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E-Learning Environments for Math and Science Teachers

Jo Ann Cady
Mehmet Aydeniz
Kristin T. Rearden
University of Tennessee, Knoxville

Abstract

The shortage of mathematics and science teachers, especially in rural areas, makes recruitment and retention an issue. However, online courses can provide professional development for these teachers that counteract the feeling of isolation. This article describes online courses that promote the development of learning communities and enhance the pedagogical content knowledge of participants. An emphasis is placed on the instructions, models, and curricula chosen for these courses.

Many educators will agree that students need to be prepared for a profoundly changing American economy, society, and home life, since technology pervades almost every sphere of life. This has profound implications for learning as advances in technology coupled with students who are technologically savvy open the doors for innovation in American schools. It is even more important for students to learn in online environments, since many corporations today use e-learning for training employees (North American Council for Online Learning and the Partnership for 21st Century Skills, 2006). Therefore, students who learn in online environments are gaining the skills necessary to compete as citizens and workers in the 21st century. Upon graduation, these students will be adept at using applications common to today's workers, such as web-based conferencing, project management, or digital media that are the reality of a global, web-driven workplace. To compete in the global marketplace, all students must be information and communications technology (ICT) literate.

ICT literacy means that one can use technology such as computers, personal digital assistant (PDA), media players, global positioning system (GPS), online social networks, and communication/networking tools to research, organize, evaluate, manage, and integrate information. It also includes understanding the ethical and legal issues surrounding the access and use of information technologies (Partnership for 21st Century Skills, 2004). To become ICT literate, one must obtain 21st century skills. These skills include: (a) knowledge of core subjects, (b) learning and thinking skills, and (c) life skills, such as leadership, ethics, accountability, and adaptability in addition to ICT literacy. To reach its full potential, online learning must incorporate 21st century skills in its instructional design, delivery, and implementation.

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The flexibility offered by online courses and the convenience they provide (i.e., no travel to distant universities) enhance the popularity of distance learning courses. While the diverse functionality of emerging technologies and the rapid infusion of various computer technologies into classrooms render online courses and programs enticing to teachers, their popularity presents a significant challenge for the education community at large and teacher educators in particular. For instance, these courses must not only address content issues (important in the Partnership 21st Century Skills framework), but they must also create learning communities to enhance collaboration, problem solving, and critical thinking skills. Educators who are engaged in distance education are now faced with the challenge of ensuring that technology-based instruction provides and promotes a learning community that reflects the essential features of face-to-face instruction.

Unfortunately, many of the uses of the computer technologies in higher education do not exemplify features that develop learning communities (Hodge, Bossé, Faulconer, & Fewell, 2006). In addition, many courses offered through higher education institutions reflect the assumptions of traditional behaviorist theories of learning and thus only focus on the delivery of information. If the goal of educators is to provide meaningful learning experiences to teachers, the online courses should promote a culture of learning emphasizing both the social and cognitive aspects of learning. This dual emphasis can be achieved when online courses are designed based on the notion of learning communities (Lave & Wenger, 1998).

Learning Communities

As social constructivist educators, we recognized the impact of interactions with others on the learning of our students. We also agreed with Crawford and Kirby (2007) that a teacher's decision to incorporate digital technologies should occur in the context of content and pedagogy. Therefore, we made every effort to create learning communities in our face-to-face courses and thoughtfully considered how to create learning communities in an online environment. The *learning community* refers to the social or technological context in which people come together to achieve shared goals by communicating, sharing resources and skills, and supporting one another towards the achievement of the shared goals (Cochran-Smith & Lytle, 1999; Heron,1996; Palloff & Pratt, 1999; Tosey & Gregory, 1998; Wegerif, 2007). The notion of learning communities is inspired by Vygotsky's (1978) theory of social constructivism, which emphasizes the role of discourse, social interaction, and language in the development of understanding (Tosey & Gregory, 1998). This implies that "students learn through communication in, and participation within, a community" (Hodge, et al., 2006, p. 3). The discourse aspects of an online learning community informed by social constructivism such as interaction, feedback, reinforcement, and accountability to a larger audience serve as a catalyst for greater learning to take place (Davis, Kumtepe, & Aydeniz, 2007; Palloff & Pratt, 1999).

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Just as teachers must carefully choose the activities and instructional models that foster learning communities in face-to-face learning environments, teachers must also consider the technology that will foster learning communities in an online environment. Because the role of the participant is central to the development of a learning community, the technology chosen for the online courses must provide a social space where participants are expected and encouraged to communicate. Thoughtful selection of tasks and modes of communication also contribute to the development of learning communities (Davis, et al., 2007). The challenges of promoting learning communities, especially in online learning environments, led us to think about these questions: What changes in curriculum and instruction must be made when translating face-to-face courses to an online environment? What aspects of the online course promote the building of communities of learners? And, how can online courses impact participants' concepts of inquiry pedagogy?

The answers to these questions became important when considering the design of online courses, as developing online communities of learners can facilitate social interactions and foster participant learning if the learning environment is carefully and deliberately designed (Lock, 2006). In developing our courses, we attempted to capitalize on the features of new communication technologies to design a social space in an online environment for enhancing participants' understanding of reform-based mathematics and science teaching. In the following pages, we offer descriptions of the curriculum and instructional models of online courses for middle school math and science teachers (hereafter referred to as *participants*).

Mathematics Courses: Background and Design

In the first set of courses where we emphasized these principles of professional development and learning communities using technology, our goal was to emphasize a conceptual, rather than procedural, approach to teaching and learning mathematics for middle school mathematics teachers. Hence, mathematics education faculty with a mathematics department consultant developed four online courses that were taught in four consecutive semesters. Course titles were Rational Number Concepts in the Middle Grades, Algebraic Concepts in the Middle Grades, Topics on Improving Instruction in Middle School Geometry, and Data Analysis and Probability in the Middle Grades.

We abandoned the linear and objectivist approaches to learning that had dominated online approaches to education (Vrasidas & McIsaac, 2001) and shifted our pedagogical focus to include student interaction and learner centered environments aligned with constructivist tenets (Belderrain, 2006). Thus, we chose Centra™ synchronous software to provide voice interactions with participants and synchronous interactions with physical and virtual tools that support learning in hopes of fostering learning communities. Participants were required to sign on using their own individual computers in cohorts of three to five participants at each physical site, thus providing multiple opportunities for them to interact with the material and with each other. Using Centra™, course instructors could randomly or manually place participants in breakout

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groups for small group discussions and then join one discussion group at a time. This software also permitted us to indicate agreement with a statement using a check or an *x*, share a whiteboard space, text chat, or share applications (appshare) from local computers. This appshare feature permitted participants to share ideas from the library of virtual manipulatives, activities using Geometer's Sketchpad™, useful websites, or applets. Each student was provided headphones, a web camera, and a Notetaker™. The Notetaker™ consisted of a clip with sensors that could be attached to paper. Its accompanying ballpoint pen would send signals to the sensors creating an electronic image of their handwritten work that could then be shared online through the appshare feature and/or saved in a word processing document. The courses also had an asynchronous component using Blackboard™ software. Using Blackboard™, instructors could post course documents, assignment directions, and external links on a password protected course website for participants to access remotely. This software also contained a digital dropbox for submission of assignments and the capability to send individual or group emails. The discussion threads available on the Blackboard™ site provided an online environment for participants' reflections on class assignments.

The University of Tennessee (UT) offers Centra™ and Blackboard™ for professors and students. Since all participants were enrolled in UT coursework, this software was available free of charge and support was offered through the Office of Instructional Technology. For the mathematics courses, course instructors met face-to-face with participants for the first class and provided instruction on using Centra™. Participants in the courses were familiar with Blackboard™ as their district used it as an instructional tool. Centra™ is simple to learn for those with minimal technology background so most participants did not have difficulty learning it. Our technology challenges were in logging in to Centra™ through the district's firewall.

We also drew from three areas of research in professional development for mathematics teachers that situated teacher learning within the context of the classroom: (a) using standards-based curricula to enhance teachers' mathematics concepts rather than procedures (Beckmann et al., 2004; Reys, Reys, Beem, & Papick, 1998), (b) using cases of middle grades mathematics instruction to expand teachers' understanding of the link between instruction and students' mathematical understandings (Merseth, 1996; Stein, Smith, Henningson, & Silver, 2000), and (c) collaboratively examining student work to increase teachers' focus on students' mathematical thinking (Franke & Kazemi, 2001; Wilcox & Jones, 2004).

Using the Connected Mathematics Project (CMP) (Lappan, Friel, Fey, & Phillips, 2004) curriculum as the foundation for the courses, required teachers to look at the mathematics they would teach from many perspectives, bolstering their content knowledge and situating the participants' learning in the context of their practice. CMP uses mathematics in real world situations, encourages modeling of mathematics through multiple representations, and develops an understanding for algorithms, formulas, and rules through word problems or manipulatives. The real-world contexts used in CMP's *Investigations* promoted connections to other mathematical concepts

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and content areas and supported the use of collaborative groups and inquiry-based practices. As participants completed these activities, they also reflected on their role as teachers—that is, how might their students approach these activities and how might CMP's *Investigations* be used in their own classrooms?

Cases of mathematics instruction supplemented the CMP curriculum. These written and video cases portrayed teachers and students engaged in middle school mathematics classrooms. For our participants, they provided an alternate vision of the classroom by providing examples of how teachers might use complex tasks and questions to uncover students' understandings or misconceptions. The teachers in the cases encouraged students to explain and justify their thinking and to make connections among ideas. The discussion regarding the cases focused on the instructional factors and pedagogical moves that would influence the students' intellectual involvement in the activity. They also focused on key mathematical ideas and called attention to ways in which the instructional actions of the teacher supported or inhibited students' opportunities to learn worthwhile mathematics. Instructors selected both written and video cases for use with the participants.

Major assignments encouraged participants to focus their decision-making on student learning. Participants could choose between using a Cognitively Guided Instruction (CGI) (Franke & Kazemi, 2001) framework or lesson study framework (Fernandez & Chokshi, 2002). Thus, participants used research regarding how children learn a specific topic and/or effective methods of teaching specific topics to create mathematics lessons. Working in small groups, they collaboratively planned lessons, taught the lessons (with observers in the lesson study model), met to reflect upon students' understanding, and then refined their lessons. These collaborative reflections of students' understanding helped participants develop a deeper conceptual knowledge about mathematics and how students learn mathematics (Stigler & Hiebert, 2004).

Science Course: Background and Course Design

The science course was asynchronous using only Blackboard™ discussion board prompts to encourage interaction among participants. Blackboard™ also has a blog and wiki tool that could serve the same purpose of providing a social space for participants to share their ideas. The course design then encouraged discussion based on the tasks selected by the instructors. The first task had science teacher participants design interactive inquiry-based lessons using WordPress (http://www.wordpress.org) software. We chose the lesson plan as our task because we felt that designing, sharing and critiquing lesson plans would allow participants to generate discussion about what constitutes reform-based science learning, what motivates students to learn science, and how to encourage student questioning. WordPress software was chosen since it was free and it enabled participants to design a well-organized lesson that includes images and videos without the need for sophisticated programming skills. Course participants used the 5E learning cycle framework (Bybee, 1997; Settlage, 2000; Settlage & Southerland, 2007) to design their lessons. This learning cycle model of

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instruction (see Figure 1), including engagement, exploration, explanation, elaboration, and evaluation, was initially developed based on Piagetian theory of psychological development. However, science educators have advanced the model by incorporating the tenets of social constructivist theories for teaching science. For instance, it is expected that the participants scaffold instruction in ways that will enable maximum student explanation and exchange of information.

In order to promote the sense of community, the instructor assigned participants to groups of three and asked each member of the group to post an online lesson and collectively evaluate the lesson. This assignment exposed participants to different perspectives on how the lesson should be designed and taught. The following are examples of two participants' evaluations of the same lesson posted to the group discussion board.

> The lesson suggests that the teacher provide a model of an organism pair from a biome not covered in the class. To draw students into the lesson, the teacher could choose organisms that are unique in adaptation or behavior. For example I could choose a pair of Australian organisms and use some of the pictures that I took while I studied abroad. By describing my experience, I can increase the student's interest about the cool organisms that live on our planet. I can also encourage student participation and ideas during the discussion.
>
> The lesson does not explicitly have the students thinking of a problem related to the concept being introduced. The lesson could be extended to have the students hypothesize and then research the consequence of climate change, habitat fragmentation, or pollution on their organisms. Students could also come up with a way to test the hypothesis by looking at data of similar species in the biome in question. (Jennifer)

> Students are assigned a species to investigate but are not instructed to address a specific problem. This could be addressed by having students investigate a news topic that relates to a particular species or biome related to real-world issues. A student could investigate the forest biome and look into mountain-top removal controversies or strip mining effects. Doing this would require students to investigate a problem and research the problem. (Nicole)

Participants' exposure to different ways of looking at the same learning activities is likely to contribute to their pedagogical understanding and give them new ideas to try in their classrooms. The functionality of new technologies enables instructors to facilitate participant learning through the lens of social constructivism. The instructor can use new functions such as blogging as a context for participants to give each other feedback and, thus, support each other's professional development.

A second task in the course that encouraged the formation of learning communities was engaging the participants in reading and critiquing educational research in the areas of the nature of science, conceptual change, assessment, and

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inquiry-based instruction. Participants were required to read three articles pertaining to the philosophies of reform-based curriculum and instructional strategies each week and write a three-page critical reflection paper based on prompts provided by the instructor. See Table 1 for a sample set of articles and related prompts.

Table 1

Articles and Prompts for Equity Issues

Articles	Prompts
Required Readings: • Aikenhead, G. S. (2001). Students' ease in crossing cultural borders into school science. *Science Education, 85*(2), 180-188. • Brown, B. (2004). Discursive identity: Assimilation into the culture of science and its implications for minority students. *Journal of Research in Science Teaching, 41*(8), 810-834. • Brickhouse, N. W. (2001). Embodying science: A feminist perspective on learning. *Journal of Research in Science Teaching, 38*(3), 282-295. Recommended Readings: • Hodson, D. (1993). In search of a rationale for multicultural science education. *Science Education, 77*(6), 685-711. • Cobern, W. W., & Loving, C. C. (2001). Defining science in a multicultural world: Implications for science education, *Science Education, 85*(1), 50-67. • Brickhouse, N. W., & Kittleson, J. M. (2006). Visions of curriculum, community and science. *Educational Theory*, *56*(2), 191-204. • Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research, 75*(4), 491-530. • Lee, O. (1997). Scientific literacy for all: What is it, and how can we achieve it? *Journal of Research in Science Teaching, 34*(3), 219-22.	1. What does “Science for All” mean to you? 2. What is the link between scientific literacy and participatory democracy? What are the implications for science curriculum? 3. Will the next generation be able to effectively participate in civic and environmental issues without knowing science? 4. If only the mainstream students achieve scientific literacy, who will be left behind? 5. Whose knowledge does current school science curriculum promote? Why is this an issue?

The instructor facilitated participation in the community through Blackboard™ discussion board prompts. However, consistent with constructivist tenets, participants were not required to limit the content of their critical reviews to the prompt posed by the

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course instructor. Also, consistent with social constructivist views, participants were required to assess their classmates' lesson plans using a set of guidelines provided by the instructor (see Figure 1).

ENGAGE PHASE: Explain your understanding of the ENGAGE component of the 5E model below. What is the purpose of activities in this phase?	
Examine and provide feedback for the ENGAGE PHASE of the lesson you are reviewing.	
Recommendations:	**Justification/Evidence for recommendations:**
Your overall evaluation of your peer's understanding of the Engage Phase. (Do you think this person understands what the engage phase should entail? Why or why not? You need to justify by focusing on proposed activities.)	

EXPLORE PHASE: Explain your understanding of the EXPLORE component of the 5E model below. What is the purpose of activities in this phase?	
Examine and provide comment for the EXPLORE PHASE of the lesson you are reviewing.	
Recommendations:	**Justification/Evidence for recommendations:**
Your evaluation of your peer's understanding of the EXPLORE Phase. (Do you think this person understands what the explore phase should entail? Why or why not? You need to justify by focusing on proposed activities.)	

EXPLAIN PHASE: Explain your understanding of the EXPLAIN component of the 5E model below. What is the purpose of activities in this phase?	
Examine and provide comment for the EXPLAIN PHASE of the lesson you are reviewing:	
Recommendations:	**Justification/Evidence for recommendations:**
Your overall evaluation of your peer's understanding of the EXPLAIN Phase. (Do you think this person understands what the EXPLAIN phase should entail? Why or why not? You need to justify by focusing on proposed activities.)	

ELABORATE PHASE: Explain your understanding of the ELABORATE component of the 5E model below. What is the purpose of activities in this phase?	
Examine and provide comment for the ELABORATE PHASE of the lesson you are reviewing:	
Recommendations:	**Justification/Evidence for recommendations:**
Your evaluation of your peer's understanding of the ELABORATE Phase (Do you think this person understands what the ELABORATE phase should entail? Why or why not?)	

EVALUATE PHASE: Explain your understanding of the EVALUATE component of the 5E Model below. What is the purpose of activities in this phase?	
Examine and provide comment for the EVALUATE PHASE of the lesson you are reviewing:	
Recommendations:	**Justification/Evidence for recommendations:**
Your evaluation of your peer's understanding of the EVALUATE Phase (Do you think this person understands what the EVALUATE phase should entail? Why or why not?)	

Figure 1. *5E* Lesson Plan Analysis Peer Feedback Form.

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Student Reaction to the Online Courses

Since there were four mathematics courses, the number of participants in each course ranged from eight to 14. Seven teachers completed all four courses, one completed three of the four and six completed two of the four courses. The development of communities of learners was conveyed through course evaluations, recorded online class discussions, and primarily through online discussion board postings. The positive aspects of the environment created by the online courses cited by participants included (a) being able to hear each other talk, (b) listening to others explain problems, and (c) being able to interact face-to-face with people from their site. While they saw value in being able to interact with others from other sites online, they preferred face-to-face interactions with all participants. Participants cited not being able to see faces and body language as a negative to the online environment. As one participant stated:

> There is limited interaction but discussion at times is good. It is harder to see other's ideas on paper but I like the option of discussing any questions on homework and being able to divide the group up and go over them in class. At times this takes longer but as long as everyone is ready and willing to present, the time seems to go faster. (Hillary)

Contrary to the notion that online courses foster isolation, our data suggest that they can actually enhance collegiality, and thus reduce isolation for rural teachers. Two aspects of the course promoted the collegiality of the teachers. First, participants were required to sign on in cohorts of three to five which allowed for some face-to-face interactions. Participants valued working face-to-face with one or two other colleagues from their school or neighboring school.

> I like the idea of working with other teachers in problem solving activities as well as designing lessons. You learn a lot about teaching styles and innovative strategies from other teachers. (Misty)

> It was nice to be able to meet close to the school and [online classes] helped develop a higher level of teamwork among the other participants at my school… It was also beneficial to observe each other teaching a lesson and then discussing what was going on in the classroom during the lesson. (Katie)

> Being able to talk with other teachers who are in the class to gain ideas and new ways of presenting topics is a big asset to our school system. (Carson)

Additionally, the focus on the concept of lesson study broadened the participants' appreciation for working with colleagues to improve instructional methods. The benefits of lesson studies clearly resonated with many of the participants. After reading an article pertaining to the implementation of this practice in Japan, participants noted that lesson studies benefited both teachers and students; teachers had the opportunity to gain and

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give feedback on lessons, and students were presented with effective, research-based lessons. Participants also had the opportunity to conduct a lesson study, thereby reinforcing their convictions.

> As I have said all along, teaching math is not about plugging and chugging it is about reasoning, problem solving, logical thinking, etc. Therefore, the lesson study concept intrigued me, because it allows teachers to gain knowledge from each other, not just from teachers in one district but from all parts of the country and focuses on problem solving. (Katie)

> I think, as the article suggested, that pooling and discussing ideas is ALWAYS a valuable activity whether within a school, state or international community. (Andy)

> Teaching may not come naturally, so we need to examine the methods of successful teachers everywhere. We must also be willing to recognize our weaknesses and change our methods in order to meet the needs of our students. (Brittany)

Shortcomings of the course structure mainly focused on two aspects: The lack of visual cues when conversing with participants at other sites, and the unpredictable nature of Internet connections.

> Technology takes away a lot of the human interaction that you have with a regular class where you communicate face-to-face. It is hard to tell if your questions or answers make sense to everyone since you can't see their facial expressions. (Carson)

> It was mostly frustrating not to be able to see the expressions on other people's faces. (Misty)

However, they also acknowledged that they could adapt to interpreting comments without the benefit of visual cues.

> Humans communicate not only with their voices, but [also] with visual cues. It is difficult both for teachers and students to "read" each others expressions while on-line, therefore not really understanding if there is understanding or any comprehending going on, especially if the participants are not familiar with one another. After time and interaction, familiarity of voice recognition and inflection/tone become easier. (Susan)

Comments from the course evaluation regarding aspects that contributed most to their learning focused on personal growth with mathematics problem solving, classroom strategies, the course instructor's attributes, or collegial interactions. Specifically, three respondents commented on the collegial interactions aspect. (Due to the nature of anonymous course evaluations, the following quotes are not attributable to specific

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participants.)

> Group meetings [contributed most to my learning].

> Talking and hearing from other students helped my learning. I like to hear from colleagues and how they teach in their class. I am still new to this teaching field.

> The interaction with adults…[contributed most to my learning]…Specifically those who share daily struggles of teaching. It was great to have an opportunity to share ideas.

In the science course, we received feedback in two forms from the participants: discussion board postings and participant evaluations. Participants (n = 17) enjoyed the online course for two reasons. The first aspect was its convenience. All of the course participants were in-service teachers. However, seven of the science participants were from three different school districts within a 100-mile vicinity of the university taking the course for professional development, and the remaining 10 were pre-service teachers in their final semester of completing degree requirements. Both participant groups felt that they were able to achieve their learning goals without spending up to three hours commuting to campus on a weekly basis.

Second, they communicated that they felt that there was a sense of community in the course. One participant said, “I really enjoyed the course. It gave me the opportunity to see my peer’s take on some of the issues discussed in the course.” When participants experienced frustration, they were able to overcome their frustration through peer support. For instance, one participant said the following after receiving feedback from her peers, “After much frustration I think I have figured it out. Will you check my site/blog again and let me know if I am on the right track? I have completed the categories of Objectives, Engagement, Materials, and Safety.”

While peer reviewing was an essential part of community building in the science course, it also increased participants’ sense of accountability and their pedagogical content knowledge. The following anonymous comments were made by participants on course evaluation in regard to peer reviewing.

> Peer reviewing helped to prompt conversation between members of the class that probably would not have been there otherwise.

> Peer reviewing made me try a little harder knowing that others would be reading (and rating) my assignments. It also made me want to give good (helpful and positive) reviews to others.

> Reading peer responses and peer critique's of my responses helped me to think more deeply about the issues addressed in class.

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Although participants acknowledged the contribution of peer reviewing to their overall learning, some questioned the validity of peer assessments. Some participants viewed peer reviewing only through the lens of grades rather than as an opportunity to learn from others and contribute to other's learning as evidenced by the following quotes:

> I appreciate that you trusted us enough to allow us to rate each other as well as use these ratings as part of our grade.
>
> However, a percentage of the grade represented peer reviewing; in what sense? If on average, my critiques have been peer reviewed as "poor", would this come to lower my overall grade? (I am talking in general, people may be scared that much subjectivity could be involved from peers, instead of the instructor's objectivity). [Interestingly, this student was a teacher who had been in the classroom for seven years.]

While qualitative comments from course evaluations were mainly positive, when we compared quantitative data from course evaluations with similar face-to-face mathematics education courses, participants' evaluations of professors were higher in face-to-face courses (see Table 2). It should be noted that our institution does not have evaluation forms for online courses that addresses online features. Therefore, the evaluations for face-to-face courses were used. In addition, the science course did not have a similar face-to-face counterpart. The higher face-to-face evaluations may be a result of the instructors' frustration with not being able to mimic their face-to-face instructional methods in an online environment.

Table 2

Course Mean on Student Evaluations

	Online n = 40	Face-to-Face n = 44
Course overall	3.73	4.68
Course content	3.65	4.56
Instructor contribution	3.83	4.79
Teaching effectiveness	3.43	4.79

When the data were further analyzed, we saw a trend that shows participants had more positive attitudes in the math courses than they did in the science course. One factor that may explain this difference is that the math participants were all teachers from the same district, while the participants in the science course were from all parts of the state. Therefore, participants in the math courses met weekly with at least one other person to sign on to the courses for synchronous instruction, and even if they did not know other participants in the course when the course started, there were

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opportunities to meet these participants at district wide events. The four courses also spanned two years and eight of the fourteen in the first course took all four courses. This provided many more opportunities to develop communities of learners. In contrast, participants in the science course were not required to participate synchronously, and no other opportunities were available for them to meet or see each other face-to-face. The science course was also offered during the four-week summer session, shortening the time frame in which communities of learners can be formed.

Conclusion

Based on participant feedback, we achieved our goal of promoting a culture of learning which incorporated both social and cognitive aspects in an online environment. In all courses, participants indicated that they valued the social interactions that took place in the courses and the impact this had on their learning about the teaching of mathematics and science. Many commented on the learning communities formed from the course and how they valued ideas from other participants. Thus, we feel that online courses and/or technology that provide a social space for teachers to interact with each other can reduce the isolation felt by teachers in rural and high-need areas and provide the social space where participants are expected and encouraged to communicate. This communication in a virtual classroom setting served as a catalyst for learning content and inquiry pedagogy and assisted participants with overcoming the barrier of rural isolation. By expanding access to high quality, rigorous academic courses teaching 21st century skills, we can expand the opportunities for all students (North American Council for Online Learning and the Partnership for 21st Century Skills, 2006).

While we had success creating learning communities using Blackboard™ and Centra™, new technologies have surfaced since we taught the courses. Social networking sites, such as Facebook, are now the rage among university students. Perhaps these sites can replace the Blackboard discussion board and stimulate more dialogue, since students are familiar with and like Facebook. We assume that students will participate more frequently in the conversations surrounding course content when Facebook is used as a platform for promoting learning and building online learning communities, as it is accessed for social interactions beyond those required for a course.

Although Facebook holds potential for building more effective online learning communities, privacy does become an issue with social networking sites. This issue can be alleviated somewhat when instructors create a group page and limit those who can access the group page to members of the class only. However, these sites may also enhance communities of learners, as students may learn more about the personal lives of classmates who choose to share this information through these sites. Students can also easily post pictures and videos.

Although the functions of new technologies provide the opportunity for creating a learning environment that is informed by the principles of social constructivism, two

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factors may hinder the achievement of this goal. First, some professors may have negative attitudes towards the learning of and, thus, use of technology in the classroom the way we have used it. Second, some professors who have positive attitudes towards the use of technology, yet lack technological knowledge, may limit the use of technology to its utility functions (i.e., using Blackboard™ to post assignments and classroom materials only). Such use of technology may leave students who are taking only online courses with the feeling of isolation and prevent them from the exposure to the knowledge of the other members of the community. In order for professors to use technology to maximize student learning, they need to be educated not only on how to use technology to deliver content but also in how to make it effective for students' learning. University professors can form their own communities of learners to make teaching through technology a fundamental goal of their professional learning, and universities can implement policies that would encourage the formation and sustainability of such learning communities. Through membership in such communities, professors can keep up with new educational and informational technologies and continue to infuse new technologies to prepare their students for a global marketplace.

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About the Authors

Jo Ann Cady, Ph.D., is an Associate Professor in Mathematics Education at The University of Tennessee in Knoxville. She encourages middle grades and elementary preservice teachers and inservice teachers in the districts surrounding Knoxville to engage students in making sense of mathematics. Her research interests include the relationship between teacher beliefs and their practice. E-mail: jcady@utk.edu

Mehmet Aydeniz, Ph.D., is an Assistant Professor of Science Education in the Department of Theory and Practice in Teacher Education at the University of Tennessee. Dr. Aydeniz's research focuses on two main areas of education, student learning and science teacher effectiveness. His research interests include: assessment of students' learning in science, facilitating students' appropriation of epistemic and social norms of science through argumentation and science teachers' pedagogical content knowledge. E-mail: maydeniz@utk.edu

Kristen T. Rearden, Ph.D., is a Clinical Associate Professor in the Department of Theory and Practice in Teacher Education at the University of Tennessee. She is interested in the development of content knowledge of middle school science teachers and the integration of children's literature in science. E-mail: krearden@utk.edu