

### 3 Community Building with and for Teachers at The Math Forum

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This chapter addresses the way in which the Internet forms the core of an intentional, online community by promoting communication between interested parties. The Math Forum ([mathforum.org](http://mathforum.org)) is a unique group of individuals who are committed to using computers and the Internet to enhance what they know about learning, teaching, and doing mathematics. The Math Forum includes programmers, project and service staff, Web persons, and an ever-expanding number of teachers, students, and other individuals (i.e., parents, software developers, mathematicians). Thus, community building for The Math Forum staff includes work with teachers, with partners (National Council of the Teachers of Mathematics, Mathematics Association of America, and so on), and with specific services developed by The Math Forum staff that enable teachers and students to come together to pose and seek solutions to problems.

The Math Forum uses the Internet to provide interactive services that foster mathematical thinking and discussion. These services include Ask Dr. Math and several Problems of the Week (PoWs); a teacher discussion format called Teacher to Teacher (T2T); an archive of problems, participant contributions (e.g., lesson plans), and past discussions; and an Internet newsletter. Within four years, with no explicit efforts to garner promotion or publicity, the site grew to include 1,600,000 Web pages and to attract 3.5 million accesses and over 800,000 visitors per month – a third of which constitutes sticky traffic ranging from world-famous mathematicians to elementary school children.

Participants, including The Math Forum staff, hold an image of The Math Forum as a community and have done so since its inception.\* For

\* The Math Forum has built out its services both with participants and in response to participants' strengths and needs. Its initial funding came from a succession of grants from

a person who logs on for the first time, however, The Math Forum may appear to be simply an online collection of resources or services. Based on in-depth, structured interviews with participants, online questionnaires, and notes to the Webmaster and staff, however, it seems that the community of The Math Forum develops through participant interactions with The Math Forum services, staff, and other participants who facilitate their thinking about the kinds of questions, issues, and solutions that participants bring to the site.

The Math Forum community is not simply lodged in its participants, but rather in the particular interactions of its participants, which include The Math Forum staff. The participants interact around the services and resources participants generate together. These interactions provide a basis for participant knowledge building about mathematics, pedagogy, and/or technology. The interactions also contribute to what might be described as a Math Forum culture that encourages collaboration on problem posing and problem solving. Participants' work together is facilitated by the design of Math Forum services and the particular affordances of the Internet.

Students who submit solutions to the PoWs,<sup>†</sup> for example, receive individualized feedback in the form of questions, observations, and/or

the National Science Foundation (NSF), beginning with The Visual Geometry Project (1986–92) in which *The Geometer's Sketchpad* was developed. Now a commercial product, this software was developed to enable geometers to depict the patterns and relations on which geometers were working. In response to users of Sketchpad, who sought to exchange figures with other users, the Geometry Forum (1992–5) was established. Its central goals included support of geometry education and the facilitation of communication about geometry.

The advent of the Web coincided with NSF's urging that The Geometry Forum expand to encompass mathematics more generally. The Geometry Forum became The Math Forum in 1996. This change extended its goals to include support of mathematics education, structuring of services to facilitate mathematical thinking, and examination of the contribution that technology can make to learning and instruction.

In 2000, The Math Forum partnered with WebCT, a business that sells, supports, and develops the use of the WebCT course tool for organizing courses that teachers and professors create for their classes online. It was expected that the Forum could serve as a model for learning communities. With the downturn in the economy, WebCT decided to focus on core services and sold The Math Forum to Drexel University. Both WebCT and Drexel University partnerships met NSF mandates for its projects to attain sustainability for their infrastructure. While The Math Forum continues to include projects and partnerships sponsored by the NSF, Math Forum staff and services are endeavoring to meet the increased need to scale services.

<sup>†</sup> Presently there are seven Problems of the Week posted each week: an elementary problem (ElemPoW), a middle school problem (MidPoW), an algebra problem (AlgPoW), a geometry problem (GeoPoW), a discrete problem (DmPoW), a calculus problem (CalPoW), and a component-enhanced problem (ESCOTPoW).

suggestions that push them to make connections between what a particular student understands a problem to ask and what he or she already understands. The feedback students receive from this service, like that of other Math Forum services, encourages them to reflect on their problem solving, including the connections they have made and the strategies they have used. This feedback does not tell students what the next step is but rather poses questions that provide the kind of support that students need to work effectively with problem demands.

Interaction on a site such as The Math Forum can take several forms. Interaction is a design feature of each service. Interaction also characterizes participant engagement with The Math Forum. In many schools, talking about either math or teaching math is considered taboo, even if you teach it. For teachers feeling the press of these settings, interaction can be participant-driven with individuals seeking collegiality or friends with whom to talk about math. Interaction also can be private, in the sense that The Math Forum is a safe community in which one can review feedback, talk about concerns, and seek answers to problems. One teacher, for example, told us that he would never admit to his colleagues that he had not had geometry since high school. He used The Math Forum archives to learn the geometry he needed to teach. At present, he uses the archives, Web units, and lessons that others have posted on the site.

As a richly textured virtual space, The Math Forum represents opportunities for its participants to deepen and consolidate their understanding of mathematics, technology, and/or pedagogy (Lave & Wenger, 1991). However, it also exists in a reciprocal relation to its participants. Participants help to define and refine its services through their responses to Forum-generated questionnaires, interviews, Web-page comments, and informal exchanges.

In this sense then, The Math Forum “community” can be thought of as a reference group with whom one shares information and interests that extend beyond the kind of physical connection one might hope for in a neighborhood. The Math Forum has no requirements or expectations like those one may encounter when one moves into a new neighborhood (that one will mow the grass when it is a certain length, lend sugar, etc.). Of importance to Math Forum participants is its provision of autonomy (Krapp & Lewalter, 2001; Ryan & Deci, 2000) – participants use as much or as little of the site as they choose, when and where they decide to do so, and may or may not choose to tell others about their work.

Autonomy appears to engender both intellectual and emotional connections between the participants and The Math Forum because

site services are interactive and, as such, supports knowledge building. Students, for example, develop connections to the folks with whom they are working online when, for example, they are asked what they understand a math word problem to be asking, given a chance to rethink the decisions they made, or encouraged to resubmit a solution to a problem. Furthermore, being acknowledged as having gotten a start on a problem is quite different from being told an answer is incorrect. In fact, relationships with staff are reinforced by features of the services that recognize students as individuals, for example, when the mentor “remembers” what the student did the week before and acknowledges this. (In actuality, the mentor may well remember what a given student did in working with a problem, but, given the volume of student submissions to The Math Forum site, this also may not be the case. Built into the design of the PoW services, for example, is the ability for mentors to draw on information about a student’s previous submissions and prior responses to these. This allows the mentor to tailor his or her response to the student’s solution in terms of that student’s strengths and needs.)

Teachers develop a connection to The Math Forum that is similar to that of the students. Teachers, too, work to understand and ask questions about math, teaching math, and so forth. This kind of use or connection to The Math Forum is reinforced by Math Forum protocol for responding to participants. This protocol emphasizes the importance of welcoming and listening to participants, confirming an understanding of the question(s), and providing links to necessary information without judgment.

Despite the fact that several types of interactions provide the basis for community on The Math Forum site, interaction is not a sufficient condition for participant re-engagement. Interaction is the vehicle that allows the kind of reflection that is critical for the development of mathematical thinking (Schoenfeld, 1992). Interaction on The Math Forum site is a structural feature that enables participants to increase their knowledge, and because of the opportunity to build knowledge, participants come to identify with The Math Forum as a community. The Math Forum community supports participant learning and enables participants to grow as mathematical thinkers.

The Math Forum’s services and resources support knowledge building much as the highly successful instructional technique called cross-age tutoring does. Findings from research on this method of grouping students for instruction uniformly suggest that both tutors and tutees benefit (Renninger, 1998). Students involved in cross-aged tutoring deepen their

understanding of topics, improve their social skills, and improve their attitudes toward school.

Like cross-aged tutoring, the interactive qualities of The Math Forum's services provide a participant with tutors or tutees, as needed. The content of the services enable users to develop their understanding of mathematics and pedagogy further. The content of The Math Forum's resources is the "stuff" around which interactions occur. This kind of knowledge construction enhances participants' feelings of competence (Renninger, 2000; White, 1959) and enables them to identify remaining questions, in turn leading them to reengage The Math Forum in search of answers.

On The Math Forum site, community and the learning that it affords are considered to be in a continuous process of evolution. The present chapter focuses on the experience of building community with and for teachers at the Forum. Descriptive information about Math Forum Teachers is provided – and the cases of three teachers are detailed – to illustrate the kinds of opportunities for learning and changed practice that an interactive, service-oriented site can afford. Following this, discussion centers on the roles of imagination and identity in the development of a community where there is a reciprocal relation between the staff's design of services and the strengths and needs of site participants as learners. Finally, discussion turns to opportunities for knowledge building as catalysts for community participation.

### Forum Teachers

The National Council of Teachers of Mathematics' *Principles and Standards for School Mathematics* (2000) has charged teachers with the need to enhance the mathematical thinking of their students by using reform-based practices including technology in their teaching. For teacher participants, the kind of mathematical, pedagogical, and technological resources available at The Math Forum site are all potentially useful.

Not all teachers use the site, but those who do range from being technology explorers to those who are technologically proficient; the teachers also range in their levels of expertise in both mathematics and pedagogy. Based on responses to The Math Forum's 1999 Internet Questionnaire,\*

\* The Math Forum Internet Questionnaire was posted to all participant (students, researchers, parents, mathematicians, teachers, etc.) who opened the home page or any of sixteen Math Forum services during the third week in May each year between 1996 and 1999. The questionnaire consisted of forced-choice and open-ended questions that were used both to provide descriptive data about users and feedback to staff about service development. A total of 814 teachers responded to the questionnaire in 1999.

for example, teachers using The Math Forum are likely to have been using the Internet for two or more years and are equally likely to:

- Hail from diverse backgrounds (rural, suburban, or urban);
- Vary from having a well-developed interest for mathematics to having a less well-developed interest for mathematics;
- Use a variety of resources for the purposes of lesson planning and self-education;
- Have found out about The Math Forum from a range of sources, most frequently by surfing the Web, doing a search, or responding to a recommendation from a colleague;
- Contribute to The Math Forum by telling others about it, sharing the resources they find, helping students to mentor PoWs, and developing materials;
- Describe The Math Forum as an important – or even an absolutely essential – part of their Internet activity.

Patterns of teacher usage of The Math Forum in 1996 indicated that teachers were initially using the site primarily for planning lessons and recreation. By 1997, teachers began to be more likely to use the site for finding resources and planning lessons. This pattern held through 1998 and 1999. Low on the set of reasons for using the site were opportunities for discussion. Although the opportunity to discuss geometry had been a *raison d'être* for building out The Math Forum, Forum teachers more typically make use of the site's interactive services, including the archives.

The next section of this chapter focus on characterizing the context within which teachers pursue particular resources on the site. The cases of three Math Forum teacher participants are described, followed by a description of the larger sample of teachers interviewed as part of this study.

### *Case Descriptions of Three Teachers*

Sonia Leach (pseudonym), Bob Nelson (pseudonym), and Alecia Smith (pseudonym) are teachers who use The Math Forum. The three teachers differ in their levels of knowledge about mathematics, pedagogy, and technology. They also vary in their initial intentions for using The Math Forum, interest for the site, levels of students they teach, and types of schools in which they work. Their cases are drawn from a sample of forty-two Forum teachers who were interviewed once a year over the three-year period, 1997 through 1999.

These case descriptions are informed by in-depth structured interviews, the Internet questionnaires conducted with all Math Forum

participants each year, service-specific questionnaires, participant observation during workshops, participant observation in Math Forum staff meetings including focus groups used to discuss service design and facilitation, and regular meetings with Math Forum staff between 1997 and 1999.

### *Sonia Leach*

Sonia Leach began using The Math Forum site when she was a first-grade teacher in a public school in a densely populated suburb. The school in which she taught had approximately 350 students and was 60 percent minority. It was a special-needs school. It had also just been named a model tech school and was in the process of getting wired for Internet use. She had one computer connected to the Internet in her classroom and access to a lab. She talked about technology as a resource for her students since they came from less-advantaged backgrounds.

Sonia initially used The Math Forum as an enrichment activity in her class of fifteen to sixteen students because she needed to be using technology in some way. She downloaded The Math Forum's Elementary Problem of the Week (ElemPoW) and had the students take it home to complete. Sonia liked the process of having parents working with their children on the ElemPoW because it involved the parents in their children's education. In fact, she reported that several of the families developed an interest in the PoW problems and were drawn to explore The Math Forum on their own. A few times that first year, Sonia worked in class with her students on the ElemPoW because problem solving was a whole-school focus.

By the end of her first year of work with The Math Forum, Sonia was thinking about how she could integrate work with the site in her classes the next year. She was looking forward to taking a computer home from school over the summer and was working on getting an Internet connection at home. She said she wanted to be able to have time to work with The Math Forum resources herself. Although she indicated that she was not strong in math, she said that her husband was, and he would be interested in The Math Forum, too.

Following a year of intermittent Math Forum use and its positive reception by her students and their parents, it appears that Sonia began to take the kind of risks necessary to engage mathematics more directly. She sought out resources in the form of an Internet connection so that she could work with the site and continue to develop her knowledge of

mathematics; in addition, The Math Forum was something that she could share with her family.

When asked about why she started to use The Math Forum, Sonia talked at first about her son, who had started using The Math Forum in his middle school class for extra credit and then began doing it for pleasure. She was very excited about sharing the changes that had taken place in her son's attitude about math. She said he had never been a hard worker before, but The Math Forum and particularly the Middle School PoW (MidPoW) piqued his interest. She mentioned that the comments Mrs. B (the MidPoW mentor) sent her son were very supportive and challenging at the same time. Sonia said he was "really touched by her. It's almost as if he knows her." This experience clearly moved both Sonia and her son; it appears to have had an impact on her teaching, the parents of her students, and her colleagues.

For Sonia, The Math Forum represented a very personal form of interaction online through the personality of Mrs. B. She saw how powerful simply recognizing what a child was able to do and encouraging him could be. This, she felt, had turned her son into a math student. This experience gave her confidence as a teacher. As she explained, "if The Math Forum could help my son so much, it could do a lot for me and my students' parents, and even help with my own math ability." Over time, Sonia began to become more innovative about how to get computer equipment and how to use The Math Forum in her class. Her interest and enthusiasm grew as she began to use the ElemPoW more regularly in her class. Sonia also began to talk with her peers about what she was learning and what they might be able to do using Math Forum resources with their students.

Mrs. B.'s responses to Sonia's son had modeled possibilities for working with students that Sonia then used with her own students. This modeling also appears to have inspired Sonia to overcome her fear of technology and the need to use it in her classes. By the second wave of interviews, Sonia had become highly motivated around computing questions. Rather than being fearful, her concerns had shifted to pragmatic problems to be solved.

Sonia now teaches in a nearby tech school for 900 gifted and talented students. Although she continues to work with a significant group of English as Second Language students in this new school, she describes its population as being upper middle class. She notes that she has four networked computers in her class, in addition to having access to a computer lab. She says that at least half of the students in her class have computers at home. The availability of computers has greatly enhanced her ability to use technology with her students.



Sonia reports that once she moved to her new setting, she began using computers a lot and began teaching in more varied ways: she introduced her students to using the computer for research and has the students working on projects in various grouping arrangements. Currently, she is reading about how to help students to develop their own Web pages. She also continues to use the Forum in her classes.

From the outset, Sonia repeatedly said how much she liked the responses the ElemPoW mentors gave her students. She likes the fact that they encouraged the students to think carefully about problems and to explain their decision making. She continues to think that The Math Forum provides her students with more challenging math than she could provide for them. She reports that she “uses anything on The Forum that I can find.” She has also been encouraging her more accelerated students to send questions in to the Ask Dr. Math service.

Sonia’s situation is typical of many of the teachers interviewed. At the first interview, Sonia, like the other teachers, did not have her own computer or Internet access at home. She expressed concern about her knowledge of mathematics and was reluctant to move in the direction of using more technology out of a fear that it would be beyond her. By the second interview, Sonia had begun to express an interest in the possibilities that computers held and was using some Math Forum resources in her class. She still expressed some trepidation about getting a system set up and connected to the Internet from home, however. By the third interview, Sonia had integrated Math Forum materials into her curriculum and was leading others in their efforts to develop Internet-based resources for her grade level. The Internet was fully a part of her home and school life. It had also afforded her an opportunity to change jobs and to work in a school that had more resources.

Sonia’s experience is emblematic of the way The Math Forum as an organization can provide support for teachers and students. The Math Forum staff (and the many who volunteer as mentors, etc.) have a set of cultural assumptions that at first rarely match those of the teachers (the parents, or the students) with whom they work. The staff loves math – seeing in it its sheer elegance, challenge, and depth. They enjoy the process of problem solving and are interested in sharing this with others. They find challenging the need to identify exactly what it is that a child (teacher, etc.) does not know and how to work with them to figure it out. For the staff, this is just another “problem” to be solved. The staff believes that it is possible for all people to work with math. They are not inclined to “give” answers but to ask questions to facilitate learning. Their

approach is what Cobb (1995) would label both indirect and multivocal. It is the kind of exchange that empowers because it is gauged to meet the individual where he or she is and in this process also stretches their understanding (Schoenfeld, 1992).

The staff, along with other Math Forum participants, helped to develop and facilitate the services that Sonia found useful. Sonia's recognition of their usefulness was based on her understanding of the power that talking and thinking about math with another person could have. Her son had been so changed in his attitude about math that he provided her with a very personal object lesson in the ways that people can be influenced by others even if those others are physically removed and only have the ability to share text over the Internet. She saw in her son's experience implications for her own students and the parents of her students who at that point were often starved for resources. Unlike some who readily see the math possibilities afforded by The Math Forum, Sonia at first focused on the relational possibilities and support that mentorship on the site provides.

In the course of working with The Math Forum, Sonia began problem solving in ways that were different than those she had been using prior to her work with The Math Forum. She began figuring out how to use site resources such as the PoW and Dr. Math in her classes even though they were not technically part of the curriculum. This method eventually led her to explore instructional approaches that enhanced the learning that she could provide for her students. Sonia also began to think about how she could get a computer at home so she would have a chance to familiarize herself with its possibilities. This decision then led her to explore other parts of the site. Her interest for technology had shifted from being something she had to engage in to something that she wanted to master. It has an impact on her instructional practice, including her feelings about herself as a teacher of mathematics.

### *Bob Nelson*

At the time of his first interview, Bob Nelson was teaching in a middle school in one of the poorest cities in the United States. The school had 750 students and class sizes of approximately thirty-two students. He had taught there for six years. By the time of the third interview, he had taken a teaching position in a progressive private school. Bob is sure that it was his technological expertise, as reflected in the work he had been doing with his students on the Forum site, that enabled him to get the

new job. In the new school, he uses the PoW as a core component of his curriculum. He has classes of seventeen to twenty-three students and several computers that have Internet hook-ups right in his room.

Initially, Bob's use of The Math Forum centered on the MidPoW. He liked the nonroutine challenge problems that were posted each week. He also liked the fact that the students had to develop their abilities to use and explain mathematical terms when they wrote out their answers. He began using the MidPoW with his sixth-grade pre-algebra students. He figured that by the time they got to eighth grade, they would have three years of work with The Math Forum and would have learned its "problem-solving approach."

Because most of his students did not have computers at home or an Internet connection, and because Internet connections were scarce at the school, Bob downloaded the PoW each week on his own computer, worked on it with his class during the week, and then wrote up the work they had done in class and sent this to The Math Forum for the class. He described the different ways his students had solved the problem, as well as the answers that they had gotten. One of the MidPoW mentors noted that Bob's work with his class was a model of how teachers might orient students to mathematical thinking.

As soon as he found the site, Bob began using the PoW in all his classes. He said that the PoW helps him to model summarizing and explanation for his students. He also said that the PoW gives students practice with skills that complement his curriculum. He likes the way that the MidPoW mentors push students to reexamine their assumptions and to explain their ideas more fully. Bob said that the mentors' work with his students makes him feel that he has an ally. It also establishes a bar for the students that is tangible and demanding and is not so easily dismissed as his idiosyncratic idea about what mathematics involves. He reports that his students consider the PoW a personal challenge and look forward to doing it each week.

Several aspects of Bob's situation are noteworthy. Like a number of the people who found The Math Forum just surfing around on the Internet, Bob is interested in both math and technology. When working on his Masters' degree in statistics, for example, Bob found a business site that compiled all the data he needed for his project. Bob developed a relationship with an editor at the site and eventually sent him a copy of his paper, had some good discussions about it, and so forth. Sharing ideas with others over the Internet so inspired Bob that he sought money from the state and matching money from his district so that he could provide better and

more immediate access to the Internet for his students. Bob also tutored online for America Online (AOL) in exchange for free hours of online time when AOL still charged by the hour. In this way, Bob first accessed the PoWs and began doing them with his students. For Bob, the PoW represented “another way to involve my students in math.”

In his new school, Bob teaches seventh-grade math using the PoW as a core component of the curriculum. Every Monday he prints off the new MidPoW because it is one of the stations that he will have all of the students do. He talks about the problems as important to student learning because they require students to draw on all the math that they know. If the content of the week’s problem maps onto the content they are covering, then this is part of their regular assignment; if the problem covers content that they have not reached yet, then they receive bonus credits.

He feels that students need to keep working with math – all kinds of math – and he works to build this into his curriculum. His students do have access to a computer lab and have the option of submitting their PoW solutions directly to The Math Forum using the Web. Some students simply write out their answers and submit them to him, and he submits them to The Math Forum. Bob also meets once a week after school with students, and they tackle PoWs that they have not done as part of class (i.e., the ElemPoW, the AlgPoW, the GeoPoW, and/or the DmPoW). He says he loves working with the students on problem solving and thinks that “The Math Forum problems are the best around.” Bob says that there are two real advantages to using The Math Forum PoWs as part of the curriculum: the PoWs make it possible for all his students to connect to math, and all of his students make progress. He commented that he currently is not only using The Math Forum for his students, but also finds himself drawn to Math Forum resources because they allow him to “keep learning,” too.

In the former school, Bob had helped students become part of The Math Forum community by downloading the problems and working with the students to figure out what the problems asked them to do and to decide how they might be addressed. He also submitted solutions for them and reviewed the mentors’ comments on their solutions. In his new school, he can leave most of the submission and review efforts to his students, but he continues to help them identify with The Math Forum community by working alongside them, providing face-to-face experience of and support for working with the PoW and other online services such as Ask Dr. Math when this is needed.

Bob likes the fact that the math on The Math Forum is challenging and deep. He has been talking about his use of the PoW in his classes to his other colleagues. One of his colleagues has started to use some of the PoW problems when she can make them work in her class. Another colleague is new this year. He has been talking with both the new colleague and the eighth-grade team about The Math Forum in the hopes of encouraging them to give it a try, too. His goal is to see that the MidPoW becomes a regular part of the middle school curriculum in his district.

Although Sonia and Bob both report on their own developing interest for The Math Forum and encourage their colleagues to check it out, Bob's case provides a contrast to Sonia's. Bob considers himself to be a mathematician and was comfortable with technology when he was first interviewed. Bob seized on the PoW as a tool for enhancing his students' abilities to problem solve, whereas Sonia had tentatively begun her work with the PoWs as enrichment for her students. Perhaps because Bob is working with older students – but more likely because of his confidence in his mathematical abilities – Bob had his students begin working with The Math Forum's problems as an extension of their class work as soon as possible.

Bob, like Sonia, continues to grow through his interaction with The Math Forum staff and his use of Math Forum resources. Whereas Sonia connected to The Math Forum because of the relational opportunity it afforded her son and her students, Bob was drawn to The Math Forum's challenging content and the possibilities it offered both his students and himself. Like Sonia's increased use of The Math Forum in her classes and for her own exploration, Bob's use of The Math Forum also shifted. He began work with the site by having his students work with the MidPoW, and now has them working with the MidPoW in addition to other PoWs. He also has been using the archives, the frequently asked questions (FAQs), the discussion groups, and Dr. Math.

The proximity of the different services on the site to other services has led him to explore and expand his use of The Math Forum. This is partly because he is a seeker and partly, as he says, because having found the quality of the PoWs to be good, he is keenly interested in exploring other Math Forum services. "They are all," as he points out, "right there."

### *Alecia Smith*

Alecia Smith attended one of The Math Forum's first summer workshops and, following it, began designing her own pages for the Web.

Alecia teaches mathematics and computers to at-risk seventh graders in a suburban Title 1 school that is racially mixed: 54 percent Hispanic, 30 percent African-American, and 16 percent white and other.

Alecia also recently arranged to lessen her teaching load so that she could assume more responsibilities for computers in the school. She says that she loves working with mathematics and computers and training students to use them. As she commented, “You don’t dwell on what you don’t have, you maximize what you have. I always tell the kids . . . we have 20 great computers.”

At first, Alecia explored how she could use technology to enhance curricular materials she had already developed. She did not know any html. She had written her lessons in ClarisWorks and was interested in synchronizing MathWeb and Mosaic. Alecia would write up a preliminary html page and send it to one of The Math Forum staff members. The Math Forum staff person would correct it and put it up. Every time Alecia got help of this sort, she figured out what the staff member had just done and integrated this into the next pages she made. As Alecia completed each of the pages, she used them in her classes, posted them on The Math Forum for others to use, and found herself engaged in online conversations about them.

For example, referring to some work Alecia had posted on the Web, one teacher asked her about the difference between a tessellation and a fractal. Alecia responded with an answer over email but then began to respond over the Web. As the conversation developed, Alecia began to link it to other sites about fractals. Alecia also archived the conversation for those who might have a use for it in the future. During the conversation, another teacher joined them and began to ask about the relation between fractals and kaleidoscopes. Alecia and these two other teachers then began to design lessons together and to link these to the work of mathematicians on the site who were working on the same issues.

Alecia first found out about The Math Forum from a professor friend who gave her information about a workshop the staff were planning to hold. Even though Alecia was teaching middle school and the call for workshop participants was directed to those teaching geometry, she decided to apply. Alecia attended the workshop but seemed to some of the staff to have little if any interest in the discussions taking place. One of them asked Alecia what was wrong. Alecia told her that she just was not that interested in the different ways that the Internet could be used. She mentioned that the Internet would be interesting if it could be more personal or dynamic. The staff member responded that the Internet could

be anything Alecia wanted it to be and offered to help her do the things she wanted to do, such as writing html so that she could make Web pages out of her lessons.

Over the years, Alecia primarily stayed in touch with one staff member because “she knows me, values me, and works with me. That feeling of support needs to be there for someone to give their time to something that is not monetarily rewarding. Also, there needs to be a way that it completely ties into their own work . . . not adding in something extra, but offering a different method of presentation or tool.”

Alecia continues to be interested in integrating technology into the fabric of her classes and most recently has been working to integrate the PoWs into her curriculum. She has assumed a leadership role in thinking about how these problems might be enhanced so that they meet student needs even more effectively. Alecia also continues to seek help for proofreading, using include statements on the Web pages she develops, and so forth. In addition, Alecia has begun to work with a number of different staff members because the basis of her involvement with the site has broadened from producing pages for classes to including mentoring teachers as part of the T2T service and using the PoWs in her classes.

Like Bob, Alecia came to The Math Forum with a solid background in mathematics and almost immediately started integrating her work with The Math Forum into her classes. Instead of pursuing the use of services on the site, however, Alecia sought ways to use technology to enhance her work with her students. Alecia contributed these Web units and lessons to the site, and conversations that have built on these contributions have helped both her and others to stretch their thinking. Like Sonia, Alecia appreciated the relational opportunities the site provided, in addition to the support The Math Forum provides for extending what she was already doing as a teacher and as a student of math.

Like Sonia, Alecia also saw in The Math Forum an opportunity to enhance her knowledge of technology. While both women were drawn to the relational quality of support provided by the mentors and staff on the site, the risks the two women assumed differed. Because Sonia had a weaker background in mathematics, she used the PoW to enhance her students' exposure to math. Sonia tentatively began learning about the possibilities that technology afforded both her and her students as she experimented with one of its services. In contrast, Alecia's strength and confidence in her mathematical abilities appear to have led Alecia to put up and share lessons with others almost immediately. Once Alecia had support for developing her lessons into pages that she could use with her students, she

sought feedback, made revisions, and began making links between her work and that of other teachers and mathematicians on the site.

Exploration of site resources and the possibilities for using the site in their classes enabled Sonia, Bob, and Alecia to “own,” or personalize their uses of The Math Forum – to make it whatever they wanted it or needed it to be. All three of these teachers developed an individual interest in the site that was supported by both the resources *and* the interaction they found. Moreover, each teacher worked to create opportunities that allowed his or her interest to continue to develop. It is notable that all three teachers changed their professional status over the three-year-period during which we talked with them. In each case, the change was facilitated by the work they had begun on The Math Forum site and their changed perceptions of possibilities for themselves as teachers using technology to work with their students.

### *The Larger Sample of Interviewed Teachers*

The case descriptions of Sonia, Bob, and Alecia are drawn from a sample of forty-two teachers whose participation in The Math Forum was studied using in-depth phone interviews and follow-up email exchanges between 1997 and 1999. Some of these teachers were participants in Math Forum workshops, some were teachers in the Urban Systemic Initiative\* with whom The Math Forum worked through its grant support from the National Science Foundation, and finally some were teachers who had just begun using the site when the sample of teachers we would interview was being identified. Teachers were selected for interview study by grade level (twenty-one elementary and twenty-one middle and secondary school teachers), experience with technology (twenty-one more, twenty-one less), gender (fourteen male, twenty-eight female), and experience teaching (fourteen less than five years, twenty-eight who had been teaching five years or more).

Most of the teachers interviewed shared characteristics with Sonia, Bob, and Alecia.<sup>†</sup> They had begun working with some aspect of the

\* The Urban Systemic Initiative (USI) is an NSF block grant to urban school systems for the purpose of facilitating large-scale systemic reform. The Math Forum worked with USIs in two cities.

† Six of the forty-two teachers (14 percent) interviewed began but did not work continuously with The Math Forum over time. Like Sonia when she first began using the site, these tended to be teachers who were required to use technology and thought that The Math Forum might be a resource. Over the three-year period, some did return to The Math Forum when they had a particular need. Most of them either found resources on other sites



site – an aspect that mapped onto either an individual strength (i.e., mathematics, teaching mathematics) or a need (i.e., mathematics, teaching mathematics). Over time most of them began to find ways to integrate one or more of The Math Forum services into their teaching and to explore the use of other resources on the site. They also either explicitly or implicitly grew to identify the site as a resource for their own professional learning. In fact, like Sonia, Bob, and Alecia, they all moved into positions that they considered exciting and challenging largely because of their work with The Math Forum.<sup>‡</sup>

It appears that teachers use The Math Forum when there is support for their efforts to connect to it (e.g., the enthusiasm of Sonia’s students and their parents, help from Math Forum staff such as that provided to Alecia), or when teachers can make The Math Forum meet their immediate needs (e.g., Sonia’s need to use technology in her classes, Bob’s interest in helping his students become problem solvers; Alecia’s desire to put her course materials up on the Web). In fact, teachers who continue to use The Math Forum over time tend to offer one of three reasons for doing so. They describe The Math Forum as offering: (a) opportunities to talk, think, and share resources with others about mathematics, technology, and/or pedagogy; (b) interactions with expert-others who model and provide support for problem posing and problem solving; and (c) a wide and ever-deepening range of quality content about mathematics, technology, and pedagogy.

The teachers interviewed were likely to connect first to a somewhat idiosyncratic and individually specified sense of community (Castells, 1999; Wellman, 2001). The teachers engage as much or as little of The Math Forum’s resources in their teaching and professional learning as they

that met their needs or simply did not use technology. They each described their changed senses of connection to The Math Forum in terms of time. None of these teachers appeared to have had a concrete vision of the possibilities Forum services afforded them beyond the odd answer to a question, and they never seemed to realize the sense of “community” at The Math Forum to which the others referred. As one teacher observed, “For teachers in this school to make good use of The Math Forum, they would need to have it be a school goal and built into in-services.”

<sup>‡</sup> Each of the teachers whose case is described began work in schools serving lower socioeconomic status (SES) students and, with the exception of Alecia (whose advancement occurred within school), moved into more technology-rich and affluent schools because of the professional learning they did with The Math Forum. This type of professional advancement also characterized teachers in the larger sample. Data from the Internet questionnaires also suggest that teachers in lower SES schools are increasingly finding and using The Math Forum with their students. These data further suggest that even though The Math Forum is serving as a resource for for teacher advancement and might be considered responsible for teachers leaving schools that serve populations of lower SES, no fewer students in these settings are benefiting from the resources that The Math Forum provides.

choose, and over time their readiness for these services changes (Lave & Wenger, 1991). Their use of Math Forum services typically deepens in the areas that were their initial points of contact with The Math Forum. Their use also expands and becomes more exploratory with respect to other aspects of the site and the contents of mathematics, technology, and pedagogy more generally.

For teachers who come to think of The Math Forum as a community, the site engages them in expanding their roles as teachers, colleagues, and members of the broader community of educators, much like Little and McLaughlin's (1993) description of substantial models of teacher professional development. Unlike more traditional forms of teacher professional development, however, The Math Forum provides services for teachers and opportunities to interact around these services; it does not specify what teachers need to do (see discussion in Renninger, Weimar & Klotz, 1998). It provides an inquiry-oriented (Bruner, 1966) extension for the mathematics classroom, as well as a "forum" through which teachers can explore and actively personalize their work with topics related to mathematics and its use.

### **Building Community with and for Teachers**

In earlier sections of this chapter, we link interactive resources with participant knowledge building on The Math Forum site and suggest that interactive resources enable participants to deepen their use of The Math Forum over time. Discussions in the literature on virtual communities have more typically focused on participants, participants' capacity for imagination about community, and identity and leadership as keys to community survival. In this section of the chapter, each of these aspects of virtual community building is considered in relation to virtual community as it exists in a richly textured site such as that of The Math Forum. Participants' capacities for imagination and identity are viewed as essential but not sufficient for the development of virtual community. Instead, interactive services and multiple avenues of communication are thought to provide critical support for participants' images of, and identification with, a site.

#### ***Imagination***

The development of the Internet and the forms of interaction that it makes possible has led to discussion of virtual communities as requiring cultural imagination (Jones, 1998). In this form of community, a person

carries an image of real-time community into their virtual interaction with others. Weise (1996), for example, describes her own discovery of the Internet and her feelings about the sense of community it gave her:

In a way [it] was like being given the gift of an extended family, something I had never experienced. Suddenly, every night I had family dinner, could sit back and nibble at my food while aunts and uncles and cousins argued and told stories about people I had never met, but whose experiences enriched me. (p. xii)

She likens the experience of being online to “a backyard fence, a coffee shop, a favorite hangout, a weekly support group” (p. xv). Echoing the power of belonging described by Weise and highlighting the importance of a shared sense of norms to feelings of community (Oldenburg, 1989; Putnam, 2000), one teacher recently said of The Math Forum’s Teacher2Teacher (T2T) question and answer service:

the best part about this Forum for me . . . [is] the chance to “chat” about math ed with educators who aren’t out to find fault with the rest of the posters. . . . [and] the chance to ask questions without fear of getting my head snapped off.

Despite the fact that The Math Forum technically is a set of resources, the image of The Math Forum as a community appears to be reinforced by its responsiveness to participants, its interactive services, and the depth and breadth of the learning it enables participants to acquire. The resources that The Math Forum provides for participants are limitless. Careful attention has been paid to archiving on the site since its inception, and the quality of its ask-an-expert services and challenge problems continue to “feed” The Math Forum’s archives. In this sense, The Math Forum enables a kind of generalized reciprocity because one can use the resources that The Math Forum provides without keeping someone else from doing so. Furthermore, contributions to the site help Math Forum staff to continue to build it out in ways that meet personal needs (Kollack, 1999).

### *The Math Forum As a Context for Imagination*

Several features of Math Forum practice reinforce the perception of The Math Forum as a community where everyone can think about math: (a) the staff – including volunteers – are trained to be responsive to users, (b) questionnaires and queries to the site are perceived as an information exchange, and (c) site resources are edited and built out as a response to users’ strengths and needs. This Math Forum culture is a shared understanding of all participants. For staff, Math Forum culture

translates as ongoing thinking about the kind of support and resources participants need to use services well. Participants talk about coming to identify with The Math Forum and feeling that the site is responsive to them.

A largely invisible scaffold, or protocol, for responding to participants ensures that the “voice” identified with each of The Math Forum services reflects a value for learning. PoW mentors, Dr. Math volunteers, T2T teacher mentors, and the like, welcome participants and ask questions as a means for clarifying their understanding of participants’ submissions, questions, and so forth.

Volunteer mentors and new staff in each of the services are trained in using this scaffold in their response to participants as part of a tenuring process. In the Dr. Math service, for example, the tenuring process ensures that the math doctors work with (as opposed to simply answering) participants who submit questions. Mentors’ questions provide background information about the efforts a participant has made to address the question and the type of resources he or she has examined (i.e., the Dr. Math archive). The Dr. Math service is not intended to provide homework help or a ready-answer service. Rather, Dr. Math is designed to allow participants of all ages to think about math.

The staff regularly consults participants about their needs and updates them on site developments. The questionnaires are presented as information gathering for site support. The questionnaire addresses two types of information: information that the staff genuinely want to know to continue to build out services (e.g., Do users mind being pointed to a FAQ, rather than receiving an answer to a question for which there already is an archived answer on the site?) and information that the staff think participants need to continue to use the site effectively (e.g., information that the PoW would be shifting to Web-based submissions to more effectively provide information to teachers about their students’ submissions). The questionnaires include both forced-choice and open-ended questions and are used to inform staff work plans. A complaint on one of the open-ended questionnaires, for example, said that the PoWs do not fit the Australian curriculum. The staff thought about this in terms of the needs of that user to understand the PoW as an extension of curriculum, rather than as a replacement for curriculum. In response to the complaint, pages were developed so that teachers could share the ways in which they use the PoW to extend and complement their curriculum. The staff felt that if one person needed this information, others were likely to need it as well.

In addition to scaffolding user knowledge, all answers to Dr. Math, the math library annotations, Web pages, and so forth are scanned as a control on flaming and spamming. This permits correction of spelling, punctuation, and grammatical errors on all archived materials. As Anderson (1996) suggested, scanning for correction of errors signals respect for participants. Edited materials also shift the readers' attention to the content of participant questions, source of information, and so forth, rather than issues of presentation.

The Math Forum staff is also responsive to what they see as perceived participant needs, even though participants may not be aware of them. The T2T service, for example, was developed in response to questions being submitted to Ask Dr. Math that were not specifically about the patterns and relations between symbols but addressed the process of learning, mathematics learning, or teaching. T2T includes questions about philosophies of learning, general issues in pedagogy (tracking, management, etc.), math pedagogy, specific information about resources and lessons or mathematics information, and professional development. While topics such as these might have fit what others have called topic drift, Math Forum staff identified the topics as participant needs. With help from the U.S. Presidential Awards for Excellence in Science and Mathematics Teaching Program, The Math Forum staff established T2T.

The T2T service was patterned on the Ask Dr. Math service. T2T is also designed to permit discussions to develop off of archived questions, which means that participants reading the archives can reactivate discussions of topics. Teacher mentors for the service include a Forum staff member and volunteer mentors. Because the Forum staff member had worked with the Dr. Math service previously, she modeled its approach to users in her responses to the teachers and the T2T mentors (the Presidential Awardees). She also developed a tenuring process that paralleled that of the Ask Dr. Math service for the mentors. This protocol led T2T mentors to hear and check out their understanding of questions before replying to them. She also provided feedback to the mentors about tone and structure (i.e., greeting, separating ideas in paragraphs to improve readability) of their responses and the usefulness of incorporating links to other services and resources on the site.

As one mentor commented on a recent questionnaire sent to the teacher mentors:

Mentoring [in] the Teacher2Teacher service is great fun but also it stimulates my thinking on a variety of subjects. I think it might be more valuable to the mentors than it is for those who write in!

Similar to the reciprocal quality of other Forum services, T2T mentors learn through their participation in this service. Those who participate in the discussions that accompany the T2T responses and those who read through the logs are afforded additional opportunities to learn from it as well.

Staff members for each of the services also continue to learn and to provide a model of how they learn for their users. As one said in summarizing the solutions submitted for the *Find the Area of this Square Problem* ([mathforum.com/geopow/solutions/solution.ehtml?puzzle=46](http://mathforum.com/geopow/solutions/solution.ehtml?puzzle=46)):

One thing that I kind of messed up was that I worded the problem poorly. I asked, “Can you find the area of the square?” That implies that there is only one possible answer, which isn’t true. Usually when I say **the** answer, I mean **all the possible answers** – keep that in mind! But here I should have asked you to find **an** answer, since in fact there are infinitely many answers to this problem. I’ll try to be more careful with my wording in the future.

I also drew a picture that was too accurate – it looked sort of like it might look, when in fact you should never rely on a picture to give you clues about what’s longer than what. You can only go by the facts you’re given in the problem.

This type of commentary helps students (teachers and participants, more generally) to cut through the notion that learning is a discrete process or that doing math is only about getting the right answer (Schoenfeld, 1992). Such intellectual honesty also helps to make explicit the culture of the Forum and distinguishes it from what many users who come to the site have previously understood mathematical thinking to involve – that math is about being right or wrong. Intellectual honesty also establishes The Math Forum as a community of practice, where participation by the novice is accepted (Lave & Wenger, 1991; Schlager et al., this volume).

Several working assumptions inform the staff’s work with participants. The staff assume that the topics of math, technology, and pedagogy provide interesting and worthwhile challenges and tools. The staff believe that people of all ages and educational backgrounds can think about these challenges. Finally, the staff design the software and invisible scaffolding of participants’ queries so that they can engage in thinking with participants by listening well and asking questions to inform and clarify. The staff’s assumptions about how to work with participants also provide a basis for participants’ perceptions of The Math Forum as a community.

The Math Forum staff understand themselves to be offering users a vision of Internet communication and community, in addition to being a conduit to connect people, store resources, and make those resources

readily available to others. The staff's cultivation of community is intended to enable quality mathematical interaction and, as such, the exchange of high-quality mathematical content. Math Forum participants have a stake in learning together and sharing their skills and ideas with each other (see similar discussions of real-time discourse communities in Ball, 1993; McLaughlin & Talbert, 1993; Putnam & Borko, 2000; Wineburg & Grossman, 1998). Staff and participants appear to expect (or come to understand) that collaboration yields more than the kind of thinking that any one person can produce for him- or herself.

Participants also have more specific, or individual, images of The Math Forum. These images vary as a function of participants' knowledge about possibilities for themselves on the site, the needs of participants' students, participants' purposes for visiting the site, and so forth. Thus, for example, Sonia might talk about The Math Forum community in terms of the mentors' work with her students, Alecia might refer to support for her classroom teaching, and a staff member might talk about the range of materials now in the archive and how they are being used, the classification of problem types, and the needs of teachers working with students at different levels of instruction.

### *The Math Forum As Virtual Community*

The Math Forum can be characterized as a virtual community because it engenders feelings of belonging and purpose (Anderson, 1991; Jones, 1997). Even though participants do not come to the site with similar levels of knowledge about mathematics, technology, and/or pedagogy, participants share a vision of the site as a community where people of all different levels of experience go to do, think, and be challenged in math. Several characteristics of the site contribute to the shared sense of The Math Forum as a community. These include the consistency of the type of interaction participants have with the different service, the quality and depth of resources that are available, and the responsiveness of the site to the strengths and needs of its participants.

The Math Forum is both similar to and different from two types of virtual communities often identified in the literature: lifestyle enclaves and electronic town halls. The Math Forum might be said to fit Bellah et al.'s (1985) description of a lifestyle enclave in that the Forum is a kind of taste and/or recreational interest group (see also Jones, 1995, 1998; Kiesler, 1997; Smith & Kollack, 1999). Bellah et al.'s work suggests that lifestyle enclaves are becoming places where individuals can

express their identities, sharing and interacting with like-minded people in an otherwise consumer-based society. Instead of real-time neighborhood gatherings (i.e., town functions such as picnics), a lifestyle community enables people to share their interests. Bellah et al. point out, however, that the downside of this kind of community is that interactions often are one-dimensional and foster identities that have a thin veneer. On the Web, these one-dimensional interactions typically take the form of a discussion of one interest (i.e., cat owners talking and sharing information) or a larger set of shared needs and interest (i.e., a writers' discussion group).

While to some extent fitting the description of a lifestyle enclave, The Math Forum is also unique. Its commitment to community allows for multiple goals, and its activities are designed to enable users to meet their strengths and needs. Participants are expected to change and be enabled to assume various leadership roles (e.g., helping a colleague to use the PoWs or mentoring for the PoWs, Ask Dr. Math, or T2T). It is not simply taste or recreation oriented. The range of possible options for engagement that The Math Forum site offers is much broader than that offered by most recreational communities. The Math Forum has intentionally proliferated the ways people can interact on the site (e.g., discussion groups, question-and-answer services, PoWs) by providing multiple points of access, more channels of communication, and opportunities for sustained interaction. Such interaction, for teachers, has a recreational function but also serves as a source of professional learning. The combination of opportunities to build knowledge and the autonomy within which to do so appears to have engendered interest for The Math Forum and a willingness to contribute to its resources.

The Math Forum also could be said to fit the description of the electronic town hall (Mitchell, 1995; Rheingold, 1993), wherein the virtual community serves as an extension of the physical community. Electronic town halls have been described as enabling the development of democratic communities not possible in the physical world because of temporal and spatial flexibility (one can participate when participation fits into one's schedule wherever one logs in). The Math Forum is more limited than a town hall in that it is only focused on mathematics and mathematics learning. On the other hand, those who choose to focus on mathematics have the opportunity to do so at The Math Forum, regardless of affiliation, location, and so on. Furthermore, Math Forum resources and services are considered to be extensions of possibilities afforded in classrooms, not replacements for them. The "democratic" possibilities of The Math Forum



may be even more explicit than the more generic town hall. Teachers in many types of classrooms are using Math Forum services with students, many of whom would not necessarily have the access or support for such access at home. In addition, teachers and students interact with others from different backgrounds and occupations on the site who think with them as mentors, provide resources, and so forth.

Lifestyle enclaves and electronic town halls hold the potential for people to participate. At The Math Forum, having a broader set of services provides a basis for participants to continue to build knowledge. Participants tend to grow through work with one service and move on to check out or work with other services. As such, the participants' sense of The Math Forum as community evolves and continues to shift as their vision of possibilities develops. With time, The Math Forum comes to be experienced as a community that has a dynamic set of resources. This perception of community differs from the more static sense of community that characterizes a lifestyle enclave or an electronic town hall. Such static communities constrain imagination about what is possible on such a site, leading users to be takers. A more dynamic community such as The Math Forum allows participants to challenge what they know through interaction and resource development with others.

Participants like Sonia, Bob, and Alecia made a particular connection to The Math Forum and from there began to explore the site and deal with its enormity. Rather than being overwhelmed by its size, they accommodated to it. The Math Forum site enables them to feel connected because the site continues to grow in a reciprocal relation to them. Importantly, it offers participants most of what they need, or they have learned to make requests.

### *Identity*

If a person is to participate in a virtual community, he or she needs to have both an image of what a virtual community is and a feeling of connection to, or identification with, that community. Identification with a community suggests that a participant has found points of overlap between who she or he is and the activity of the community. For example, participants in The Math Forum, like Bob, know that they can learn from participation and in this process contribute to shaping The Math Forum to meet their needs and serve those of others. Participants like Sonia and Alecia can be supported to identify with the community, and in working with the community expand their sense of possible selves (Markus & Nurius, 1986).

In online discussion groups, people check others out, looking at email addresses, signature styles, and phrasing that marks their membership in a group (Donath, 1999). Achieving recognition, or becoming known by name, is a goal for many discussion list participants (Baym, 2000). On The Math Forum site, this kind of identity exists. At least theoretically, there also is support for the possibility of changing identity because a richly textured site on the Web affords anonymity. Participants do not need to use their real voices or pictures of themselves in their responses, for example. On Web pages, they can use fantasy substitutes. This makes their Internet identity dream-like, where identities can be re-imagined at will and can be either condensed or diffused images of other identities (Turkle, 1995; see also Kirkley, Savery & Grabner-Hagen, 1998).

Participants who continue to grow their knowledge as they work with a site (exploring other services on the site, integrating a service such as a PoW into their work with their students, etc.) begin to shift their identities, and this is internalized into their physical personas. Sonia's enthusiasm for her son's changed attitude about mathematics following work with and support from Mrs. B. on the PoW, for example, is paralleled by both her own shifting attitudes about technology and teaching math. Her son began thinking of himself as a person who could do mathematics, and she sought more opportunities to work with technology and expanded her usage of The Math Forum in her classes.

Once a person connects to The Math Forum site (e.g., has explored it enough to know something of its potential), he or she has a role in its development and grows through this role to take on other roles. Teachers take on all kinds of roles on The Math Forum site. They tell others about it; share resources that they have downloaded with other teachers; involve their students in using the PoW(s), Ask Dr. Math, and the archives; help students to mentor the PoW; develop, share, and comment on materials; participate in Math Forum discussion groups; supervise students who mentor a PoW; use Math Forum software as a template to run their own PoW; involve preservice teachers in Math Forum projects; act as support cavalry for a PoW; offer math education resources in a language other than English; serve as a T2T mentor; serve as a math doctor; contribute Web units or other resources; provide feedback and comments on pages; and so forth. Given that these roles are also archived as contributions, they continue to be resources that are available to others over time.

Each of the roles teachers assume on the site involves knowledge building (Scardamalia & Bereiter, 1997). The roles require reflection on the question posed or problem submitted, restatement of service goals and

applications, and so forth. In assuming these roles, teachers act on the knowledge they have and organize, restate, or develop it so that they can think with others. Teachers both identify with the site through these roles and continue to reengage the site because it provides opportunities to extend their knowledge in ways that they continue to value – by helping them answer their questions, challenging them to think in new ways, and so forth.

On a site such as The Math Forum where users move between services that provide different opportunities for engagement, all the roles teachers assume can be thought of as forms of site leadership. Site participation is a form of leadership since it helps to stretch the thinking of other participants (in discussion, because it is archived, etc.). Teachers like Sonia, Bob, and Alecia maintain roles and extend themselves to assume new ones. Math Forum teachers (and staff) typically move into new roles as the challenge piques their interest. This means that the teachers (or staff) carry what they have learned about working with other services to any new context. It also means that they are in a position to suggest needed adjustments and the like.

The continuity and overturn of leadership on The Math Forum site is an important feature of the site and one that distinguishes it from most other sites. In discussion groups, for example, leaders represent a small fraction of the users, and many of them cross-post to other sites (Smith, 1999). For less dimensional sites, leadership is typically a cause of anxiety because it is considered important to both maintaining and building this type of virtual community, and it is not known what exactly is needed for existing leaders to continue to lead.

Shifting between leadership opportunities on The Math Forum site is a natural part of participant learning. It might also be expected to lead to fragmentation, or what Gergen (1991) called the saturated self, since a person invests him- or herself into many different situations (Little & McLaughlin, 1993). On the Web, there is no expectation that one could see all that another is doing. Saturation appears to ensure a sense of belonging. Many of the teachers interviewed, for example, reported that they had been lonely in their schools and had few if any colleagues who shared their interests. Meeting like-minded teachers (researchers, staff, etc.) through The Math Forum and being able to stay connected with them provides teachers with an extended professional community. In the cases of both Sonia and Bob, participation in The Math Forum community actually enabled them to join real-time communities in new school settings that

included support for their interests and equipment and expectations that allowed them to further develop these interests.

Another teacher whom we interviewed uses the site with his students and also volunteers as a mentor (math doctor) for Ask Dr. Math. He told us about a particularly difficult meeting his math department had about curriculum issues. He said he took some of the key questions they had been raising in their meetings to one of the math discussion groups on The Math Forum Web site. In talking through the issues with his Math Forum colleagues, he found himself able to think fully about their complexity, and this experience enabled him to revisit the issues differently at their next meeting. It seems that teachers using The Math Forum identify with the site through the roles that they can assume. The teachers continue to reengage The Math Forum because they find others who provide them with opportunities to extend their knowledge in ways that they continue to value – by helping them to answer questions, challenging them to think in new ways, and so forth.

The Math Forum also identifies for its participants that participation and contribution to the site is not only their right but that this right makes the site the resource that it is. Participants have opportunities to comment on all pages, the Webmaster is in touch with participants about their comments and inquiries, and questionnaires are regularly posted on the site that both solicit participant opinions regarding possible directions for The Math Forum and intentionally provide note of anticipated changes on the site. Thus, participants who return to the site over time come to understand the community as one that is open to and in a process of change, as well as one that is responsive to their needs.

### **Knowledge Building and Change**

As Jones and Spiro (1995) pointed out, it is not sufficient to assume that providing sources of information such as facts, statistics, lists, visual data, and so forth on the Web will necessarily lead a participant to thinking about their meaning. Data from the interviews described suggest that teachers who continue to engage interactive services on The Math Forum site are enabled to use such resources and positioned to help others find meaning in their use. Furthermore, many teachers do not come to The Math Forum site with the ability to effectively use Web resources in their teaching, or for their own edification, but develop this ability through work with the site.

At The Math Forum, there is a reciprocal relation between the design of services and the strengths and needs of participants as learners. The balance of services and support that individual participants need from the site varies, however. The cases of Sonia, Bob, and Alecia represent three types of teacher participants. There are (a) those like Sonia when she first found the site *who need a reason to engage and need support to continue this effort*; (b) those like Alecia when she first joined The Math Forum workshop *who see in The Math Forum an opportunity but need support to make it work*; and (c) those like Bob *who immediately begin to change what they have been doing to be able to take advantage of the opportunities they have found*.

When she first came to the site, Sonia exemplified *the teacher who needs a reason to engage and needs support to continue this effort*. The community she found at The Math Forum was initially lodged in one of the PoW mentors. Mrs. B was the person who, in responding to Sonia's son's PoW submission, helped him to change his attitude about mathematics. Mrs. B modeled the unstated but clear premise of site culture, that a person can and will learn over time. The model of Mrs. B's interactions enabled Sonia to imagine what the community of The Math Forum could mean for her students and for her. Sonia's efforts to make her connection to The Math Forum work were also supported by the demands of her school, which had recently become a model tech school; the mentors who responded to her students; her students' parents' enthusiasm for doing the PoW; and her students' positive response to working with PoW problems. Sonia received what may appear to be a tremendous amount of support. She continued to need support even after she had moved on to seeing more of the opportunities The Math Forum afforded, much as Alecia had when she first found the site. Sonia's need for support shifted, however. Because Sonia saw opportunities, she developed an interest in how she could use these opportunities in her teaching and in her own professional learning.

For teachers like Alecia and Bob, the community found at The Math Forum was easily traversed from the first visit. They were comfortable with mathematics and were excited to find a resource that enabled them to stretch their students. Alecia, when we first met her at The Math Forum teacher workshop, represented *the teacher who sees opportunity but needs support to be able to use it in her work with her students*. Like Sonia, Alecia needed the connection to a Math Forum staff person who enabled her to master html, insert graphics into her pages, and so forth. Support from Math Forum staff enabled her to begin putting her own lessons on the Web; with time she linked these to other resources, and so forth. She talked about the support she received from The Math Forum as making

a difference in her participation, and she was clear that the rewards for her participation were reaped from the professional learning that work with The Math Forum staff afforded her. Over the three years that we talked with her, Alecia shifted from needing support and drawing on one Math Forum staff member for this support to working with multiple Math Forum services and providing support to other users. She moved from being able to see opportunity and needing support to being able to make use of it, creating opportunities for herself and others including her students on the site.

When he started his work with The Math Forum, Bob exemplified *the teacher who immediately begins to change* what he was doing in order to use Math Forum resources in his classes. He put in substantial effort to take advantage of the opportunities he found for himself and his students. Bob was more interested in the quality of the responses received and the level of mathematics which The Math Forum offered his students. He too had begun his use of the Web in a more individualized relationship with an editor at a business site. By the time he found The Math Forum, he had been socialized to think about sharing as one of the “great opportunities” of work on the Web. During the three years in which he was interviewed, he continued to expand the number of services on The Math Forum site that he explored and used. He built The Math Forum into his curriculum and in his new job modeled this integration for his colleagues. Bob intends that The Math Forum PoWs will be an established component of all middle school mathematics courses in his district. Like Math Forum staff who model approaches to thinking mathematically in the design of services and in their mentoring, Bob is working to support his school colleagues’ use of The Math Forum. In fact, he commented that he hoped to end up with colleagues that are challenged and students coming into his classes who think about mathematics as problem solving.

Over the three year period that we talked with the teachers, each teacher changed in the amount of support he or she needed to check out site resources and figure out how to make use of them. At the end of three years, Sonia’s needs for support began to share characteristics of Alecia’s needs when Alecia first found The Math Forum, and Alecia’s need for support had begun to share characteristics with Bob’s needs. In fact, by the third year of the study, all three of the teachers were working with others to use The Math Forum and were learning more about their practice because of this experience.

Not surprisingly, shifts in the teachers’ usage of the site were accompanied by changes in their description of The Math Forum as a community.

The teachers shifted from first identifying their community at The Math Forum with a particular person or service to recognizing that the community included groups of individuals, contributions to the site on which they could confer, and a host of resources that they had yet to explore. It appears that making meaning (and use) of available resources could not have taken place for the Sonias and Alecias, in particular, unless they felt individually supported in their questioning, solutions, comments, and so forth. Furthermore, it was important to both Sonia and Alecia that they were able to grow through support and become supportive of others' learning. This allowed them to recognize their changed sense of possible selves (Markus & Nurius, 1986).

The Math Forum's experience of building out a community with and for teachers suggests the importance of opportunities for knowledge building and changed participation to the sticky traffic that characterizes the site. Site participants do vary, and much like the success of cross-aged tutoring as a pedagogical tool (see Renninger, 1998), Math Forum staff have seized on participant differences as a strength. They facilitate the match of persona who have a particular form of knowledge with others who need to understand it, are willing to teach another about it, and so forth. Math Forum staff assume that participants range in their knowledge about mathematics, technology, pedagogy, and the like, and that the way to figure something out is to look in the archives or ask a question. Moreover, as descriptions of site resources suggest, the staff also work with participants to learn how to ask questions. The staff request participants to provide some background about how they have approached a question. They are interested in the dead-ends encountered, and so forth, because this information enables them to take up a more useful conversation with the participant.

In addition to facilitating knowledge seeking, the need to scale services with limited numbers of staff\* have necessitated the voluntary support of participants in answering other participants' questions, responding to student submissions, helping to provide support for teachers, and so forth. Usefully, activities such as these involve reflection about what is understood and the kind of thinking with others that enables participant volunteers to continue to build knowledge (Scardamalia & Bereiter, 1997; see also discussion in Bransford, Brown, & Cocking, 1999). The

\* The GeoPoW alone went from receiving 60 questions a week to 1,400 questions a week over the three-year period of NSF funding. One staff member and volunteers provide the individualized responses to these students.

opportunity to continue to grow understanding in ways for which one is ready provides autonomy (Ryan & Deci, 2000), as well as a basis for the kind of valuing that characterizes the asking of follow-up questions and the development of individual interest (Renninger, 2000). Site engagement in this sense then is intrinsically motivating and might be expected to be self-perpetuating.\*

Several characteristics appear to have enabled the site to build out and the community that is The Math Forum to continue to evolve. These include support for learning that enables participant value to develop. The Math Forum provides for different forms of support and types of participation. The Math Forum staff expect that participant change will occur and that knowledge building based on interactive services will provide a catalyst for community participation. However, there is little expectation about what the particular methods to be employed are or which questions need to be asked when. The staff works with teachers and other participants as learners in much the same way as the literature on student learning suggests that students be instructed (Bransford et al., 1999). The staff start with what a participant does understand and works together with the participant to figure out what he or she does not understand.

The staff's goal is to provide participants with the kind of support that enables changed understanding to occur. They do this through scaffolding, modeling, and apprenticeship (Collins, Brown & Newman, 1989). As the cases of Sonia, Alecia, and Bob suggest, supporting other participants enables teachers to help themselves. While it is legitimate to participate peripherally on The Math Forum site, and many do, only the teachers who were not supported in their use of site resources remained

\* One challenge for The Math Forum has been the NSF requirement that the infrastructure for ongoing projects such as The Math Forum become sustainable outside of funded NSF research and development projects on the site. In addition to figuring out how to develop online a sticky community that enables its participants to grow their knowledge, this NSF requirement also necessitates that staff dedicate time to both scaling (because of the success of what they have been able to accomplish, they have a rapidly increasing number of participants) and sustainability of the services.

The Math Forum staff view themselves not only as providing an infrastructure for building out The Math Forum community but also as being of the community in the sense that they engage and work with participants. Their discourse about community and how it develops has informed both the scaffolding that they provide and the design of the services. A critical dimension of The Math Forum's facilitation of participants' possibilities for knowledge building and changed participation in the site has been its support first by the NSF, then by WebCT and, more recently, by Drexel University. One can discuss the building out of community with and for teachers provided that the infrastructure for the site is supported.



peripheral participants of The Math Forum community over time. In this sense then, Forum participants are a community of learners whose participation evolves (Lave & Wenger, 1991). The community is dynamic and responsive to participants as individuals.

In fact, once identified as a site for classroom use and professional learning, The Math Forum is more than a set of interactive resources, and participants can capitalize on the time and space afforded by the Web as they work with it (Duffy, Dueber & Hawley, 1998). Teachers can use as much or as little of Math Forum resources as they want to, when and where they choose. Importantly, it is The Math Forum's interactive resources on which teachers continue to draw. Interactive resources provide models and opportunities for apprenticeship for teachers as well as their students. Instead of heralding the disappearance of community (Oldenburg, 1989; Putnam, 2000), The Math Forum's richly textured site appears to be extended and enriched by its participants. They continue to grow in their understanding of what the possibilities for themselves as users of the site include. It is the mix of interactive opportunities that appears to have enabled The Math Forum to build out its site with and for teachers.

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