ScribbleProv: Supporting Disciplined Improvisation During Face-to-Face Discussion

YEAR 1 REPORT: ACTIVITIES

Executive Summary

We have categorized the activities conducted during the first year of the ScribbleProv project in terms of 6 activities: theory development, software development, activity development, evaluation, dissemination and outreach, and synergistic activities. These activities are described in detail in this report. In summary, we:

- Developed a framework for how improv techniques are enacted, modified, and augmented in the classroom, through transcript analyses, pilot tests, and design discussions
- Re-designed Group Scribbles to improve the stability, performance, and extensibility of the software
- Generated a set of activities to exercise the space of Group Scribbles functionality for use in our pilot studies
- Refined the software based upon informal feedback from other groups at CTL, an extensive network of collaborators, and four small pilot studies
- Promoted the software, activities, and finding through several forums, including a newsletter, a project web site, a community wiki space, and presentations
- Collaborated with a number of researchers, K-12 teachers, and their students from around the world—including the U.S., Singapore, Spain, Taiwan, and England—providing professional development and training opportunities and resulting new highly-rated papers submitted to conferences

Activity 1: Theory Development

A number of researchers and teacher educators (e.g., Borko & Livingston, 1989; Sawyer, 2004; Lobman, 2007) have drawn parallels between expert teaching and theatrical improvisation (Polsky, 1998; Spolin, 1999). Some (e.g., Sawyer, 2004) has called for the use of improvisation as a new metaphor for teaching, and others (e.g., Lobman, 2007; Lobman & Lundquist, 2007, Shechtman, Kim, & Knudsen, 2008) have trained teachers in improvisational techniques.

Despite the suggested importance of improvisation, little empirical analysis has been done of how expert teachers use improvisation in the classroom. Further, computational tools to support classroom discussion have focused on supporting a fixed repertoire of activities such as multiple-choice assessment, ranking, or concept mapping. Missing is a characterization of how teachers use (or don't use) improvisation in the classroom and how tools adapt to their unanticipated needs.

In this work, we set out to identify teachers that exhibit improvisational skills, focusing on expert teachers who are knowledgeable in their discipline, exhibit improvisational techniques, and are in a school environment that supports a constructivist approach to teaching. We narrowed our search to middle school mathematics teachers in order to focus our research and build on our knowledge from a related project at SRI, called Bridging Professional Development (Shechtman, Kim, & Knudsen, 2008). The Bridging project aims to provide middle school teachers with specific methods for applying newly learned mathematics to their classroom practices, calling on math content knowledge, teachers' established wisdom of practice, and techniques from theatrical improvisation.

We reviewed over 40 classroom transcripts from the Bridging project, and from these, chose 5 transcripts of expert teachers for coding and deeper analysis. In this case, "expert" was defined as teachers who (a) scored highly on measures of Mathematical Knowledge for Teaching (MKT) and (b) promoted mathematical argumentation in the classroom (i.e., more and higher quality episodes of mathematical arguments were co-constructed between the teacher and students in the classroom). We also conducted working meetings with the Bridging project team to enact Group-Scribbles-like activities and learn more about the needs and gaps they have identified during their classrooms observations and how these gaps could be addressed by technology.

In the Findings section of this report, we describe the core techniques of theatrical improvisation; similarities and differences, based on our analysis, between theatrical improvisation and teaching techniques; our framework for improvisation in the classroom; and implications for extensions and refinements to Group Scribbles to better support productive collaborative activities in the classroom.

Activity 2: Software Development

Co-PI Nathan Dwyer led a redesign and rewrite of the old Java version of Group Scribbles (GS1) to Adobe Flex, using LiveCycle Data Services for the back end instead of TSpaces to improve stability, performance, and extensibility. The new client runs on any device that supports Flash. Alpha and beta versions of Group Scribbles 2.0 (GS2) were tested in March and April, and an initial release will be made available in June 2008. The new architecture allows developers to easily extend GS2 (e.g., create and drop in new tools) and will simplify multiple, parallel development efforts.

All of the features of GS1 were implemented in GS2 (e.g., scribbles, pads, boards, background images, line and text drawing tools, panning, zooming). Figures 1-3 show screenshots of the existing implementation of GS2.

In spring 2008, we worked with an interaction designer to design icons, color treatment, and branding for the GS2 interface. The new interface design is currently being implemented, and we expect it to be completed before our June 3 evaluation study.

The theoretical understandings derived from our analysis in Activity 1 suggest a number of extensions and refinements to Group Scribbles so that can it better support productive collaborative activities, particularly when teachers need to make real-time accommodations to a breakdown that triggers a change in approach. New features derived from the theoretical framework (e.g., auto-generated background screens, support for deixis, improved support for group work) are described in the Findings section of this report. Development of these features will begin during the summer of 2008 (end of Year 1).

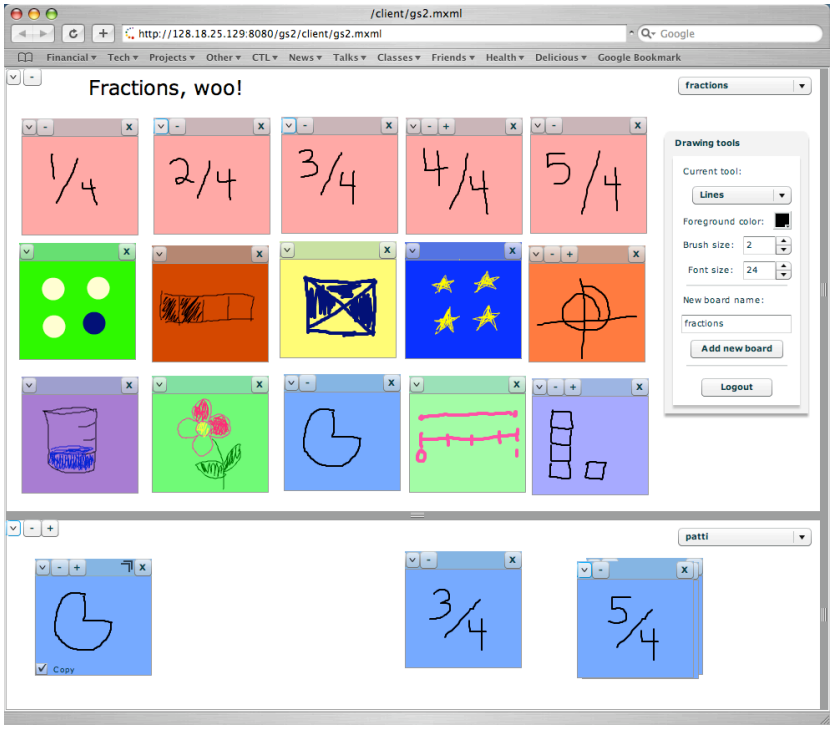

Figure 1. Fractions activity in GS2.

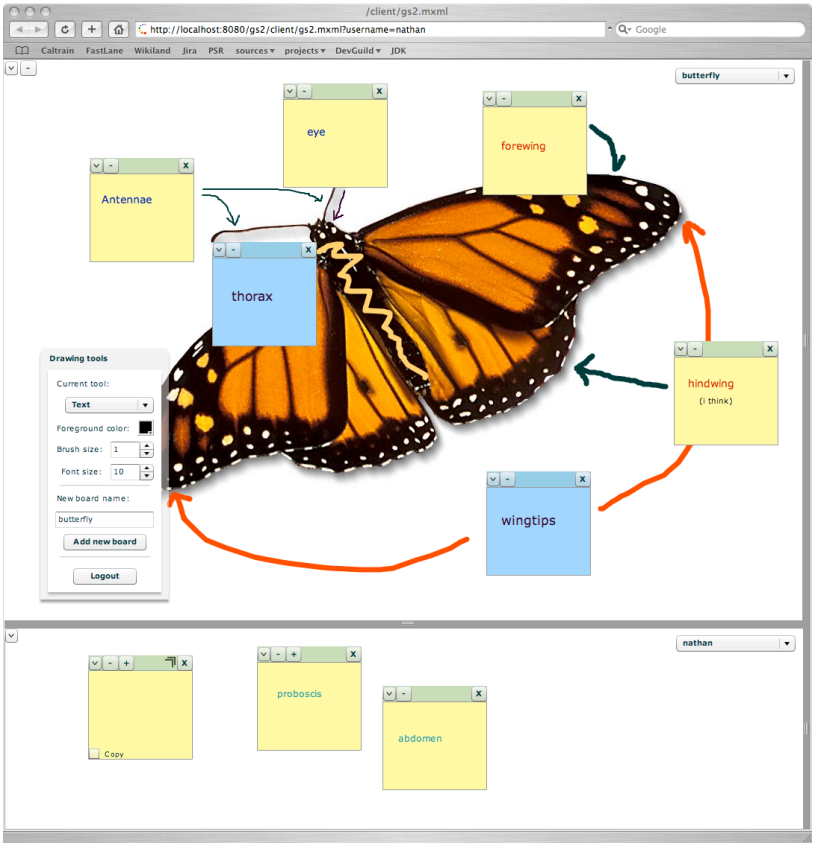

Figure 2. Collaborative labeling of an image in GS2.

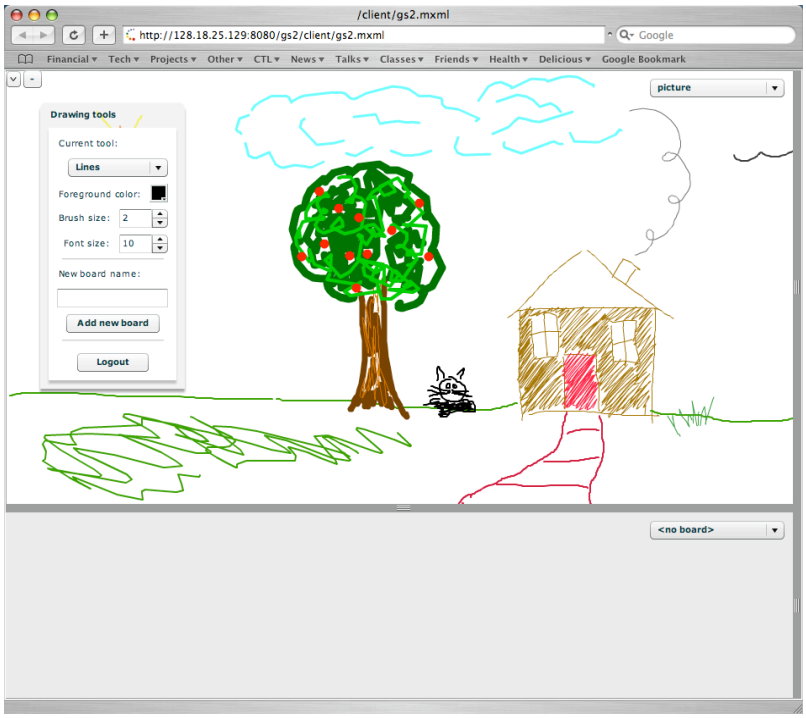

Figure 2. Collaborative drawing in GS2.

Activity 3: Activity Development

A set of activities was generated to exercise the space of Group Scribbles functionality for use in our pilot studies. Steps in the activities were categorized by simple pedagogical design patterns supported by Group Scribbles (e.g., distributed content creation, tagging, focusing, spatial sorting, unique task distribution). The activities included:

1. Fractions activity. Students generate a set of fractions and then a set of associated graphic representations. The graphics are clustered by type and then students attempt to match fractions to graphics.
2. Compute the sum activity. Students generate a set of numbers, and discuss different ways they could compute the sum of the numbers. They then enact a distributed computation algorithm: Each participant takes any 2 numbers on the public board, adds them, and then puts back the sum in the public space. When there is one number left, that is the sum.
3. Guess my function. 1:1 game in which two students each have a function. They take turns guessing x values and computing y values until one can guess what the other's function is.
4. Pick a point. Students are shown a linear function plot (on the background of a board). They are asked to label one point on the plot. Then they are asked to compute the rise/run from their point to the point one to the right.
5. Exploring data with box plots. Students generate a data set and work collaboratively to sort the data, group it into quartiles, generate a box plot, identify outliers, and interpret results.

Additional activities will be generated in the final quarter of Year 1: Two local K-12 teachers are interning with the project over the summer of 2008, and will work together and with the ScribbleProv team to create additional math activities for use in implementation studies

in their classrooms during the second year the project. The teachers are interning through the Industry Initiatives for Science and Math Education (IISME; iisme.org) Fellowship Program for Teachers. IISME is a nonprofit collaborative of San Francisco Bay Area corporations, universities, and local educators working to improve mathematics and science education.

Activity 4: Evaluation

Beyond informal discussions within the ScribbleProv team and informal feedback from other groups at CTL (e.g., the Bridging Project) and our collaborators (e.g., Singapore; see Synergistic Activities below), we conducted four small pilot studies in Year 1 to investigate the usability of Group Scribbles features and observe participants to further understand improvisation techniques and discussion dynamics. Design issues raised by the tests and informal feedback were documented and discussed during weekly design meetings, and proposed enhancements were reprioritized on the basis of perceived utility for supporting directed improvisation, user priorities, and implementation difficulty.

First, the ScribbleProv team hosted a focus group with 10 members of the Evaluation Guild in the Center for Technology in Learning (CTL) at SRI on April 3, 2008, to gather recommendations on how to evaluate Group Scribbles in the classroom. Participants experienced the Group Scribbles technology in an hour-long, hands-on session in CTL's Learning Lab, as both users and potential evaluators of the technology. To begin the session, participants engaged in the Compute The Sums activities (see above), in which everyone played the role of a student and worked in pairs, led by an instructor (a member of the ScribbleProv team). Next, the participants split into two roles—half students, half evaluators—as another member of the team lead the Fractions Activity (see above). The evaluators took notes during the second activity, and then the entire group discussed the following three questions:

1. What are potential evaluation strategies related to student achievement, student participation, and teacher performance?
2. What are some of the things you need to know to do such evaluation(s)? What key variables would you need to track?
3. How would you implement the evaluation?

The discussion and recommendations that resulted from this session are summarized in the Findings section of this report.

Second, on April 11, 2008, 22 students from Palo Verde Elementary School visited SRI for a school field trip, along with their teacher and 7 parents. The students engaged in several different activities, one of which was to use the Group Scribbles technology for a fractions activity. Unfortunately, partway through the activity, the application quit responding when numerous students began scribbling madly (and simultaneously) on the background board. The instructor improvised by using paper Post-It notes to complete the activity. After the session, the development team identified the problem—the server had run out of memory—and addressed it by removing old, unused activities from the server, adding more memory to the server application, and profiling the code to identify memory leaks to be corrected.

Third, on May 28, 2008, the ScribbleProv team hosted another testing session that involved 10 adults from CTL to test the scalability of the server, bug fixes, and new features. Finally, the ScribbleProv team will be visiting a (different) classroom of about 20 students at Palo Verde Elementary School, where Jeremy Roschelle, Director of CTL, will lead an activity on

probability using Group Scribbles. The results of these pilot tests and tests conducted over the summer with our visiting IISME teachers will be summarized in the Year 2 report, along with the description of Year 2 evaluation activities.

Activity 5: Dissemination and Outreach Activities

We engaged in several dissemination activities, and Group Scribbles was used and promoted by many other individuals and institutions. Below we summarize these activities and informal feedback on the materials.

Group Scribbles Web Site

The Group Scribbles web site (http:// groupscribbles.sri.com) provides public access to Group Scribbles software and activities, presentations and publications, research findings, and project contact information.

Group Scribbles Community Wiki

A Group Scribbles Community Wiki was established in September 2007 to provide a "watering hole" where Group Scribbles users can share their experiences and contribute their ideas for the development and use of Group Scribbles, and developers can share development tips and implementation ideas for Group Scribbles. The Community Wiki is available at https://wiki.sri.com:1800/display/groupscribbles/Home

Group Scribbles Newsletter and Announcement Mailing List

A Group Scribbles community mailing list (gs-announce@ctl.sri.com) and semi-annual newsletter were established in November 2007 to enable SRI to send quick updates on activities by SRI and our colleagues to the Group Scribbles community. The newsletter is posted to the Community Wiki and sent to the community mailing list (gs-announce), including over 25 colleagues in Singapore, Taiwan, Spain, England, Chile, and the US.

Papers and Presentations

Group Scribbles software and activities and findings have been presented in numerous forums, including the annual meeting of the Computer Supported Collaborative Learning (CSCL), the International Review of Research in Open and Distance Learning, and Computer magazine. The following articles are in press or were recently published.

- Brecht, J., DiGiano, C., Patton, C., Tatar, D., Chaudhury, R., Roschelle, J., & Davis, K. (in press). Coordinating networked learning activities with a general-purpose Interface. To appear in the *International Review of Research in Open and Distance Learning.*

- Dimitriadis, Y., Asensio, J.I., Hernandez, D., Roschelle, J., Brecht, J., Tatar, D., Chaudhury, S., DiGiano, C., & Patton, C. (2007). From socially-mediated to technology-mediated coordinatin: A study of the design tensions using Group Scribbles. Proceedings of *Computer Supported Collaborative Learning 2007 Conference*, CSCL 2007.

- Roschelle, J., Tatar, D., Chaudhury, S. R., Dimitriadis, Y., Patton, C., & DiGiano, C. (2007). Ink, improvisation, and interactive engagement: Learning with tablets. *Computer, 40*(9), 38-44.

In March 2008, Jeremy Roschelle, director of SRI's Center for Technology in Learning and co-developer of the original Group Scribbles system, visiting Mike Sharples Learning Science Lab in at the University of Nottingham and gave a Group Scribbles talk and demo.

Activities by Research Colleagues

Group Scribbles is being actively taken up by researchers and their students around the world, resulting new highly-rated papers submitted to conferences.

- Foo-Keong Ng, Chee-Kit Looi, and Wenli Chen at the National Institute of Education at Nanyang University in Singapore presented a paper on Group Scribbles at the ICLS Conference 2008 in Utrecht, entitled "Rapid Collaborative Knowledge Building: Lessons Learnt in Singapore Primary Schools".

- Robin Lin at the National Hsinchu University of Education submitted a paper on Group Scribbles to the International Conference on Wireless, Mobile and Ubiquitous Technologies in Education (WMUTE208) that was nominated for the Best Paper award.

- Yannis Dimitriadis, a professor of telecommunications engineering at Universidad de Valladolid in Spain, is pilot testing Group Scribbles with K-12 teachers in Spain, using Group Scribbles in his own classes, and working with his research team to conduct traffic analysis and interaction analysis based on Group Scribbles log data.

- Raj Chaudhury, a professor of physics at Christopher Newport University, recently used Group Scribbles with 16 students in an introductory physics course. The students (in groups of 4) identified rules for how elementary particles combined with their groups and by using analyses of other groups as displayed on their group boards.

- Mike Sharples, professor of educational technology at the University of Nottingham, UK, has been funded by an HP Technology for Teaching grant to explore tablets to support student learning in HCI and software design. They are installing Group Scribbles on the tablets provided by HP, and plan to use it to support students in technology design and prototyping sessions. Separately, they also plan to use Group Scribbles for group idea sharing sessions and to explore joint group work (combination of Group Scribbles and videoconferencing) between their Nottingham and China campuses. Mike's PhD student Jitti Niramitranon is creating a teacher interface for constructing a sequence of Group Scribbles screens.

- After Jeremy Rochelle's visit and presentation on Group Scribbles at the University of Nottingham, UK in March 2008, Dr. Charles Crook at U. Nottingham emailed us that "At least two of my students are now taking up Group Scribbles, so plenty of both social and scholarly impact."

- Colleagues at SRI are also using Group Scribbles in undergraduate courses at Stanford University and San Jose State University. Bill Penuel, a senior education researcher at SRI, used Group Scribbles in *Contexts That Promote Youth Development* in the School of Education at Stanford University. Judi Fusco, a research social scientist at SRI, used Group

Scribbles in *Contextual Influences on Cognitive Development* in the Child and Adolescent Development Department at San Jose State University.

Activity 6: Synergistic Activities

National Institute of Education (NIE), Nanyang University, Singapore

The Learning Sciences Lab (LSL), led by Dr. Chee Kit Looi, studies learning and teaching in Singapore schools to advance theoretical and research perspectives in the learning sciences. In December 2007, Dr. Looi won funding for a 2-year project called "Group Scribbles: Flexible Collaboration for Interactive White Board (IWB) Classrooms." The goals of the project are to research collaboration patterns, develop and implement effective Group Scribbles activities Singapore classrooms, enhance the design of Group Scribbles as a rich digital media collaboration environment, and study the effects in Group Scribbles classrooms.

SRI was awarded a services agreement with LSL to collaborate with them throughout the course of the project on technical, design, research, analysis, testing, and implementation issues.

References

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YEAR 1 REPORT: FINDINGS

Executive Summary

We have categorized our observations, conclusions, and recommendations from the first year of the grant in terms of three main findings: theory development, implications for feature development, and evaluation. These findings are detailed in this report. In summary, we:

- Found that teachers do use improvisational moves frequently, but they also explicitly break the rules of theatrical improvisation just as frequently
- Document how improv techniques are enacted, modified, and augmented in the classroom
- Derived, based upon our analysis, a number of extensions and refinements to Group Scribbles so that can it better support productive collaborative activities, particularly when teachers need to make real-time accommodations to student contributions
- Propose, based upon recommendations from evaluation experts, to enhance existing, NSF-funded, classroom-tested curricula with Group Scribbles activities and assess the value added

Finding 1: Theory Development

Comparing Theatrical and Classroom Improvisation

Theatrical improv is a particular style of interaction marked by flexibility and creativity. In particular, members of an improv ensemble are equals with a shared goal who consistently acknowledge and affirm each other's contributions. Achieving this style of interaction requires certain skills, and these skills can be developed using well-defined techniques. Improvisational moves, such as giving and receiving offers and "yes, and..." type responses, are intrinsic to a successful improvisation (Polsky, 1998; Spolin, 1999).

Our transcript analysis suggests that teachers do use improvisational moves frequently, but they also explicitly break the rules of theatrical improvisation just as frequently. The most significant situational difference we found between stage and classroom is the asymmetric power relationship between teacher and students. This constrains the offers and responses that teachers and students are allowed to make. An equally significant difference is that teachers have multiple, pre-specified goals for each interaction, but students are either unaware of these goals or lack the knowledge to understand them.

Despite these differences, there is some intriguing overlap between theatrical and classroom interactions. Regardless of a teacher's high-level goals, the actual unfolding of the classroom activity is embedded in the practical actions of teachers and students. Student progress may require the teacher to create new material on the fly, and unexpected student contributions can lead to productive detours in the classroom activity.

Both stage and classroom interactions are emergent products of multiple individual's activity. Because of this similarity, the vocabulary of theatrical improv is a useful starting point for examining teacher practices. Below we discuss how improv techniques are enacted, modified, and augmented in the classroom. The names for the elements described below are drawn from common terms used in training classes and books for improvisational actors (e.g., Polsky, 1998; Spolin, 1999). For each element, we also report how frequently it occurred in the classrooms transcripts that we coded in our initial analysis (see Activity 1).

Structural Elements

The following elements occur mainly at the classroom process level, structuring the lesson content and the participants in its presentation.

Play Writing. To playwrite is to think more than one turn of dialog ahead, so that you are driving the scene and have an expectation of what the other performers are going to say. Playwriting undermines theatrical improv because it limits other performer's options and defeats the emergent and unexpected nature of the improvisation.

One of the biggest contrasts between theatrical improv and classroom activity is that the teacher is *constantly playwriting*. This is not to say the teacher's contributions are completely scripted, but that teaching is a form of "disciplined improvisation" (Sawyer, 2004) that occurs within overarching constraints. Playwriting, in this sense, is practical and necessary for accomplishing the work of the classroom. In our initial analyses, we found that on average, about 27% of teacher utterances involved some playwriting. The number of playwriting moves ranged widely across all teachers, from a minimum of 12% to a maximum of 37% of all utterances.

At a high level, each classroom session is embedded in multiple levels of learning goal structures: the competencies expected from K-12 education, the curriculum goals of the year, and the teacher's lesson plans for the session. One challenge of teaching is to be open to the unexpected while still progressing in each of these goals. The teacher defines goals for each class session, and monitors the progress of the class towards these goals. The teacher is playwriting in the sense that each student contribution is evaluated against the goals for the session. The teacher cannot predict the classroom dialog, but shapes responses around each contribution.

Students are likely unaware of the teacher's script except in the sense that they know they are being evaluated. A benefit of playwriting is that student contributions can be evaluated as "on script" or not independently of the specific words that constitute them. Students are "on script" when their contributions demonstrate successful progress towards the learning goals. At the level of individual conversational turns, teacher responses are most frequently designed around encouraging students who are "on script" and correcting students who are not.

The following two examples illustrate playwriting in the classroom. Example 1 shows an extended exchange of playwriting at the beginning of an activity. Example 2 shows a brief, unsuccessful playwriting exchange during an activity.

Playwriting Example 1 (Teacher ID 600)

T: So we are gonna do today is to start with, we are gonna find our similar rectangle. So I'm gonna pass out a piece of rectangle to you. I want you to find your similar rectangle. <Counting rectangles> Three four five six seven eight nine ten eleven twelve. Okay, so choose one <passing out rectangles>. Quickly quickly quick quick. Choose one. Choose one.

[Teacher passes out a rectangle for each student.]

T: Okay so everybody in the front now: has: a similar rectangle. Remember yesterday some of us were folding and some of us we've been doing lots of different thing to kind of figure it out. But remember just like in our pictures up here at the beginning what: looks: the same: to you. Might not be the same size, but what: looks: the same: to you. What looks similar to you? Something really short and skinny is not gonna match something short and fat right? Get up right now and amongst yourselves see if you can find out the rectangle that matches yours. <No one moves> you can stand up. Look around. You can find it. What matches?

[Students move around to find matches]

S1: Who's got squares?

S2: Ms. T. is this right?

T: Let's see. Do those match? <Looking in a note> yes you match <to S2 who comes to front to check with T>. <To S3 who comes to front to check with T> let's see. I think you guys match. Um- yes you guys match. <S4 shows rectangles to T> nope. <To whole class> okay when you find your match, similar rectangle, sit down with your partner. <To a student sitting in his seat> Stand up and find. Stand up.

S5: Is this match?

T: <to S5 who shows rectangles to T> do those match? No.

S5: I mean it matches mine. Is it the brown?

T: I don't know. Go see. Go walk up to him.

T: Yes you guys match. Sit with your partner. <To whole class> Everybody has to get up and find your matching rectangle and sit with your rectangle.

T: Do you guys match? Cathy, why don't you work with. Choose a group to work with.

S5 shows her rectangles

T: Go fold it.

Playwriting Example 2 (Teacher ID 472)

T: Let me ask. Basically I'm saying you have not convinced me all squares are similar.

S1 (in group 7): Uhm, well, it's a perfect square because if you have, one of our squares, the smallest one, is 2 ½ inches by 2 ½ inches, and it's like even on both sides, so we just make all the squares the same like 18 by 18, 2 ½ by 2 ½. So they are all similar, all the squares.

T: Because?

S1: Because they are all the same length and-

T: <interrupting> Try using the word "as". Because "as" one side?...

S1: Because

T: Doesn't help you. Sorry.

Fourth Wall. The fourth wall is a theatrical improvisation term that refers to an imaginary barrier between the stage and the audience; "breaking" the wall is considered bad form in improvisation. That is, performers should not speak directly to the audience in an aside, and they should not explicitly narrate the action. Both of these actions tend to undermine the collaborative nature of the ensemble.

Teachers, on the other hand, either have no fourth wall, or are constantly reconfiguring it. If we consider the teacher and students as an ensemble, then there is no audience to speak to, and no fourth wall to break. Many of the teacher's moves are intended to reconfigure the participants and audience members in the classroom activity. Shifts in these configurations are often used to advance the teacher's script for the class session. In our initial analyses, we found that, on average, about 13% of utterances by teachers were examples of breaking the fourth wall (e.g., metacommunicating out of frame). Examples of breaking the fourth wall ranged fairly narrowly across all teachers, from a minimum of 10% to a maximum of 20% of utterances.

There are several classroom configurations and transitions between them. The teacher may carry on a public conversation in an individual student for the benefit of the rest of the class. The students may present as a group, in which case the teacher is an audience member along with the rest of the class. When lecturing, the teacher becomes the sole performer, and the whole class is configured as the audience. Finally, the teacher may step back and comment on the classroom dialog. This reconfigures the students and teacher as audience to foregoing student/teacher performance.

Reconfigurations of the performer/audience distinction are usually explicit. The teacher may turn from an interaction with a single student and ask for a reaction or comment.

In the following example, we see the teacher carrying on a public conversation with two groups of students who are standing the front of the class, then turning to the rest of the classroom (students who are sitting) for advice, and then finally calling out a single student for a reaction on how to solve the problem.

Fourth Wall Example 1 (Teacher ID 472)

[Students from Group 1 are helping Group 2. Both groups are standing at the front of the class, and the teacher is talking to students in the two groups.]

T: So. So what?

S1: They went wrong with this one?

T: I didn't tell you to-<overlapping>

S2: <overlapping>This one's wrong. This one's wrong.

T: They're not wrong. They are rectangles. What's the problem?

S2: They are not similar. Every other one *IS* similar except the big one.

[Back to whole class discussion]

T: So how can they fix it?

S3: Get rid of rectangles.

T: So how can they fix it so that they can prove it in a different way? What would you do? What would you do if you were a member of this group? You are a member of this group right now. Here you are in front of the whole class with visitors being told you can't prove your claim. Now that's not a stopping point. Okay? That's not a stopping point. Because what's gonna be the next piece is how do you fix it? How do you fix it? So if you were a member of that group what are you gonna do? S4?

S4: get rid of every other rectangle from the… group <overlapping>.

T: <overlapping> that's one way. You can get rid of ones that aren't, they don't fit your plan. What else can you do?

Progression Elements

The basic unit of improv is the "offer" (Spolin, 1999). Each contribution to an improvisation is an offer to the rest of the ensemble that can move the scene forward and open up new directions for the improvisation. The interaction proceeds according to how offers are taken up and responded to. The framework elements described here are ways in which teachers make and respond to offers to manage student participation and the progression of the lesson.

The first progression element described here is taken from theatrical improv. We introduce the last two to describe additional observed techniques.

Yes, And… This is considered the cornerstone of improvisational technique: "yes, and…" statements accept an offer from a member of the ensemble and then build on it. Effective use of "yes, and…" affirms previous contributions and simultaneously offers new material and directions for the interaction. Teachers use "yes, and…" statements to acknowledge student contributions and then advance the classroom script. This might involve moving the dialog to the next topic or moving the lesson on to the next activity. In our initial analyses, we found that on average, about 6% of teacher utterances were of this form. The use of "yes, and…" moves ranged fairly narrowly across all teachers, from a minimum of 2% to a maximum of 10% of utterances.

In the following example, the teacher acknowledges contributions from two students. She then expands on the concept of similarity using a copy machine analogy.

Yes and… Example (Teacher ID 452)

S1: They are the same number of sides; they are the same length and width, same number.

T: Right. That's what a couple of other people have said. That's true. So what can we say about all squares? All square are-

S2: Similar.

T: <*pointing S2, smiling*> thank you S2. All square are similar aren't they? You could put a square in a copy machine, you can blow it up, you can shrink it down and it's still gonna be a square right?

<*SS: yeah*>

Yes, and…? A variation on "yes, and…" is the "yes, and…?" statement. A "yes, and…?" statement acknowledges a student's contribution, but then prompts the *student* to continue the dialog and expand on the contribution. This can allow the teacher to draw a more complex idea from a student, to lead the student down a particular line of thought, or to make the student reflect on their contribution in order to evaluate it in some way.

In contrast, a core rule of theatrical improv is to *avoid* asking questions. Questions are considered scene killers because they force your partner to stop whatever they are doing and come up with an answer, and they also constrain the range of possible responses. Unlike in theatrical improv, expert teachers quite frequently acknowledge responses and then ask follow-up questions. Indeed, we found that the, "yes, and…? variation was used almost four times as often as the original form. In our initial analyses, on average, about 22% of teacher utterances were of the "yes, and…?" variation. The use this variation ranged fairly widely across all teachers, from a minimum of 14% to a maximum of 29% of utterances.

In the following example, the teacher is prompting a student about different ways she could create a set of four similar rectangles. After acknowledging the student's contribution, she leads the student to consider alternatives to measuring.

Yes, and…? Example (Teacher ID 452)

S: We did the ruler for these.

T: Right. Is there something you could use besides the ruler to come up with?

S: Squares.

T: Is there anything else you can do? Just think about that.

S: <inaudible> just make a line before

T: How would you ensure that they are all similar though? I guess one of the things I was thinking is this is paper. Could you fold it in a way?

S: Yeah.

T: So you are gonna get exact proportion of length to width. Could you do that? I want you to think about alternatives besides measuring. That's all.

Statement. Finally, the teacher may simply bring an exchange to a close and start a new dialog segment. Other elements that occurred infrequently, such as listening to and repeating utterances (without adding to or interpreting the utterance), were grouped into this category.

In the following example, the teacher comments on a student's idea that if rectangles are similar, you can line up rectangles so that they share a corner and then draw a diagonal line from the shared corner to the opposite corner. The teacher then calls on a new group to learn how they determined if their rectangles are similar. This is allowable in a classroom because of the asymmetric power relationship between teacher and students. It is also necessary in order to advance the teacher's script for the lesson. In our initial analyses, about 9% of teacher utterances were coded under this category, and ranged from a minimum of 3% to a maximum of 15% of utterances across all teachers.

Statement Example (Teacher ID472)

T: What a concept! What a concept! That's fabulous. Questions? Did you see that, N? Did you see that phenomenon before S presented it? Did you see that concept, K?

S: E said it, figured it out <inaudible>

T: So E saw the concept.

T: That's very creative I think. In my opinion. When I saw that this summer, it kind of blew me away. I thought it was fascinating. I thought that was a real discovery about a relationship of similar rectangles. I think that's fabulous. Next group? Who's gonna go first at that table? <Group 1-1>

Content Elements

Aside from purely informational statement, the content of the teacher's responses to student contributions are used to keep students "on script". At the conversational level, these responses explicitly and implicitly cue the students to keep the conversation moving forward.

Affirmation. Theatrical improv is accomplished in a supportive, collaborative atmosphere. The use of "yes, and…" provides a continuous, implicit affirmation of ensemble member's offers and creates a level of trust that encourages creative play.

Teachers regularly use explicit affirmation to reward and motivate students. In our initial analyses, we found that on average, about 6% of teacher utterances were of this form. The use of affirmation ranged fairly widely across all teachers, from a minimum of 1% to a maximum of 14% of utterances. Again, this aspect of the teacher's role is enabled by the asymmetry of the teacher/student relationship. In the following example, the teacher praises a student for "something very important" the student realized about similar rectangles (that you draw a diagonal line through them), and queries the class for their understanding. After this segment (not shown), the teacher explains what S1 did in more detail to help all of the students understand the new concept.

Affirmation Example (Teacher ID 600):

S1: Now if I can draw this rectangle. And <inaudible> this angle this and this <indicating the vertices of each rectangle the a diagonal line passes through>.

T: Perfect. Does everybody understand what she did?

Students: No.

T: Did everybody see what she did?

S3: I saw but I didn't understand.

S4: Kind of.

S5: I saw what she did.

T: <to S1> okay, so can I? Thank you very much. That was excellent.

[Students clap]

Denial. To deny a fellow performer is to reject what he/she has just introduced into the dramatic frame; it is the opposite of saying "yes." A core rule of theatrical improv is to never negate or deny an offer. Denial is considered bad form in theatrical improvisation—another scene killer—as it can exclude performers and limit the improvisation. However, expert teachers quite frequently correct and point out errors in student contributions as a way to move the classroom dialog forward. In our initial analyses, we found that on average, about 7% of teacher utterances were of this form. The use of denial ranged fairly narrowly across all teachers, from a minimum of 2% to a maximum of 10% of utterances.

In the following example the teacher uses a series of denial statements to correct students when they are having difficulty explaining their claim that their rectangles are similar.

Denial Example (Teacher ID 472)

T: What do you get? Another

S: *A similar rectangle!*

T: No you don't. You just proved that. A said you don't get another rectangle.

S: Dissimilar.

T: No you don't right? Isn't that right?

SSS: Yeah <a few students overlapping at once>

T: <overlapping> So you get another rectangle? No they are not right. Sorry.

S: Couldn't you take three rectangles that are similar to each other and divide all of them by 2 or whatever, 2 by 6, 4 by 12, 6 by 24…

T: okay

S: Then you can see that they are all set in common like they are 1 by…<overlapping> 1 by 6

T: <overlapping> they are called the

S: <overlapping> equal

T: They are not equal.

S: Similar

T: Because their ratios are

S: All equal

T: No they are not equal. 1 by 4 is not equal to 2 by 8.

S: Yeah it is.

T: No it isn't. Why not? Why isn't it equal?

S: Proportion.

T: Why not? Why isn't it equal? What's the right word?

S: They are not the same?

T: One dime is not equal to two nickels. They are not the same thing.

S: Same value.

T: They have to have same value when they have to be equal. Words that describe the same value is…

S: Similar

T: Starts with "e", but it's not equal.

S: <all shout> Equivalent.

Endowing. To endow is to assign attributes to another performer's character. Endowing is considered bad form in theatrical improvisation, because it puts the performer in a position of being controlled: her responses may be limited by the endowment. However, expert teachers frequently restate what students say, endowing the student's statement with meaning that wasn't explicit in the student utterance. In our initial analyses, we found that on average, almost 10% of teacher utterances were of this form. The use of endowing ranged fairly narrowly across all teachers, from a minimum of 5% to a maximum of 13% of utterances.

Endowing plays two roles in the classroom. In the first case, when a student contribution is partially correct (borderline on-script), endowing can be used to amplify the on-script elements of the contribution, as shown in the following example.

Endowing Example 1 (Teacher ID 472)

T: I don't know what you mean.

S: Okay. So let's see. If one of our square is 3 inches by 3 inches, then the fraction will be 3- uh, ok… 3 is to 3 as 2 is to 2 or whatever. And if you reduce either or both of those, reduce down to one.

T: Are you telling me by definition if I reduce or increase the length of one side, the other sides will automatically increase or decrease proportionally? Is that what you're trying to tell me? Cause I understand that. Cause it's my words. <Teacher laughs>

In the second case, endowing can be used to completely "re-interpret" a student contribution. Sometimes teachers will even make completely wrong interpretations to see if the student catches it. In the following example, the teacher is trying to develop student language to support math understanding, and throws in "area to perimeter" as an incorrect distracter.

Endowing Example 2 (Teacher ID 472)

S: So what we did was ratio by both the length and the width <mumbling>… Similar proportions.

T: When you say ratio, you mean area to circumference right? Area to perimeter.

S: length

T: To?

S: width

T: Is that help clarify? Good job. That was a struggle. That's a good job. Next group <group7>?

Finding 2: Implications for Feature Development

The theoretical understandings derived from our analysis suggest a number of extensions and refinements to Group Scribbles so that can it better support productive collaborative activities, particularly when teachers need to make real-time accommodations to student contributions. The extensions described here are at the structural level to help the teacher frame and respond creatively to the classroom discussion. As such, are based on the structural (Playwriting and Fourth Wall) elements of the framework outlined above.

Playwriting

These features are derived from the teacher use of playwriting. Each of them provides tools for the teacher to structure or re-structure the classroom activity.

Support for lightweight constraints. One potential feature would be to allow teachers to implement simple constraints on the student contributions and progress through an activity. These constraints might include things like limiting the number of contributions to a public space or requiring a certain minimum number of contributions. Making access to the scribble board contingent on teacher-specified requirements would allow a teacher to checkpoint student work. For example, an activity could involve small group work that is eventually shared on a public

board. In this instance, the teacher could require each group to get teacher approval before gaining access to the public board where small group work is aggregated.

Smart backgrounds. A teacher may improvise the use of categorization or other organization to re-frame the student's work and cause them to reinterpret it. A potential feature is to implement "smart" backgrounds for group scribbles' boards. A smart background allows the teacher to easily generate board backgrounds to support data organization tasks. A simple example is shown in Figure 1. The smart background in this case allows the teacher to easily generate any number of identifiable areas in the board to support a categorization task. Other smart background could generate more complex organizational tools (e.g., sequences, bins, Venn diagrams) or useful imagery like a Cartesian grid.

Figure 1. Smart (auto-generated) background to support simple categorization activities.

Library of activity templates. Group Scribbles activities can be useful in multiple contexts. Another potential feature would be to allow teacher to build libraries of activity templates. Instantiating one of these templates would produce a new, pre-configured collection of boards, scribbles, and tokens. Activity templates could be easily and quickly instantiated at the moment the teacher recognizes an appropriate classroom situation. For example, a teacher could have ready several activities that address specific misconceptions or typical problems with the lesson content. An activity template might define a public board with a specific back ground, and number of group boards, and a collection of tokens and other materials. When the teacher recognizes that the class is having trouble with the material one of these activities could be instantiated to provide a more content-focused task.

Smooth transition to new activities and back. In concert with activity templates would be enhanced functionality for moving between activities. This could include facilities for transitioning a whole class to a new activity, assigning different activities to smaller groups, or nesting an example exercise within an ongoing activity. Continuing the activity template example from above, the teacher might want to put the current activity on hold and then transition to the more targeted activity defined in the template. One the targeted activity is completed, the teacher would be able to return to the same place in the previous activity and continue the lesson.

Fourth Wall

This second set of potential features is based on teacher's flexible use of the fourth wall to frequently reconfigure the classroom.

Indication (pointing). Reconfiguring the fourth wall in a classroom often requires indication of an object around which the reconfiguration is organized. A typical contribution might consist of an utterance such as, "does anyone have a comment on S's answer?" In this case, S's answer is highlighted as the object of interest. A useful extension to Group Scribbles would be to allow users (teachers and students) to indicate interest in specific board contents. In Figure 2 the teacher has highlighted a few scribbles to accompany the comment, "does anyone have an idea about where to put these?"

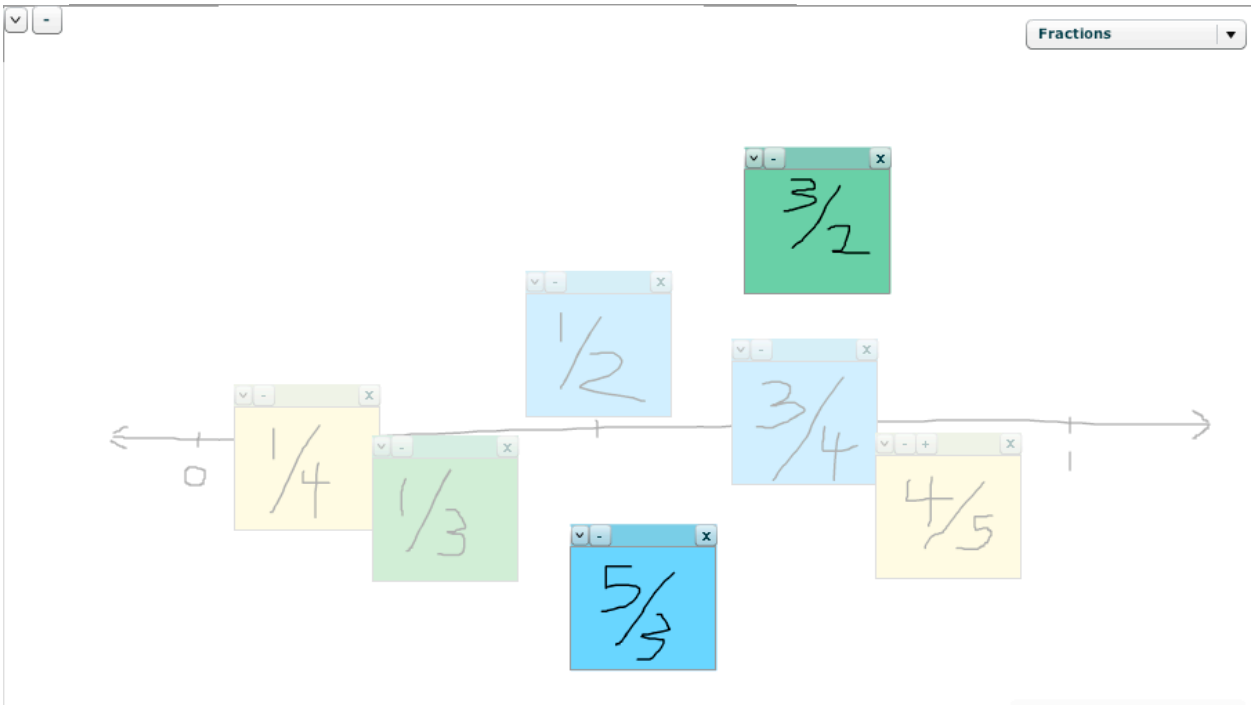

Figure 2. Highlighting scribbles to focus attention and discussion.

Lifting scribbles to new group/public board. An extension of indication would be to generate new boards based on indicated items. This would allow the teacher to begin multiple new interactions around a set of scribbles. One use of these features would be to assign different workspace elements to groups to discuss. Another use would be to create multiple group boards based on the same starting elements.

Highlighting group work. The functionality to highlight work by a group, point out connections across groups, and then return to a whole class activity would complement smooth transitions between activities. Teachers often interrupt group work to point out the work of another group in order to teach a specific concept or as an instructional device to get students on track. For example, teachers could use the functionality to easily show one group's work or to show how different groups had instantiated the same idea. The teacher could continue to highlight the group's work on screen or return to the activity view.

Multiple board view for teachers. A final potential feature would be a considerably enhanced activity management console. This might include features like allowing the teacher to see a collection of boards simultaneously by presenting scaled views of the boards tiled in the console window (see Figure 3). Another feature might be to create a dual view representation for the teacher (a la' PowerPoint) that includes a public display meant to be visible to the students along with a private display that provides visibility into student work and control of the activity flow.

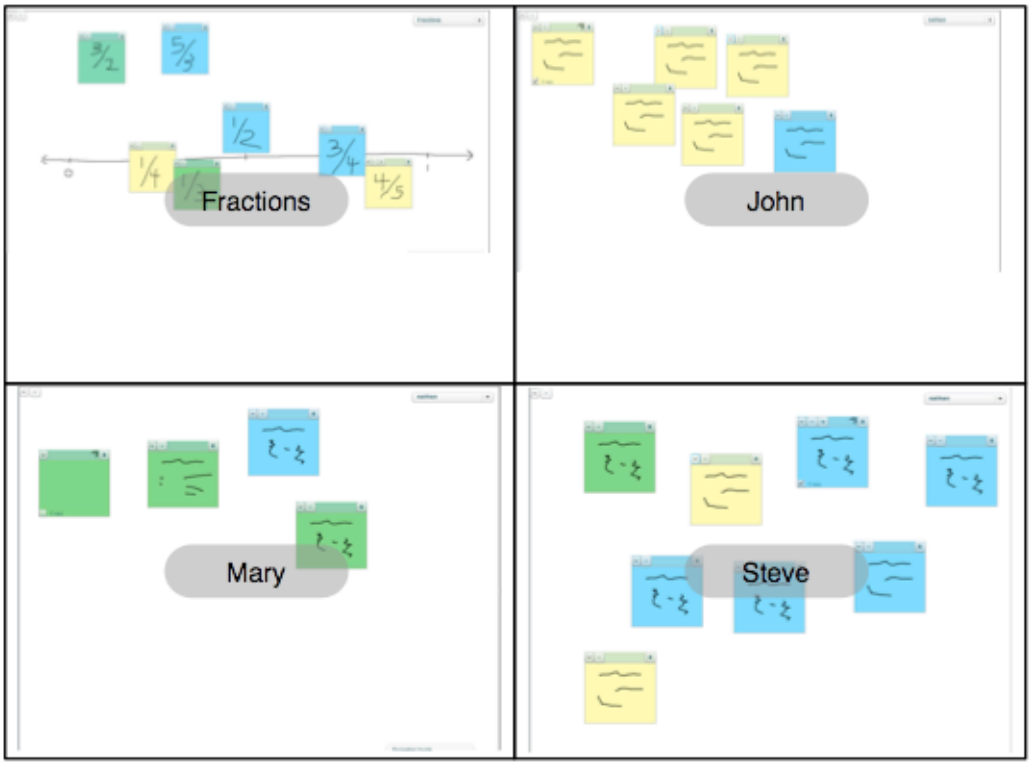

Figure 3. Teacher view of multiple boards.

Finding 3: Evaluation

Our evaluative research has informed the theory building and prototyping strands of our research approach. We are iteratively designing and testing new Group Scribbles features and observing participants in their classrooms to further understand improvisation techniques and discussion dynamics. Another primary goal is to evaluate the effectiveness of specific features in Group Scribbles for learning and teaching. A panel of SRI colleagues who specialize in evaluation have recommended that in order to do this, the technology must be situated in a more specific learning context—including a specific curriculum and professional development approach—and have measurable learning goals. In general, they suggested that the team choose one or two classroom-tested curricula, enhance them with Group Scribbles activities, and then evaluate the value-add of the Group Scribbles activities.

Our evaluation colleagues argued that if a teacher isn't familiar with the various collaboration patterns that Group Scribbles can support, we'll likely observe an extraordinarily narrow range of uninteresting experiences. They recommended that as a first step, we train teachers on collaborative activity patterns such as those described in DiGiano (2004), which provide non-technical templates for generating high-quality collaborative learning activities that make the most of emerging technologies. They also recommend that we train the teachers to use a specific curriculum—or adapt the curriculum they are using—before we determine exactly what we will be measuring in the evaluation.

CTL's Director of Evaluation, Bill Penuel, offered a lesson learned from a previous project. They too had created general, very versatile tools, but found that the results were quite difficult to evaluate. He felt that at the end, they were unable to say how the technology impacted teaching and learning because there were just too many variables. He and others repeated that it is very difficult to evaluate technology without a complete curriculum-activity package, one that includes high-quality curriculum as well as teacher professional development. If the curriculum is poor, the technology and teacher practice won't really matter—the poor curriculum will wash out any effects. If the teachers aren't trained to use the technology in a specific curriculum context, they won't know how to orchestrate interesting activities with the technology. (Indeed, we have seen this problem with our collaborators in Singapore: They are studying several teachers who are using Group Scribbles in their classroom, and virtually all of the teachers are using Group Scribbles as a simple whiteboard for displaying student work. These are good teachers, but they were not trained to take advantage of the unique affordances of the tool to support more engaging collaborative activities, and they are not engaging in these activities spontaneously.)

The evaluation panel also offered a specific, recommended path: Get one teacher, choose a topic for the next six weeks, and work with the teacher as needed to create or adapt a collaborative activity using Group Scribbles. Begin by modeling the process for a few days, then work with them to create/adapt an activity, and then see if the teacher can create an activity on her own. Focus on one lesson, once a week. This approach requires a lot of time on the researchers part, but it is necessary it to ensure that the activities developed are high-quality, engaging, and work well with the teacher's curriculum—and that the unique impact of the technology-enhanced activity can be evaluated. In the end, we will have an adapted curriculum or a replacement unit that tightly integrates the curriculum with the software.

Fortunately, we are well positioned to begin exploring this approach. As mentioned in Activity 3, two local K-12 math teachers are interning at SRI with our project over the summer of 2008, through the Industry Initiatives for Science and Math Education (IISME; iisme.org)

Fellowship Programs for Teachers. These teachers will work together and with the ScribbleProv team to create Group Scribbles math activities for use in their classrooms that build on engaging collaborative design patterns. They will also work part-time with up to four other NSF-funded math education projects in CTL: Bridging Professional Development (Shechtman, Kim, & Knudsen, 2008), SimCalc (Roschelle, Tatar, Shechtman, & Knudsen, 2008), Thinking with Data (Vahey, Yarnall, Patton, Zalles, & Swan, 2006), and TechPALS: Getting Fractions Right with Technology-Mediated Peer-Assisted Learning. Working with these projects will provide excellent opportunities for us to create collaborative Group Scribbles activities that are grounded in proven curriculum with teacher professional development support. In turn, these projects can leverage our work and introduce collaborative activities into their curriculum. Our IISME teachers have agreed to participate in classroom implementation studies during the 2008/2009 school year using the Group Scribbles activities that are generated.

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