are geographically distributed.

3. RELATED WORK

Many remote collaboration systems in both research and industry (Microsoft Live Meeting, WebEx Meeting Center, Macromedia Breeze, Lotus Sametime, and Centra) exist, though their dominant focus is holding distributed meetings in corporate environments [48], and include concepts such as application-sharing, shared annotation, floor control, whiteboards, and voting. Social, interaction and organizational factors are key and include a need for simplicity [48], recreation of social interactions normally absent in formal remote meetings [25,31], and contextualization[46].

Such systems have been applied to "distance education" scenarios in the traditional sense [15, 46]. [32] outlined the numerous ways in which technology products interrupt and impede virtual classes. Tools also exist for one-on-one remote teaching [43], and mediated remote education [10].

Much DE software takes the form of web-based courseware so that all parties can access the content independently. In the present DE system, the problem is bridging gap between class and teacher, not between students.

A different body of work focuses on technology use by individual students within a traditional classroom, primarily to get real-time feedback [3] and student submissions [2, 3, 47] Methods for anonymous and non-anonymous, structured and free-form individual feedback can be used to motivate students (though anonymity can lessen it) and aid the instructor.

From an interaction perspective, [24,27,29] note that Instructors in the remote teaching process should have sufficient feedback, or visual cues [46], to stay engaged and "motivated", or may perceive a "lack of interest" and possibly "get offended" [25].

Research into supporting social 'awareness' [20] and translucence [13] via technology applies directly for increasing feelings of connectedness between remote parties. talk of creation of a "common ground" in order to transmit the "presence, positions and actions of other people in the virtual space", these relate to the concepts of social and workspace awareness. [20] and MED attempt to address them.

The model of Single-Display Groupware (SDG) [41] was successfully applied to education by [9,22,23,35,38,40]. Multiple mice have been found to lead to higher engagement, better task performance, and also affect collaboration and motivation

4. USER RESEARCH OF THE CHINESE RURAL EDUCATION SYSTEM

The project was motivated by problems present in most developing nations but in order to deeply understand and model an actual classroom culture, we isolated cultural variables by conducting observations in only Chinese schools. The observations were corroborated by researchers in India.

4.1 Methodology

Our inquiry aimed to understand cultural aspects, the infrastructure, technology usage, and how DE is currently being used in China. We visited 5 schools in 2 Chinese provinces: 1 urban (7^{th}-11^{th} grade), 3 semi-rural (1^{st}-3^{rd} and 4^{th}-6^{th} grade), and 1 rural (1^{st}-3^{rd}). Among these, we observed 10 classroom sessions of grade 2-10 and interviewed 20 teachers. Each class had about 50 to 80 students for a total of about 600 students. We also visited 3 distance education sessions with a total of 56 teachers viewing the content: 1) 10 teachers in a semi-rural school's computer lab with two elevated computer monitors, 2) 40 teachers in a semi-rural multi-purpose room equipped with a projector, and 3) 6 teachers in a rural school's equipment room on a computer borrowed from the local internet café.

We always had at least one native Chinese researcher with us to translate and contextualize the observations. The classes and teachers we observed were chosen by the school administrator. For this reason, our observations are potentially subject to the Hawthorne effect.

4.2 Distance education sessions

Our visits to the Tsinghua Distance Education Center [42] allowed us to see the highest level of China's approach to DE as Tsinghua University is China's premiere technical institution. Their approach relies on synchronous and asynchronous teaching sessions where the content is sent to, and viewed by, rural high schools in different ways. Real-time classes are not feasible due to the equipment required to send and view the material.

Figure 1. Left: Elementary school teachers viewing drawing instruction in a pre-recorded lecture from a top university. Right: Teachers view instruction material on an elevated monitor in a computer lab. In both, no interaction or discussion took place.

In the DE sessions we observed, teachers watched the pre-recorded lectures intently and were engaged. However, no teachers asked any questions or started any discussions. The lectures were digitized and shown using relatively expensive equipment. However, we did not see any advantage over using VCDs and TVs to display the content. The timeliness of the lectures did not seem relevant.

4.2.1 A lack of real-time distance education

The reason that the universities primarily produce content for teachers is because it is more efficient to teach teachers than to attempt to teach all of China's rural youth. This is because use of the university's purpose-built, state-of-the-art DE classrooms is expensive. Disseminating the equipment necessary to conduct such sessions is also prohibitively expensive.

Such systems use speaker-sensitive and strategically positioned microphones and video cameras to make remote participants feel they are part of a lecture. The efficacy of such DE systems is thought to be a function of the quality of audio/video transmission, speaker identity, and detection of the object-of-focus (e.g. the blackboard). Such automatic detection is far from perfect. For these reasons, real-time DE is currently a high-risk investment existing between select institutions of higher-education.

After these observations we set out to model what we considered essential social classroom interaction in an inexpensive manner to make real-time DE feasible for developing regions.

4.3 Social behavior in traditional classrooms

The observations of social behavior in the Chinese classrooms that most influenced our design can be broken down into two types of interaction:

1. Teacher-class: Blackboard usage, unison response, and gauging class status.
2. Teacher-student: Blackboard usage, positive reinforcement, individual attention, and hand-raising.

4.3.1 Blackboard usage

In addition to standard extensive use of blackboards in the traditional sense (i.e. teacher-class interaction), a less frequent but important use for blackboards is for student presentation (i.e. student-teacher interaction). A teacher may ask up to 5 students to "come up to the board" to write their answer to a question (see Figure 2). This is used as means of public display and public positive/negative reinforcement by the teacher.

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

4.3.2 Personal and group identity

The teacher addresses the children by name, and recalls their scholastic progress. Students were often put in groups for activities and these groups have names and representatives. Answers from the group are given by a representative.

4.3.3 Individual attention

By physically pointing or making eye contact, the teacher transfers her own and the class's attention to individual students. This serves two purposes: 1) for children to feel that they 'count' and are being tended to and 2) to give the student an opportunity for public response to a question.

Figure 3. A teacher making eye contact and pointing at a student in order to grant individual attention.

4.3.4 Public positive reinforcement

Positive reinforcement comes in many forms and is most valuable when a student's peers see it. For example, a teacher awarded a young child by applying a sticker directly to the child's forehead so that other children would notice it. In another class, the teacher had the class applaud individual students by clapping or chanting rhythmically when those students answered a question correctly. Most often, teachers simply gave verbal compliments.

4.3.5 Raising hands

The practice of hand-raising is culturally relevant. In China, children raise hands to answer questions, volunteer for activities, or to vote. Students seldom raise their hands to ask questions.

4.3.6 Unison response

Frequent interaction between the teacher and the class helps to maintain engagement and set a rhythm, especially in large classes. This is often done with quick, rhetorical questions like "That's what we saw earlier, right?", "Is everybody with me?", and "Raise your hand if you understand." These elicit vocal and physical unison responses and create a unique pace of the class (see Figure 4). While unison, or 'chorus,' response is not unique to China, it holds an especially important role here.

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

4.3.7 Gauging class status

The teacher continually, quickly, and almost imperceptibly ascertains the high-level status of the class as a whole in three ways: visually, audibly, and spatially. Visually, she scans the class to see outliers or unexpected behavior such as poor student posture (see Figure 5). Audibly, if she's looking at the class or not, she listens for children's voices, papers rustling, lack of sounds (implying they are working quietly or perhaps confused), or chairs moving. Spatially, she recognizes and recalls certain areas in the class as problematic or particularly receptive.

Figure 5. A teacher visually, and audibly, and spatially observes class status.

5. SYSTEM DESIGN OF AN INEXPENSIVE CLASSROOM INTERACTION METHOD

This section presents a method of classroom technology access to improve the real-time DE experience.

5.1 System setup and requirements

Both parties (teacher and class) communicate orally via a standard telephone network but this could also be streamed via the digital network, if bandwidth is sufficient, bi-directional video is streamed via common webcams.

The teacher has two displays: a bird's eye view of the classroom and a shared graphical user interface (the MED application) controlled by keyboard and mouse. The classroom has two corresponding displays but the video is replaced by a video of the teacher (a 'talking head'). Mice with extra-long connecting cables and placed on the desk of each student (if sufficient mice are available). If this is not feasible, small numbers of students can share a mouse. The mice are all connected to the same computer.

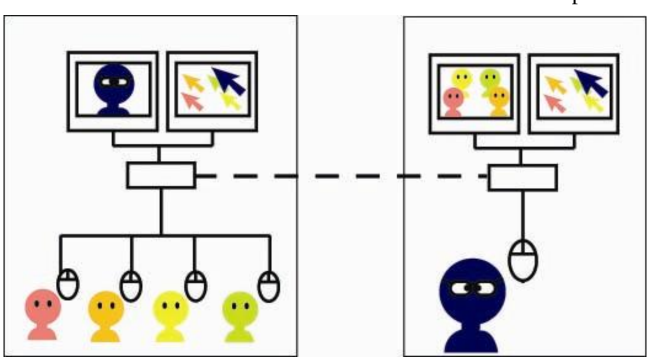

Figure 6: Using single-display groupware with mice cables long enough so students can sit at desks.

The MED system assumes clear audio from the teacher to the class and relies more on an appropriately-designed MED application rather than being dependent of video quality. For this reason, MED could be used from homes of teachers rather than expensive DE lecture halls. A teacher or facilitator in the classroom acts as a caretaker and this could also act as a form of teacher-training where rural teachers learn new techniques as they watch an urban teacher teach their students, similar to DSH [44].

Such a system should allow for a 'backchannel' for communication from the students to the teacher. More than a method of getting questions from students, a backchannel provides an ambient sense of awareness about the class for the teacher. As discussed in the related work section, a critical factor for success in DE systems is the remote teacher's awareness, affecting motivation and engagement.

6. Interaction DESIGN

This section first describes the visual and interaction design precepts of the MED application then describes how they reflect the classroom observations. The goal of the system is to increase student engagement [7, 37] with a remote teacher and offer multiple modes of interaction akin to traditional classrooms.

The MED application, based on the Multimouse [36] implementation, is a virtual space shared between teacher and class, meant to augment the bi-directional audio and video communication. Both parties see an identical user interface in real-time.

6.1.1 Cursors and identity

Each participant (or group of participants if there are not enough mice) is represented on the virtual blackboard by a unique cursor as in [17]. The teacher's cursor is the larger black *supermouse* and the cursor of each student is a cartoon animal in a unique color, shape, and feedback sound (Figure 7). The number, color, and cartoon animal character is visible on the corresponding physical mouse. Some widgets respond to input from the teacher's cursor and some only from students'. When a student's cursor is visible clicks on a legal target, that animal's noise is played. This is done to increase feelings of connectedness to the avatar and to reinforce the unique identity of each student. Further, the teacher may recognize patterns of student interaction (e.g. "the 'lamb' always answers first"). This could improve teacher awareness of the class.

6.1.2 Student list

The teacher can toggle the display of the *student list* where she can see the students' answers in the current *activity* (described below), and the number of *stars* (described below) they have received in the session so far. This information is aligned horizontally for quick vertical scanning. The teacher can left-click on a student's name to *activate* or *deactivate* each individually. *Activating* renders that student's cursor visible. The teacher may right-click on a student's name to award a *star*. When this occurs, all parties see the congratulatory auditory and visual feedback.

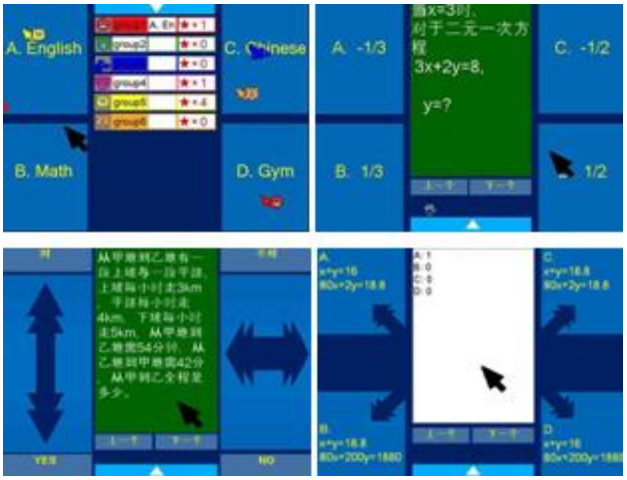

Figure 7. UpperLeft: Student list opened and students activated. UpperRight: Multiple-choice with a student's hand raised. LowerLeft: Binary question with student cursors deactivated. LowerRight: Multiple-Choice activity with student answers visible when the teacher left-clicks.

6.1.3 *Raising hands*

At any point, students can raise their hands to display a small visual flag next to that student's name in the *student list* and in a separate designated area for instances where the *student list* is closed.

6.1.4 *Activities*

From [7], "Two other simple yet effective ways to involve students during a lecture are to insert brief demonstrations or short, un-graded writing exercises followed by class discussion. Certain alternatives to the lecture format further increase student level of engagement." MED is based around 4 *activities* whose order and frequency is controlled by the teacher and are described below:

1. Viewing a lecture slide (as with Powerpoint)
2. Multiple-choice questions (4 possible answers, done by clicking a choice)
3. Binary questions (e.g. true/false, done by mouse gestures)
4. Shared keypad input (come-up-to-the-board)

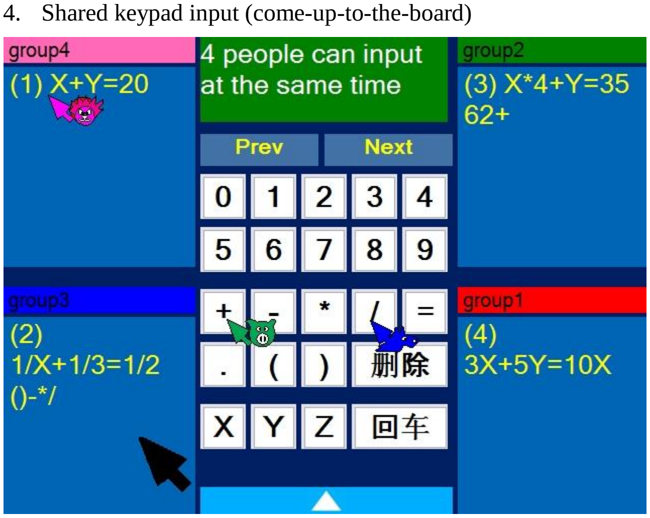

Figure 8. Shared Keypad Input activity. Four students have been activated to complete math problems.

6.2 Supporting social interaction

Here we describe how the designs support our design goals.

6.2.1 *Individual attention*

Cursors as telepointers have been found to help mediate conversation, support gestures, and communicate focus of attention between remote parties [18]. They have similar advantages in educational use [1]. In MED, the remote teacher is able to click on different interface elements to simulate direct eye contact with students. The teacher can click on an answer in the multiple-choice activity to see which students chose that answer. The teacher can also click *atop* a student's cursor to see that student's answer for the current activity displayed next to their cursor (akin to looking a student in the eye and asking them their answer in a classroom).

The teacher can also choose one student to correct the work of another student's by deactivating the active student and activating the new student, whose keypad activity will be displayed in the former's workspace. This method of transferring virtual workspace ownership differs from shared whiteboard models in that it is based on SDG.

6.2.2 *Unison response*

Multiple students are able to give answers simultaneously during an activity and the teacher is able to inspect those answers in an efficient manner by scanning the *student list*.

To ensure the pace of the class matches that of an actual class, we attempted to support the response and acknowledgement of the quick, rhetorical "Yes/No" questions described above. The question is asked over audio and students answer with simple, explicit mouse gestures modeled on shaking one's head "Yes" or "No" (Figure 7). This method could supplant or augment voice responses, depending on the audio connection quality. To recreate the anonymous submission ideas of [2, 3], users can perform the gestures with their cursors visible or invisible, as decided by the teacher.

Another method for binary responses from class entails the student right-clicking to "raise a hand", displaying a small icon in that user's space (Figure 7) as in [48].

Anonymous responses during the multiple-choice activity are done when the teacher chooses to deactivate all students in the class during a multiple-choice activity. Students must position their invisible cursors in the desired target area given no feedback of their cursor position. This results in a repetitive drag motion towards one of the four corners of the screen (we call this 'petting the sheep') (see Figure 7).

6.2.3 *Gauging class status*

In addition to being able to scan the *student list* at any time to get a sense of the status, the teacher has an ambient auditory method of feedback in the form of *audible mouse activity*. If any student cursor is moved (visible or not), a subtle, aquatic-like sound effect is emitted on both the teacher and class's sides. This is, in effect, a construct to replicate the ambient class sound for the teacher's benefit. This helps augment the visual feedback the teacher is getting from the webcam, or supplants it if it's un-available.

7. EVALUATION

Our studies focused primarily on observing initial reactions to the system, before users appropriated or adapted to it over time.

7.1 User Study Design and Participants

We introduced the MED system into different contexts of use in order to gain a high-level understanding and to prepare for more focused studies. We ran 4 different types of sessions using the MED system: 1) 30-minute ‘Tutorials’ where the system was shown to students and the activities were explored, 2) 20-30-minute ‘Math Classes’ that mirrored real classes. Session types 3 and 4 were *co-located* versions of types 1 and 2, i.e. the teacher was in the same room as the students and used the same shared display. The studies were conducted in both China and India, with a total of 88 children and 2 actual math teachers from developing parts of their respective countries.

The Tutorials began with the teacher asking the children to ‘Follow my cursor to this position’ and eventually covered all the activities, allowing each child to try the features. At the time, our application and interface only supported 10 mice at a time, so many children shared. However, this makes the study environment somewhat realistic.

Mathematics was chosen as the subject because of ITS question-answer nature. The activities exercises in the Math Classes were chosen ahead of time by the teachers themselves. Each student had a paper and pencil on their desk.

7.1.1 User Study in China

Two studies administered 1 week apart were administered outside Beijing, China at Xingzhi School, a semi-rural school for the children of migrant workers, chosen as the children are recent migrants from rural provinces. In total, 58 students (30 female) from grade 4-8 participated, (30 students in the one study, 28 in the second). The studies were done during the summer so students participated in their free time.

83.3% of the students used computers only once a week. Indeed, only 56% of the students rated themselves as “comfortable using a mouse.” A 24-year old high-school teacher from Beijing with computer experience was hired as the remote teacher and given a 2-hour training session with the system.

The teacher pre-planned the activities, by mirroring one of her actual math lesson plans, telling the developer what content to display on the screen. She also had a 2 hour training session to practice using the different features. A facilitator was present with the students, documenting the process but not interjecting or mediating. In their first use of the system, the students did not know the teacher or facilitators before the experiment.

A remote teaching session was simulated by placing the teacher in a room *adjacent* to the class. In the classroom, 2 19” monitors showing identical images were used rather than a projector. Audio transmission was done via microphones embedded into the webcam into each room. The quality of the audio was quite low, especially on the teacher’s side. The video transmission to the teacher was done with a common webcam. The teacher was able to detect who the speaker was and large movements in the screen but was not able to determine facial expressions.

Figure 9. One of the user studies in China. Two monitors display MED and one displays the video of the teacher. These could be combined into a single display.

7.1.2 User Study in India

The India study was conducted in an after-school center for rural children near Bangalore, India. The 30 10^{th} grade semi-rural students (17 girls) had come to the center before. The age 30 male math teacher usually tutored students after school for extra pay. Normally he uses a blackboard but he used the MED system with a projector for one of classes. A 20-minute Tutorial was followed by a 30-minute Math Class. The teacher was co-located with the students to observe how the MED system was used in such a case. He was encouraged to teach the content via MED as much as possible in order to maximize our observation time.

Figure 10. The India user study. Students sit in groups, filling in a questionnaire. The location of the mice is highlighted.

8. RESULTS AND DISCUSSION

The results of usage with individual interface components are presented as they contribute to our observations of how the system affected the overall class experience. Overall, the system contributed to a collaborative, game-like mode of use where students felt like part of a larger group as well as individuals.

8.1 A collaborative social game

Many students likened the system is comparable to a game, probably because of the question/answer format and the visual design. General system interaction began to seem simple, but in both India and China the ‘game’ feeling meant that students were sometimes distracted by the visual and audible feedback for various mouse actions. Game-based learning, however, has been lauded as a useful tool in increasing learner engagement [37].

Vitally, we observed a strong social nature of students helping each other when using the system. This “interdependence such that learners need one another in order to succeed, and social support” was observed in [26], a comparable system. Because mouse control is generally simple, helping one another became simple as well. Such sharing and social use in a game-like experience technology may be possible with notebook computers but the present system seems to make such collaboration especially simple and affordable for developing regions.

Sharing mice was more agreeable than anticipated. Such practice may actually be preferred as claimed by [2]. In that work it was preferred to have students share technology devices in the classroom rather than have their own. Indeed, we witnessed groups voluntarily cheering one another on when they were awarded stars.

A possible avenue of exploration in this area is to support interaction between student avatars as a means of collaboration between students. This might reinforce the game-like nature as well as emotional bonds to one's avatar.

While encouraging, this game-like classroom culture mirrors our user research to only a certain extent. Our user research found rural classes to feel more like drilling-sessions interspersed between uninterrupted lectures. They were not necessarily fun and such game-like activity is frowned upon in rural classes. In urban schools, we sessions of collective inquiry take place where discussion was very important. MED has little support for such discussion and relies on audio/video communication to do so.

8.2 Transition of focus from class to individual

We observed a clear distinction between holistic classroom interaction, where students operated more-or-less anonymously (i.e. not singled out), and attention focused on a single student or small group of students. This use of MED follows the intended design.

8.2.1 Uniquely identifying remote students

The remote teacher addressed students by their group number or animal because they did not know the names of the individual students. The teacher would often address activated students by their avatars (e.g. "green piggy") or use the video image to qualify the reference (e.g. "girl in group 7"). This was due to the fact that the developers did not know the student names beforehand. This could be mitigated by a simple name-input process before class starts. Notwithstanding, we did find that students identified strongly with their animal and happily responded to being referred to as such.

8.2.2 Discipline

The remote teacher administered discipline verbally (e.g. "The boy in the green shirt, yes I'm talking to you – look at the monitor"). Such verbal discipline interrupted the flow of the class, as validated by the teacher comment, "Even if I'm angry, the kids may not care." Simply activating a student became a common method of getting that student's attention, sometimes for discipline reasons. Similarly, displaying the *student list* was sometimes used as a means of communicating to the class, "I am looking directly at you."

8.2.3 Pressure to perform

Most children learned shared keypad input quickly and its use was successful for two reasons. First, when a student used the keypad, their every action was seen by the class, just as when writing on an actual blackboard. This increases social pressure but also secures the attention of peers. Second, the speed of writing using the keypad is quite slow, but again this is akin to writing on a physical blackboard. This reinforced the 'performance' feeling of 'going up to the board.' During keypad activities, the class generally became quiet and focused intently on their peer's mouse movements. This activity was a successful method of transferring attention and scrutiny to individual students.

When compared to multiple-choice answering, a clear difference can be drawn as compared to shared input. In multiple-choice, the students often clicked often and changed their answers, knowing they were seen as only one of 10 moving cursors and could not be tracked. When the *student list* was opened, however, students felt the virtual 'glare' of the teacher. Such a dual-phase activity was useful in transitioning attention.

8.2.4 Public positive reinforcement

Stars were granted very often across both teachers, most often accompanying verbal encouragement. Though stars were intended to be 'special' prizes given to especially good students, they were often distributed liberally (e.g. when an activity was complete and the teacher gave stars to all students who got the answer correct). This observation motivates different magnitudes or methods of encouragement.

Stars might be more relevant if MED was used over time and they could be visible from one session to the next. In the current version, a student's number of stars is visible only when the *student list* is opened. Having the stars constantly visible (i.e. directly on students' cursors) may better reflect practices in actual classrooms.

The Chinese teacher mentioned that older students "won't care about stars," a comment confirming our own user research. Providing positive reinforcement for older students must be done differently, and this restricts the present method to young children (i.e. perhaps under 13). We plan to look at successful games to design a different encouragement method for MED.

8.3 Summary

The MED system was originally intended as a means of increasing social awareness and engagement in a way that resonated with children in developing regions. Inadvertently, the system looks and feels like a game due to the visual design, quiz-like activities, competition features, physical activity brought on by mouse gestures, collaborative opportunity, and pressure arising from public performance. This game-like experience could be reinforced further by various means in order to increase educational value [14].

As found in [2, 3], student interaction techniques can give a voice to even shy students in the classroom, potentially increasing participation as a whole. Techniques for further improving upon student voting and submission methods by MED interaction techniques could also increase participation.

In the co-located study, the teacher often mediated digital education material (e.g. CD-ROMs) in previous classes with those students. Our comparison of the MED session to these mediation sessions was that the possibility for interactivity retained student engagement and increased the level of discussion dramatically, though this is in part a result of the Hawthorne effect. This could make such SDG systems useful for TVI systems such as DSH and for improving engagement with previous non-interactive educational radio and television stations.

Making each student feel like they count and that they have the opportunity (whether positive or negative) for individual scrutiny is a crucial feature for any remote collaboration system. MED presents multiple ways of achieving this.

9. CONCLUSIONS

We demonstrated a working model of this interaction and studied how this was used by students and teachers in our target communities.

This work proposed a model for dealing with lack of teaching support and individual access to computers in schools in developing regions. First, observations of classroom behavior in rural China were presented. Then, it a novel method of classroom interaction was introduced, based on a novel form of SDG. This interaction technique is then applied to the application of distance learning. The MED application was evaluated in multiple teaching scenarios in two representative developing countries, China and India. Results and observations of system usage were categorized and presented, pointing to classroom cultural changes that occurred as a result of using the system.

The novelty of this work lies partly in its elegantly simple means of achieving classroom participation with a digital tool. Further, the application of SDG to remote teaching in developing regions has shown promise in improving social awareness and student engagement. From an interaction design perspective, the utility of toggling visibility as a means of indicating locus of attention has been presented. Finally, the context of the user study is novel in that deployment is so difficult and published results rare.

Through a discussion, the merits and points of improvements have been collected, with the findings shown to have implications beyond distance education and into classroom activities, TVI, and other locally-mediated content such as CD-ROMs and TV content.

9.1 Next steps

At least three significant efforts are necessary to improve this body of work. First, longitudinal observations should be done to assess how usage of the system varies over time and how education is altered (if at all). Second, the application of MED to other applications such as TVI is has interesting possibilities. Third, iteration of the design is required given the findings of the present user studies, and more formal usability evaluations are also required.

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