Teaching Routines to Enhance Collaboration Using Classroom Network Technology

Angela Haydel DeBarger
William R. Penuel
Christopher Harris
Patricia Schank
Center for Technology in Learning, SRI International, United States of America

ABSTRACT
This chapter presents an argument for the use of teaching routines (pedagogical patterns) to support collaborative learning using the Group Scribbles classroom network technology. Teaching routines are a resource for structuring student opportunities to learn within lessons. They address known challenges associated with making the most of classroom network technology by scaffolding teacher enactment, enabling contingent teaching, and providing an anchor for expanding practice. In this chapter, we articulate the theoretical and empirical basis for using teaching routines to support diagnostic interactive formative assessment of student learning. We describe the goals and features of routines, types of collaboration instantiated in the routines, technological aspects of Group Scribbles, teachers’ perceived utility of the routines, and anticipated implementation challenges of the routines within lessons designed for middle school Earth science.

INTRODUCTION
Classroom network technologies enable unique forms of participation in classrooms in which elements of online learning are integrated fully into face-to-face instruction. This class of technologies includes student response systems (“clickers”), networked graphing calculators, and tools that enable participatory simulations. With these technologies, students can work online in private and group spaces while simultaneously participating in classroom activities. These technologies have been the focus of much research in recent years (see, Penuel, Roschelle, & Abrahamson, 2005, for a review), though explicit attention to how teachers can use them well has not been widely studied.

To make the most of classroom network technologies, teachers need support for the design and enactment of classroom teaching strategies to use in conjunction with them. Our candidate for the form that support should take is what we call a teaching routine. Teaching routines are recurring patterned sequences of interaction teachers and students jointly enact to organize opportunities for student learning in classrooms. Routines are familiar features of classrooms, and remarkably stable and recognizable across large timescales and distances: they form part of the very “grammar of schooling” (Tyack & Cuban, 1995). Many routines are enacted principally through classroom discourse, as when teachers pose students a question whose answer is known to the students, students respond, and the teacher evaluates the response (Mehan, 1979). Classroom formats for organizing student participation in class, such as recitation, small group discussion,
and whole-class discussion are ubiquitous and differ little in structure from subject to subject (Nystrand, Wu, & Gamoran, 2003).

This chapter provides an overview of the challenges to using classroom network technology routines are intended to address, presents examples of routines developed for a new classroom network technology called Group Scribbles, shows how routines have been embedded in lessons designed for middle school Earth teachers, and describes professional development for teachers in using routines. The chapter also presents evidence about how teachers perceive the potential of routines and challenges they anticipate in using them.

BACKGROUND

Technology can transform how teachers organize learning opportunities for students in the classroom. Technology readily facilitates re-use of learning processes (Koper, 2003; Schroeder & Spannagel, 2005; Zumbach, Muhlenbrock, Jansen, Reimann, & Hoppe, 2002), by providing a record of interaction that can be used as a guide for enacting processes again so that they can become routine sequences of interaction. In addition, with the aid of certain forms of classroom network technology, learners can participate anonymously, in ways that may facilitate their being willing to ask for help when they do not understand something (Davis, 2003). With this technology, students can engage in participatory simulations and acts of collective representation that help them master difficult subject matter, from complex adaptive systems in biology to functions in algebra (Hegedus & Kaput, 2004; Stroup, Ares, & Hurford, 2005; Wilensky & Stroup, 2000).

Collaborative Scripts and Design Patterns

The introduction of technology either to change the medium of learning (e.g., from face-to-face to online learning) or to augment face-to-face interaction may necessitate the development of new teaching routines and transformation of existing routines to make the most of new affordances of technology (Penuel, 2008; Roschelle, Knudsen, & Hegedus, in press). Designers of educational technologies have been aware of the need, potential, and limitations of designing sequences of interactions to better facilitate learning for some time. For example, recognizing that on their own, students may not collaborate effectively to learn together, designers have developed collaborative scripts that prescribe how students should form groups, interact, and approach problem solving (e.g., Hoppe & Ploetzner, 1999). Such scripts may facilitate collaboration, but they also have the potential to overly constrain learners’ efforts to collaborate to learn in certain situations (Dillenbourg, 2002).

In an effort to help designers of collaborative, classroom network technologies ensure that technology supports a wide, rather than limited, number of ways learners can collaborate, other teams have sought to articulate sets of collaborative design patterns. The notion of a design pattern comes from the field of architecture, where the term refers to common features of well-designed spaces (Alexander, Ishikawa, & Silverstein, 1977). DiGiano and colleagues (2003) developed a set of collaborative design patterns to guide the design of software for emerging classroom network technology, such as networked graphing calculators. Their design patterns articulate different sequences of collaborative activity that could be used to organize learning opportunities across different subject areas. Their intent was to enable designers to think broadly about collaboration, not on the one hand to build in features that “over script” while at the same time supporting the kind of structuring of interaction that research suggests is optimal for individual and group learning.

A limitation of these earlier approaches is that they provide little guidance to teachers for how they are to make the most of classroom network technologies. The need for such guidance arises from the fact that reviews of research suggest that unless teachers are able to use the technology
to promote discussion and reflection on student thinking, the technology alone is unlikely to improve teaching and learning (Judson & Sawada, 2002). In fact, many teachers do not use classroom network technologies in ways that promote discussion and reflection; not surprisingly, these teachers choose to use technologies less often than those who employ the technology in more powerful ways (Penuel, Boscardin, Masyn, & Crawford, 2007). Below, we review specific challenges teachers face in using these technologies, for which we have designed teaching routines as a tool to address.

Specific Challenges to Teaching with Classroom Network Technologies

One way that the potential of classroom network technologies becomes limited is in how they are used to engage students in thinking about content. One of the most common routines, the I-R-E (initiation-response-evaluation) sequence in which teachers pose a question to students, students answer, and the teacher evaluates the response, offers little room for dialogue among students (Mehan, 1979; Wells, 1993). In science classrooms, the use of this sequence also limits opportunities for students to articulate complex concepts and arguments that are the hallmark of scientific reasoning (Lemke, 1990). Studies of K-12 teachers’ use of classroom network technologies indicate many teachers use I-R-E sequences with the technology, without much classroom discussion (e.g., Penuel, Boscardin, et al., 2007). These teachers see less benefit from using the technology, and our conjecture is that they see less benefit because using classroom network technologies in this way does not take sufficient advantage of the shared display as a focal point for attention, discussion, and reflection.

Another challenge is to motivate students to participate and learn from activities including investigations, teacher explanations, and text. Particularly in investigations, helping students stay “minds on” while they are “hands on,” attend to the question at hand and figure out how their investigative methods or procedures help answer it is difficult (Petrosino, 1998). Students’ conceptual development may depend on teachers’ providing explanations of phenomena and on learning from text (Klahr & Nigam, 2004), but students may not be motivated to learn from these sources. Classroom network technologies have the potential to help teachers track student progress and also keep students motivated and on task by responding to check-in or reflection questions, but teachers may not be aware of how to incorporate these kinds of procedures with the technologies.

One of the greatest challenges of teaching may be the need to make multiple decisions about what to do next during a single lesson based on their diagnoses of individuals’ and classes’ changing understanding of content (Hinds, 2002; Solomon & Morocco, 1999). On the fly, teachers must decide whether to provide feedback to all students or particular students. If feedback is appropriate, teachers need to determine when it should be provided and what form it should take (e.g., written, verbal). Not only are aggregating and interpreting data challenging for teachers who typically have limited training in analysis of assessment data and face multiple demands on their time, but support materials packaged with classroom network technologies and curricula rarely provide this type of “what if” guidance about what to do when students are having difficulty mastering a concept.

TEACHING ROUTINES AS A TOOL FOR HELPING TEACHERS MAKE THE MOST OF CLASSROOM NETWORK TECHNOLOGIES

Teachers need tools beyond curriculum and infrastructure to overcome these challenges. Teaching routines are designed to address these known challenges associated with making the most of classroom network technology to improve student learning in the classroom. Depending on their role in the classroom, the grain-size of a teaching routine may vary from a small part of
an instructional session (e.g., checking in about progress on a task) to spanning several days or weeks (e.g., an inquiry cycle beginning with identifying research questions, then testing hypotheses in investigations, analyzing results, drawing conclusions, and reflecting on what was learned).

Enhance Classroom Communication

A primary goal for teaching routines is to enhance student opportunities to communicate with the teacher and with peers about their thinking. Classroom network technology makes it possible for teachers to pose questions to all students and thus to learn about the class’s state of knowledge. In addition, response system technology allows the cycle of question-and-answer to take place in a very short time, thereby providing students and teachers with rapid feedback without slowing the pace of teaching (Roschelle, Penuel, & Abrahamson, 2004). To make the most of network technologies, routines facilitate the design of classroom activities to create multiple opportunities for students to participate, both by contributing responses to student questions and by discussing their thinking with peers and the class. Routines enhance classroom communication by providing guidance about how to facilitate classroom conversations, structuring interactions among peers and small groups, and focusing discussions on epistemological ways of thinking within a domain.

Drawing upon the underlying components of the Peer Instruction model for guiding teaching with student response systems, as well as those of a similar method developed by the Physics Education Research Group at the University of Massachusetts (Dufresne & Gerace, 2004), routines provide useful scaffolds for teachers in orchestrating discussions. Researchers have observed that discussion based on the distribution of student responses encourages student thinking about alternative ways of addressing a concept or problem (Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996) and aids in developing deeper student understanding of the meaning of concepts (Judson & Sawada, 2002). Explanation to a peer has the potential to transform students’ misconceptions (Judson & Sawada, 2002). Response systems facilitate discussion by providing an anchor (aggregate responses on a shared display) and a set of artifacts to which students can refer in the process of building knowledge (Truong, Griswold, Ratto, & Star, 2002).

Routines encourage dialogic, as opposed to monologic, forms of communication (Bakhtin, 1981; Holquist, 1990). Dialogic communication occurs whenever teachers’ and students’ utterances anticipate and respond to one another, and where the course of a conversation cannot easily be predicted ahead of time. By contrast, monologic communication “speaks with one voice,” often the teacher’s, and the speaker is not necessarily concerned with learning about the audience’s interests, concerns, or questions but rather with compelling them to be, do, or act in a particular way. When students have more opportunity to engage in genuine classroom dialogue rather than recitation, they learn more (Nystrand & Gamoran, 1991). Analyses of learning in science classrooms also highlight the potential of classroom conversations in which students shape the flow and direction of discussion. For example, van Zee and Minstrell (1997) demonstrate a model for orchestrating discussion in which the main goal is to elicit what students think, rather than to evaluate them, and in which subgoals of conversations emerge through particular conversational moves and are not dictated ahead of time by the teacher. These kinds of discussions facilitate students’ development of scientific explanations, as well as reflection and revision of ideas about subject matter (diSessa & Minstrell, 1998). Teaching routines may be useful in improving dialogic communication in the classroom, since at present, teachers do not use them widely and many find them more difficult to orchestrate than monologic forms of classroom communication.

While routines are not content- or domain-specific they are structured around important epistemological ways of thinking in a domain. In the case of science, these ways of thinking include designing questions, relating processes, and data creation. Because routines are designed
to be applied in multiple instances within a curriculum, specific questions are not identified
within a routine, but the steps of a routine are intended to inspire the design of diagnostic
questions that will allow teachers to elicit deeper student reasoning.

Diagnostic questioning is consistent with a growing body of cognitive science research that
suggests it is necessary to engage rather than ignore problematic student ideas in order to promote
conceptual change in science (di Sessa & Minstrell, 1998; National Research Council, 1999;
Posner, Strike, Hewson, & Gerzog, 1982; Smith, di Sessa, & Roschelle, 1993-1994). The
diagnostic approach, in its emphasis on eliciting student thinking, stands in contrast with the
typical approach of science curricula and with the view of some advocates (e.g., Muthukrishna,
Carnine, Grossen, & Miller, 1999) that focus solely on teaching correct concepts to students. To
stimulate discussion, researchers have suggested that questions that yield divergent student
responses are more effective than those that are easy or lead all students to a single answer
(Beatty, Gerace, Leonard, & Dufresne, 2006). The timing of questions further shapes the nature
of information an instructor gains about student understanding. Questions posed after a lecture or
explanation can be used to check understanding (Dufresne, et al., 1996). Together, these findings
suggest it matters not just what questions to ask but also when to ask them. Teaching routines
explicitly address the kinds of questions that are appropriate for diagnosing student understanding
as well as when they should be posed to students. As a result, teachers who use routines should be
better equipped to address problematic student ideas within and across lessons.

Motivate Students to Participate Actively

A critical role for routines is to create an appetite for learning concepts by tackling a challenge,
reflecting on it, and realizing that additional learning is needed (Daniel L. Schwartz & Bransford,
1998). To accomplish this task, routines need to help foster a classroom environment that
supports students’ developing goals for learning. The emphasis on grades and high-stakes
performances that is typical in classroom and standardized assessments creates the opposite kind
of environment, namely one in which students orient toward displaying competence and avoiding
situations that would show them to be confused or lacking in skill (Maehr & Midgley, 1991;
Wigfield, Eccles, & Rodriguez, 1998). By contrast, when teachers provide feedback that is task-
focused and that gives specific guidance about how students can improve, assessment can
actually help motivate students to learn and create a classroom environment that encourage
students to adopt goals for content and skill mastery (Black & Harrison, 2001; Butler, 1987;
Butler & Nisan, 1986).

An example of a routine that has as its primary goal motivating learning through feedback is a
writing conference (Harris, 1986), in which a student presents a sample of original writing to a
teacher or peer, gets feedback, and then revises their paper. The conference begins with an initial
effort by the student—planning and producing a draft of his or her own creative or expository
writing. Typically, it is the student who selects the topic and organizes the text; students rarely
have more than a broad assignment from the teacher to constrain their creativity or imagination.
The conference with the teacher or peer is an event where students get feedback, not to make a
final judgment on their performance, but to motivate them to make changes to the text to make it
clearer, more compelling, more engaging. Students are likely to be motivated to revise their
writing on the basis of the conference, to the extent that they are motivated by a desire to write for
an external audience, a desire that can be enhanced by the very act of the writing conference.
Improve Teachers' Ability to Use Feedback To Engage in Contingent Teaching

Classroom network technology can play an integral role in improving feedback, by making it easy for teachers to involve all students in assessment and making visible the range of student ideas at any point in a student’s learning trajectory (Roschelle, et al., 2004). Classroom network technologies are systems of technology in which individual devices for students and teachers are connected to a local, or classroom-based network; a mechanism to display contributions of students to the system is usually part of the technology (Penuel, in press). Research on this technology suggests its potential for dramatically increasing participation of students, facilitated by the ability to pose questions to all students simultaneously, aggregate results, and present them for all to see and discuss (Penuel, et al., 2005).

Routines of various kinds facilitate teachers’ becoming efficient in making instructional decisions on the fly (Calderhead, 1981). Routines can recommend alternative sequences of activities for teachers to follow, depending on how their students are learning from particular curriculum activities. If, furthermore, as a consequence of following a routine in which students have been given the opportunity to learn and are still having difficulty with a concept or skill, routines provide a basis for revising plans for future lessons. Routines can provide such information when they elicit the range of student ideas about a concept (van Zee & Minstrell, 1997), enable active student participation in assessment activities (Black & Wiliam, 1998; Dufresne, Gerace, Leonard, Mestre, & Wenk, 2003), and foster divergent thinking about particular problems (Beatty, et al., 2006; Stroup, et al., 2005).

TEACHING ROUTINES FOR GROUP SCRIBBLES

A central focus of our work has entailed developing routines that leverage Group Scribbles to support teaching and learning of important science content and practices. Group Scribbles (groupscribbles.sri.com) is a general-use collaborative application developed by SRI International. It offers instructors and students a powerful metaphor for thinking about and realizing collaborative learning activities. The metaphor is based on common physical artifacts from the classroom: adhesive notes, bulletin boards, whiteboards, stickers, pens and markers. Participants can scribble contributions on sheets similar to adhesive notes and jointly manage the movement of these electronic notes within and between public and private paces. Because Group Scribbles encourages decentralized control and individual initiative within a collective framework, students are highly involved in both contributing and responding to content.

Group Scribbles allows for open-ended questions that require students to construct an answer interactively using a range of representations, including text, sketches, and images. Group Scribbles displays can be continuously manipulated as the discussion proceeds to support emergent collaborative activity. In addition, Group Scribbles supports simple creation of individual and group workspaces to support flexible classroom configurations and highly parallel interactions. Figure 1 displays an image of a Group Scribbles board with student responses.
A classroom activity can take place entirely within the Group Scribbles environment and the software allows *in situ* assessments of student thinking. This potentially affords the teacher much richer and finer-grained diagnosis of student understanding that is situated within the particular learning occasion. The open-ended structure provides the opportunity for a more contextualized understanding of potentially problematic student ideas and allows teachers to take new and more innovative instruction paths based on their professional interpretation. Teachers using Group Scribbles are able to assess and respond to actual student images and language in an improvisational fashion. They can use multiple attributes of student work as basis for further discussion—either to illustrate a specific misunderstanding or to reframe and re-present knowledge. With this increased flexibility in types of student responses that may be collected,
there is the additional challenge of unpacking how students’ responses reflect their underlying conceptualizations of the content.

The teaching routines that we have developed help to scaffold for teachers sequences of instructional moves that promote discussion and reflection on student thinking and take advantage of the affordances of Group Scribbles. An outcome of our design process was a collection of six teaching routines that provide a frame for teachers to enact different sequences of movement across public and private workspaces and between computer-mediated and face-to-face communication to make student thinking transparent. Each teaching routine describes a sequence of instructional moves for creating a particular kind of interactive formative assessment opportunity.

Our six teaching routines support six types of interactive formative assessments with Group Scribbles: concept mapping, data creating and sharing, question posing and categorizing, interpreting images, designing tests, and predicting. Each teaching routine follows a design principle aligned to how people learn (National Research Council, 1999). The steps in routines are designed to foster communication, enhance student motivation, and provide guidance to teachers about when to provide feedback and what to do after collecting and aggregating student responses to questions. Table 1 outlines the six teaching routines used in Group Scribbles along with their respective design principles and a brief description of how each routine enhances classroom communication, motivates student participation, and supports contingent teaching practices by improving teachers’ ability to adjust instruction. Many of these routines include individual, small group, and whole class work or discussion; all require some student construction of knowledge. To facilitate formative interactions among the teacher and students, a teaching routine can encompass part of an instructional session or an entire instructional session. Some of the routines (e.g., Group Data Creation and Comparison) are particularly well suited for formatively assessing students’ inquiry skills.
<table>
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<tr>
<th>Routine</th>
<th>Design Principle</th>
<th>Instantiation</th>
<th>Goals</th>
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<tbody>
<tr>
<td>Concept Mapping</td>
<td>Construction of causal or other links among concepts helps students grasp important relationships among ideas and enrich their knowledge networks.</td>
<td>Students create concept maps in GS and iteratively revise and refine them with their peers.</td>
<td>Communication: Students discuss, debate, and refine their thinking with peers and teacher about how ideas relate to one another. Participation: Comparing and contrasting ideas encourages students to reflect upon, clarify and refine their own ideas. Contingent Teaching: Teacher gains insight into students’ thinking and how students connect ideas.</td>
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<tr>
<td>Group Data Creation and Comparison</td>
<td>Organizing and comparing data helps students understand key data to be collected and appropriate representational forms that can be used to display data.</td>
<td>Students work in small groups to organize and represent data using GS. They discuss similarities and differences among the groups’ data.</td>
<td>Communication: Students present data for peer review and discuss different ways to organize and represent data. Participation: Students’ own contributions, including data, are a centerpiece of classroom work. Contingent Teaching: Teacher obtains feedback on students’ abilities in organizing, representing and interpreting data.</td>
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<td>Question Posing and Categorizing</td>
<td>Developing and refining questions helps students identify questions that can be tested in investigations.</td>
<td>Students use GS to collaboratively generate and share research questions. They discuss similarities and differences among their questions.</td>
<td>Communication: Students collaborate with each other to generate and refine research questions. Participation: Students are invited to generate questions that will guide their own research. Contingent Teaching: Student-generated questions provide feedback to teacher regarding students’ grasp of the type of questions that are researchable.</td>
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<td>Where on this Image?</td>
<td>Comparing and contrasting processes or events using images helps students construct causal links about relationships of phenomena.</td>
<td>Students use images (e.g., maps, drawings, and pictures) posted in GS to explore phenomena and their underlying processes. They note the occurrence of processes or events and discuss why these processes/events occur in similar or different locations on the image.</td>
<td>Communication: Students use symbols to represent and communicate processes. Participation: Students create their own symbols to represent processes. Contingent Teaching: Teacher has an opportunity to assess students’ understanding of how two or more processes are related.</td>
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<td>Design a Test</td>
<td>Designing a scientific experiment, test, model, or procedure helps students learn a fundamental practice of science.</td>
<td>Students develop an experimental design including independent and dependent variables on a GS board. They invite peer comment, review, and feedback on their designs prior to conducting their experiments/tests.</td>
<td>Communication: Students critique and provide feedback on each other’s test design. Participation: Students use their refined procedures to test their ideas. Contingent Teaching: Teacher has an opportunity to assess students’ understanding of test design and implementation.</td>
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<tr>
<td>Predict with Reasons</td>
<td>Making a prediction (stated outcome) supported with reasons based on conjecture or partial evidence helps students develop reasoning skills and understand the underlying scientific significance of an investigation.</td>
<td>Students describe a likely outcome/prediction for a test, observation, or model using GS. They discuss underlying reasoning for the prediction, and revisit the prediction after an experiment, test, or event is completed.</td>
<td>Communication: Students discuss, compare, and refine their thinking about likely outcomes of an experiment, test, or event. Participation: Students have a personal investment in conducting an experiment, test, or event. Contingent Teaching: Pressing students to base predictions on reasoning provides insight into how well students grasp the significance of investigations.</td>
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Each teaching routine was designed to serve as a template from which an instructional designer, such as a teacher or curriculum developer, can create more specified interactive assessment opportunities to help teachers make instructional decisions. For example, the teaching routine *Group Data Creation and Comparison* (shown in Figure 2) identifies the key steps for enacting the routine to support students in collaborative collecting, organizing, sharing, and comparing of data. Because the teaching routine is generic in design and not linked to specific science content or lessons, it can be used as a foundation for creating assessment opportunities with Group Scribbles within or across lessons and units of instruction encompassing the same or different content. In this way, teaching routines encourage a level of consistency in assessment practice that enables both teachers and students to gain familiarity and comfort with enacting formative assessment over time.
Interactive Formative Assessments Based on Teaching Routines

The final step in our process was to use the teaching routines to develop content-specific interactive formative assessments (IFAs) within lessons of a middle school Earth Systems science unit. An IFA is an instructional sequence that incorporates diagnostic questioning and contingent teaching facilitated by classroom network technology. It differs from traditional formative assessment because the classroom network technology, in this case Group Scribbles, supports even greater collaboration and interaction among the teachers and students than are typically possible in classrooms. All IFAs developed for this project adhere to four key principles, elaborated below.

*All IFAs should build from existing curriculum materials.* We have chosen to build assessments using a particular middle-school Earth science curriculum, *Investigating Earth Systems*, as a base for a number of reasons. First, these materials are already widely adopted, and focused additions to the curriculum have a good chance at being incorporated into future editions of the curriculum. If that happens, the scalability of our materials is greatly enhanced. Second, these materials have been evaluated in an efficacy trial; when coupled with professional development that prepares teachers to adapt these materials to their local standards, the curriculum can be effective in increasing student learning in Earth science (Gallagher & Penuel, 2009). Third, the curriculum provides a useful anchor point for constraining development of both activities and assessments. Our aim is not to develop summative assessments but rather assessments that can be used to
adjust instruction. Embedding them into materials teachers use to plan instruction provides the kind of guidance teachers can use to make the most of assessment information.

All IFAs should incorporate routines. We want all assessments to incorporate routines so that they can serve as models for teacher adaptation and lesson creation. Incorporating the routines into assessments will make visible the versatility of routines as resources for development and will also provide concrete illustrations that reflect our best thinking about how assessments can be designed with the technologies.

All IFAs should incorporate learning processes consistent with research on how students learn from participating in assessment activities in science. Key processes for learning from assessment in science activities are feedback and student reflection. Feedback helps students understand what they know and also to know how to improve (Black & Harrison, 2001; National Research Council, 2001). Network technology provides another source of feedback that may be important to learning: feedback on what others know and are having difficulty learning (Penuel, et al., 2005). Good classroom assessments also have students reflect on and revise their ideas (Black & Wiliam, 1998; National Research Council, 1999, 2001). Network technology supports reflection indirectly, by providing a focus (a shared display) for reflection, but to be effective, teachers must facilitate discussion of ideas to make reflection an integral part of a networked classrooms. The assessments will provide examples of how to foster reflection by providing more concrete guidance than do the teaching routines about questions to pose and about how to orchestrate classroom discussions.

All IFAs should integrate diverse sources of expertise. Developing assessments that incorporate network technology, employ routines, and assess Earth science content and skills requires a diverse set of expertise. Software engineers are needed to clarify the current and possible capabilities of the technology and to support classroom implementation. Learning scientists are needed to develop lesson plans using routines that reflect what we know about how people learn. Assessment and subject matter experts are needed to develop diagnostic questions and see to it that the connections encouraged in the IFAs reflect both accurate and significant content. Teachers’ perspectives are needed to address questions about what is feasible to implement in real classrooms with students at particular grade levels.

In our work, each IFA has the same components as a teaching routine but is tailored to a lesson and its learning goals. Because IFAs are embedded within lessons and directly align with the target content of lessons, they can only be used with Group Scribbles in specified lesson contexts. For example, the Where on this Image? routine (Figure 3) was used to design an IFA within an Earth Systems lesson on tectonic plate boundaries (Table 2). In this way, a teaching routine becomes a resource for designing IFAs within lessons. As illustrated in Table 2, each step in the routine becomes instantiated within the Ring of Fire IFA.
Figure 3. Where on This Image? Routine.
Table 2. Instantiation of Where on this Image? Routine in Ring of Fire Interactive Formative Assessment.

<table>
<thead>
<tr>
<th>Steps in <em>Where on this Image?</em> Routine</th>
<th>Steps in Ring of Fire IFA</th>
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<tbody>
<tr>
<td>1. Teacher posts an image to individual/group boards.</td>
<td>The teacher creates 3 boards: (1) Volcanoes, (2) Earthquakes, (3) Fault Lines and uploads a background image of the map of the North Pacific Ocean and surrounding land masses. The teacher assigns students to one of 3 groups (volcanoes, earthquakes, or fault lines).</td>
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<td>2. Groups mark images to indicate where processes occur.</td>
<td>After conducting research on their assigned topic (volcanoes, earthquakes, or fault lines), students work in groups to mark their group board. Group 1 marks major volcanoes (using the red triangle stamp tool) and labels their locations by name and country using scribble notes. Group 2 marks to mark major earthquakes (using the blue circle stamp tool) and labels their locations and year of occurrence using scribble notes. Group 3 draws major fault lines (using orange lines) and labels the plates they run between using scribble notes.</td>
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| 3. Discuss similarities and commonalities in groups’ markings. | When each group has finished their boards, the teacher projects each group’s board from the teacher computer. To facilitate discussion, the teacher can display 2 or 3 boards at the same time. The teacher asks the class the following questions: Based on the various maps, what patterns do you see? *(Key idea: Earthquakes and volcanoes tend to follow the fault lines around the Pacific Ocean.)*

Why are volcanoes and earthquakes common in some areas but not in others? *(Key idea: Earthquakes and volcanoes typically occur at plate boundaries.)*

What conclusions can you make about where plate boundaries are located? *(Key idea: Plate boundaries can usually be identified by the presence of fault lines, volcanoes, and earthquakes.)* |
| 4. Students use discussion ideas to write an explanation of how processes are related. | Students write in notebooks or journals conclusions about the relationships among volcanoes, earthquakes and fault lines. |

In the Ring of Fire IFA, students explore an area in and around the Pacific Ocean, called the Ring of Fire, where large numbers of earthquakes and volcanic eruptions occur. This is due to the movement of the tectonic plates that make up the area. The use of Group Scribbles as an interactive formative assessment space enables the teacher to “make thinking visible” by creating a public display of students’ contributions to a map of the Ring of Fire. In this IFA, students use the tools in Group Scribbles to show and label the locations of volcanoes, earthquakes and plates.
in the Ring of Fire. To enact this IFA, the teacher needs access to the Group Scribbles server, a teacher computer with web browser, a projector connected to the teacher’s computer, and student computers with web browser and Group Scribbles. The teacher has teams of students conduct research on different aspects of the Ring of Fire (volcanoes, earthquakes, or fault lines). Teams use the internet and classroom text materials to research information regarding their assigned feature of the Ring of Fire. Each team creates a Group Scribble board to showcase their learning. To facilitate discussion, the teacher can arrange the display to display multiple boards simultaneously. Examples of questions to promote discussion along with target responses are also included in the IFA.

**Using Teaching Routines to Design IFAs as a Professional Development Opportunity**

In so far as teaching routines offer strategies to addressing complex interactions in the classroom, we view them as having great potential for professional development for teachers. We have conducted several workshops and teleconferences with teachers on teaching routines. A key feature of the professional development was to involve teachers as co-designers of IFAs with learning scientist researchers, assessment developers, and Earth scientists (Penuel, Roschelle, & Shechtman, 2007). The teachers involved in the design of these teaching routines were from the middle- and high-school in large urban school districts that include diverse student populations in terms of ethnicity and socio-economic status.

The co-design process with teachers first involved the unpacking of the IFAs drafted by the project team. Through this process the relationships among the teaching routines and the components of the IFAs were made explicit. To complete drafts of new IFAs and teaching routines, small groups worked collaboratively. Each group was assigned a range of expertise: a learning expert, an Earth science content expert, a teacher, a technology specialist, and a researcher. Not only did this activity result in the creation of IFAs for others to use; the act of design also was intended to be a form of professional development for participating teachers. By providing teachers with access to diverse expertise, we hoped to extend the range of what teachers could imagine was possible with the technology and the curriculum.

A key reason why we created teaching routines was to enable teachers to use them to design lessons on their own, as the need arises. The project’s vetted IFAs are likely to be only one source of inspiration for teachers in doing so. By reviewing and unpacking routines embedded in IFAs, our intent is to provide teachers with the tools they will need to make the most of Group Scribbles technology. We have planned a series of professional development sessions (workshops and teleconferences) to identify ways that teaching routines can be incorporated effectively into classroom activities and to obtain feedback on the teaching routines and IFAs.

To date, co-design teachers have reported that most teaching routines are transparent with respect to the goals of enhancing communication, motivation and feedback. In addition, teachers believe that the routines would help students learn high-level skills such as interpreting images, monitoring their understanding, designing experiments, and communicating specific information clearly. Several teachers predicted challenges related to classroom management, such as: (1) figuring out the “right amount of time” to allow students to answer questions, (2) keeping students on task during group work, (3) building in time for discussion and revision to each group’s ideas, and (4) managing responses from multiple groups/individuals.
FUTURE RESEARCH DIRECTIONS

Future research studies are planned to investigate further how often and reliably teachers integrate teaching routines in their instruction, how students of different backgrounds and attitudes perceive the IFAs and Group Scribbles technology, and how implementation varies for teachers with different levels of content knowledge and prior experience with using technology in their classrooms. These data on implementation will inform planning for revisions to the intervention in three ways. First, data will be used to identify additional technology support and training needs if teachers report that they experience significant difficulties that affect more than one to two students when they use their response system technology. Second, the data will be used to focus efforts to identify phases of instruction where teachers find it easier to use the instructional routines. Third, data from teaching routines and IFAs that were not successfully enacted will be analyzed to determine whether they need to be revised or eliminated, or whether additional training should be provided to teachers.

CONCLUSION

Teaching routines are designed to address some of the biggest barriers to using online classroom network technologies to collect and aggregate student data and make instructional decisions on the basis of those data. Teaching routines used in conjunction with classroom network technologies, such as Group Scribbles, have the potential to advance knowledge and understanding about classroom practices that build from research on student learning, assessment, cognitive science, and teacher learning to address a major challenge to effective use of classroom network technologies. When instantiated as a sequence in the classroom, teaching routines are intended to increase student opportunities to communicate with the teacher and with peers about their thinking, to motivate students to want to participate and learn from lectures, investigations, and readings, and to encourage student feedback to inform the teacher about how to adjust instruction.

One of the most important contributions of this approach is that teaching routines make explicit good teaching practices with classroom network technology. In the past, teaching has been described as a profession where practice is “ privatized,” that is, where instructional decisions are largely left to individual teachers to make and where opportunities to observe colleagues limit learning from peers (Little, 1990; Lortie, 1975). Both accountability systems and efforts to promote opportunities for teachers to learn from one another, however, aim to expand the horizon of visible practice and bring teachers’ practice into closer alignment to improve student learning (Little, 2002, 2003; O'Day, 2002).

The process of making practice visible to peers is aided when teachers can develop a common language for describing their practice (Grossman & McDonald, 2008). In our work, that common language will be provided by teaching routines, and we expect it will serve not only as a resource for teachers to use to enable their own collaborative learning but also as a “boundary object” for anchoring discussions where researchers and teachers are both present and discussing how to improve a particular activity.

As specifications of sequences of an IFA, teaching routines can also serve as a resource for instructional design. In developing curriculum or in planning instruction, individuals and teams benefit from models for how to structure resources and opportunities for student learning (Gallagher & Penuel, 2009). To the extent that these resources instantiate principles of how people learn, these routines also make it more likely that the lessons developed will promote student learning. For example, teaching routines that embed into their designs what have been called “quasi-repetitive activity cycles” have been shown to familiarize students with the process of learning from reflection (Schwartz, Lin, Brophy, & Bransford, 1999; Vye, et al., 1998).
REFERENCES


**ADDITIONAL READING SECTION**


**KEY TERMS & DEFINITIONS**

*Classroom network technology*: technology that enables teachers and students to share questions, ideas, data, or responses via a local classroom network

*Co-design*: collaborative process in which researchers, teachers, and software developers design an educational innovation

*Contingent teaching*: adjusting instruction on the basis of particular patterns of student thinking

*Diagnostic questioning*: questions designed to elicit student preconceptions and relate student responses to known goal or problematic understandings related to the domain

*Formative classroom assessment*: a process that provides feedback to teachers and students about students’ understanding and thus can be used to help teachers adjust their instruction to better address students’ learning needs

*Interactive formative assessment (IFA)*: instructional activity based on a teaching routine that is expressly designed to use classroom network technology to enhance communication, motivation, and feedback
Teaching routine: recurring, patterned sequences of interaction teachers and students jointly enact to organize opportunities for student learning in classrooms