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USING INNOVATIVE LEARNING TECHNOLOGIES TO PROMOTE LEARNING AND ENGAGEMENT IN AN URBAN SCIENCE CLASSROOM

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Recent reform movements within the United States have called for science for all and educational reforms to support this goal. In light of these reform movements and concerns regarding learning within urban schools, science educators and policy makers have pushed for the incorporation of learning technologies within schools as a way of creating equity and promoting learning among diverse learners. The Center for Learning Technologies in Urban Schools has been working to create and adopt standards and project-based science curricula in a large systemic reform effort. A core challenge of this partnership has been to embed learning technologies within these units to support active and engaged learning. This article examines how two interactive learning technologies embedded within an extended project-based science curriculum unit are capable of engaging urban students in actively learning key science concepts.

Keywords: *science education; project-based instruction; technology integration; inquiry; standards-based instruction*

Recent reform movements within the United States have called for "science for all" and educational reforms to support this goal (American Association for the Advancement of Science, 1989). In light of these reform movements and concerns regarding learning

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within urban schools, science educators and policy makers have pushed for the incorporation of learning technologies within schools as a way of creating equity and promoting learning among diverse learners (Atwater, 2000; Lynch, 2000). Atwater (2000) specifically suggested using new technologies and the Internet to create relevant standards-based curriculum to engage and motivate urban African American students.

The Center for Learning Technologies in Urban Schools (LeTUS) has been working to create and adopt standards and project-based science curricula in a large systemic reform effort (Blumenfeld, Fishman, Krajcik, & Marx, 2000; Marx et al., 2004; Rivet & Krajcik, 2004). A core challenge of this partnership has been to embed learning technologies[1] within these units to support active and engaged learning (Singer, Marx, Krajcik, & Clay Chambers, 2000). This article examines how two interactive learning technologies embedded within an extended project-based science curriculum unit are capable of engaging urban students. The two interactive learning technologies, MIT Media Laboratory's Thinking Tags and the University of Michigan's Artemis Middle Years Digital Library (Artemis), when facilitated by the teacher, provided an opportunity for students to engage in inquiry. Allowing urban students opportunities to engage in the use of technology in an open and interactive manner has been suggested as one possible way to address some of the "digital divide" issues facing urban schools (Becker, 2000). The work of LeTUS provides a unique setting in which students use the technologies within the context of a large systemic reform effort to promote higher order thinking and skills.

OBJECTIVES

The purpose of this article is to describe an initial study on the use of embedded learning technologies within a project-based

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curriculum enacted in an urban public school. The unit "Can Good Friends Make Me Sick?" enables eighth-grade science students to investigate the biology of communicable diseases with an emphasis on sexually transmitted diseases. We focused on the following questions:

- What characteristics of inquiry are seen when urban students and their teacher use learning technologies embedded within a project-based science unit?
- What levels of engagement are seen when urban students carry out technology supported inquiry?

INTRODUCTION

Recent reform documents call for science for all and for instructional changes to support this mandate (American Association for the Advancement of Science, 1989; National Research Council, 1996). Urban American public schools face a wide range of challenges in carrying out these new reforms. These challenges include overcrowded buildings and classrooms, a lack of resources, a constant need for additional qualified teachers, student attendance problems, and lack of curricula that support the ideas put forth in reform documents (Lynch, 2000).

Systemic reforms in urban school districts have begun to address these challenges through a wide range of measures. One aspect of school reform has been targeted at the school curriculum and school text. Review of current science textbooks highlights the shortcomings of commercial materials (American Association for the Advancement of Science, 2000; Kesidou & Roseman, 2002; Stern & Roseman, 2004). Lynch (2000) has called for systematic development of science curricula with accompanying technology to support learning and eliminate inequities in science classrooms. In looking at the issues surrounding a specific urban school population, African American students, Atwater (2000) suggested that by using engaging standards-based curricula, computers, and Internet access, the current achievement and attitude gaps would narrow for these students. This article highlights a curriculum designed to meet these challenges and examines if the use of learning technologies within the curriculum successfully addresses these challenges.

Learning technologies, such as those called for by Atwater (2000) as well as Lynch (2000), include the Internet, probes, modeling tools, and visualization software. Learning technologies can be used by students to extend their thinking and create multiple representations of their understanding; they can help students and teachers communicate, experience scientific phenomena, conduct investigations, and develop products (Edelson, 1998; Linn, 1998; Spitulnik, Stratford, Krajcik, & Soloway, 1998). Using learning technologies to explore natural phenomena can potentially make students more motivated and engaged (Blumenfeld et al., 1991; Krajcik, Blumenfeld, Marx, & Soloway, 2000). A central challenge in the development and enactment of LeTUS curricula has been how to embed different learning technologies to successfully engage students in learning (Blumenfeld et al., 2000; Singer et al., 2000).

We choose to focus on the use of two learning technologies within the school context. The first tool, Artemis, a Web-based tool, has been used successfully by middle school students in carrying out online inquiry projects. Students used Artemis to search a preselected collection of sites in a digital library and save their work to a permanent work space (Hoffman, Wu, Krajcik, & Soloway, 2003; Wallace, Kupperman, & Krajcik, 2000). In this learning environment, students are provided with online supports to help them manage their work and successfully handle some of the challenges that searching the Internet often creates. This article adds to initial studies on Artemis by examining how urban students use Artemis within an extended project-based science unit in which they need to find information related to the driving question of the unit. The initial studies investigate how students could use Artemis to help them with Internet research projects (Hoffman et al., 2003; Wallace et al., 2000), but these studies did not take place in an urban setting with the unique issues that such a setting provides. The use of Artemis and the issues surrounding its use are explored in this current study. The findings add to our understanding of how to design instructional materials using innovative learning technologies in urban schools so that students can use the learning technologies in a meaningful manner.

The second learning technology, Thinking Tags, provides students with a tool in which they can explore the phenomena of how a disease can spread through a population. Thinking Tags are small wearable programmable computer badges with infrared sensing devices used to communicate between badges with a variety of digital displays for students to use in data collection. Developed by MIT's Media Laboratory, students use Thinking Tags to virtually experience scientific phenomena and create personal understanding (Colella, Borovoy, & Resnick, 1998; Resnick, Martin, Randy, & Silverman, 1996). In this type of experience, called a *participatory simulation*, students participate in the simulation, not simply observe the simulation (Colella, 2000). Thinking Tags allow students to virtually experience phenomena repeatedly and under different experimental conditions as they investigate the simulation. This learning technology also helps develop cooperative and collaborative interactions among students (Borovoy, McDonald, Martin, & Resnick, 1996).

Thinking Tags and other handheld technologies have been shown to increase student engagement in part because students ask questions and begin to answer these questions as they carry out investigations (McFarlane & Friedler, 1998; Soloway et al., 1999). Using the Thinking Tags in a participatory simulation, Colella (2000) and Colella et al. (1998) found students were able to engage in inquiry activities and classroom activities to construct new understandings about the underlying scientific principles. The results presented herein build on what Colella and colleagues reported because the use of the Thinking Tags was an integral part of the extended project-based science curriculum described here. The Thinking Tags were used as part of normal classroom instruction carried out by the teacher. This integrated use of a novel learning technology in a meaningful manner is what supporters of reform in urban education advocate.

In this article, we build on this previous work by examining how these two different technologies, when embedded within an extended science inquiry unit, enable student participation and engagement in inquiry. We describe general characteristics of student inquiry and engagement that the two learning technologies support. The *National Science Education Standards* call for increased attention to be given to inquiry in the science class (National Research Council, 1996). By having students ask questions, plan experiments, and collect, analyze, and share information, inquiry learning environments provide opportunities for students to experience scientific phenomena and to become cognitively engaged in their learning.

Engagement is the mindful investment and commitment of students as they create a deep understanding of science concepts and processes (McCormick & Pressley, 1997). This cognitive engagement is inferred through students' behavior and the artifacts they develop. Student engagement has been shown to vary with the type of task that students perform (Blumenfeld & Meece, 1988; Lee & Anderson, 1993). The question of how to successfully challenge students to become cognitively engaged in their inquiry activities is crucial if students are to learn through this type of activity as recommended by reform (Marks, 2000). Grounding our study in the previous research looking into student engagement, we examined aspects of student engagement: attending to, connecting to, and planning their investigations. We report on particular characteristics of student inquiry and student engagement as students used the two learning technologies in an urban school setting.

BACKGROUND

LeTUS is a collaboration between two research institutions, the University of Michigan and Northwestern University, and two large public school districts, the Detroit Public School and the Chicago Public School systems. LeTUS takes as its core challenge the improvement of learning for all students by the infusion of technology in urban classrooms. To accomplish this, LeTUS has developed curriculum units based on principles of social constructivism. Several resulting design principles (Rivet & Krajcik, 2004; Singer et al., 2000) include the use of extended inquiry projects situated in real-life contexts, the use of embedded learning technologies, and collaborative work. LeTUS curricula are created to address national and state standards. Previous research shows that these materials, used in the broader context of the district's urban systemic reform program, lead to enhanced learning as measured by curriculum-specific assessments (Marx et al., 2004) and state-mandated examinations (Geier et al., 2004).

SETTING

This study was conducted in a middle school in a large urban center with a single eighth-grade class (33 students) and teacher. The teacher holds certification in science and had taught science for 7 years. The school had adequate but not extensive technology access (two computer labs with intermittent Internet access). The student population was largely minority (primarily Latino, Latina, and African American). Of the student population, 60% score below grade level on state-mandated achievement tests; 80% of the student population qualifies for free or reduced lunch. Students used the Thinking Tags in their classroom and Artemis in a computer laboratory.

CURRICULUM

The 8-week curriculum unit addresses important learning goals through students' investigating the driving question, "Can Good Friends Make Me Sick?" An initial activity about the spread of disease introduces students to the concept of disease and the devastating impact it can have on an individual and a community. Students return to concepts introduced in this activity throughout the unit. The curriculum unit addresses national standards related to cells, human body systems, and disease as articulated by Project 2061 Benchmarks for Scientific Literacy (American Association for the Advancement of Science, 1993) for the middle grades. In addition, the unit addresses a number of health-related issues specific to the nature of communicable diseases addressed, including sexually transmitted diseases. We developed the unit to address both the science content and some of the social issues surrounding sexually transmitted diseases. A district administrator who believed that middle school students should study issues surrounding sexually transmitted diseases initially suggested the development of the unit. The data reported were collected during the pilot enactment in the 1999-2000 school year. The curriculum has been revised each year based on the results of enactment. The current version of this unit can be found at http://know.umich.edu/.

We designed the use of the two learning technologies discussed above into the unit. Using Artemis, students searched and synthesized online information of different aspects of sexually transmitted diseases and the measures used to stop these infections in humans. Students selected a sexually transmitted disease and investigated a range of criteria about this disease using Artemis. Students worked on the disease investigation throughout the unit and presented a final class presentation about the disease. Using the Thinking Tags, students modeled the relationships of the infectious agents that they studied (bacteria and viruses) to known diseases and investigated how such diseases are transmitted. Students explored a variety of scientific concepts central to understanding a disease epidemic. This embedded technology activity is similar to the initial activity that uses liquids of different pH and a pH indicator to highlight the presence of a contaminant (or a disease). The technology-based simulation allows students to investigate issues that were introduced with the liquid-based activity but with more detailed and extensive activities not afforded by the liquid simulation. Using the Thinking Tags, students investigated the concept of immunity, incubation period, and disease source. Students designed their own investigations and carried out and modified them based on the results of previous trials.

METHOD

DATA COLLECTION

The classroom was videotaped throughout the enactment of the unit by the curriculum developer and a classroom support person. Students were videotaped throughout their use of the two technologies. These tapes were examined for evidence of student engagement and for characteristics of inquiry supported by the use of the two technology tools. Approximately 10 hours of classroom tape were analyzed for this study. Informal interviews were done throughout the period of enactment where student opinions were probed about the activity and the use of technology. Final presentation artifacts were collected and examined for confirming evidence of student engagement.

CLASSROOM CONTEXT

The classroom context of this study is an important factor in the analysis of the data. This enactment was the first time that the participating teacher had taught an extended project-based science unit and the first time that the students had participated in such instruction. Issues of classroom management were present in the classroom throughout the unit; they were simply noted as part of the context. In addition, the findings are based on the classroom enactment captured on videotape, individually taped student conversations, and student artifacts. In the videotape, conversations were identified and transcribed from approximately 10 students who could be followed for extended periods of time. The limited natures of these data sources restrict generalization; however, the results add to the growing body of evidence on patterns of student inquiry and engagement with technology in the urban classroom. In addition, the results of this study can aid the revision process of both the curriculum and the learning technologies.

ANALYSIS

We analyzed student inquiry and engagement for specific characteristics during two technology-embedded inquiry activities: the spread of disease investigation incorporating the Thinking Tags and the disease investigation incorporating Artemis. This analysis was done through a series of data reductions, starting with a detailed summary of classroom videotape where the two technologies were being used and identifying events with the enactment that addressed the two questions (these procedures are modified from Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 1998, and from Miles & Huberman, 1994) and noting trends. The summary contained descriptions of the student and teacher behavior as well as

TABLE 1
Questions Used to Guide Data Analysis

Inquiry Component	*Questions Used During Analysis*
Asking questions	Were the questions worthwhile? Were the questions meaningful for the students?
Collecting information	Was the research investigation worthwhile? Were the topics meaningful for the students?
Designing and carrying out the investigation	Was the investigation planned out? Were students specific in their investigation plan? Did students follow the plan? Was the experiment meaningful?
Data collection, analysis, and drawing conclusions	Was data collection carried out in a thoughtful and planned manner? Were data used in making the conclusions?
Presentations and communicating findings	Did they relate their conclusions to their question? Did they connect findings to the "real" world or to their own lives?

conversations pertaining to the use of technology. These behaviors and conversations were coded for characteristics of students' inquiry and engagement. Original videotape was then used to determine the detailed conversations as needed for illustrations. The levels of student engagement are embedded within the framework of inquiry. This method of analysis allows for the examination of student engagement in the process of doing science.

CHARACTERISTICS OF STUDENT INQUIRY

Characteristics of student inquiry examined include asking questions; collecting information; designing and carrying out the investigation; data collection, analysis, and drawing conclusions; and making presentations. In examining the characteristics of student inquiry, videotape was analyzed using criteria modified from Krajcik et al. (1998; see Table 1). In this article, the concept of *worthwhile* means that students address appropriate content for the unit or activity. *Meaningful* refers to the relevance that the event has for the student—does the event (a question, investigation, trial, or presentation) have meaning for the student outside of class? Trends were examined across both learning technologies and a descriptive synthesis was drawn from the data.

TABLE 2
Descriptions of Engagement Levels

Level	*Description*
Low	Off task regarding inquiry component
Mid	Few observable events of the inquiry component observed in a procedural manner
Mid to high	Some observable events of the inquiry component observed with involved students
High	Multiple observable events of the inquiry component observed with substantially involved students

STUDENT ENGAGEMENT

Levels of student engagement were determined using the same inquiry components and identifying the different engagement trends. These trends were identified by conversations and by visual cues present on the videotape and confirmed by student artifacts. The analysis of these characteristics enabled us to categorize student engagement into one of four levels—low, mid, mid-to-high, and high engagement—as they carried out the two investigation activities (spread of disease or disease investigation; see Table 2).

FINDINGS

We describe how the Thinking Tags and Artemis provided opportunities for students to become engaged in two different types of inquiry activities within a project-based science unit on communicable diseases. Themes are discussed in detail in five sections corresponding to the inquiry components described in Table 1.

ASKING QUESTIONS: WORTHWHILE AND MEANINGFUL

Many of the questions that the students posed throughout the two activities were worthwhile and meaningful, although the quality and complexity of the questions varied. During the spread of disease activity, using the Thinking Tags, students posed a number of questions that addressed identification of the disease source. For example, one student asked, "Where did it get started?" This question addresses the concept of identifying the origin of a disease, a key concept in this activity illustrating a basic engagement with the activity (midlevel cognitive engagement). The higher level cognitive engagement questions were questions that built on this type of initial question.

Additional and more sophisticated concepts asked by students concerned the rate of transmission and length of incubation before symptoms appeared in the spread of disease activity. Students were paying attention to the issues that could be addressed in the inquiry activity and were discussing their ideas and raising additional questions that they wanted answered, as seen in the following two questions raised by two students in the class. In one episode captured on the videotape, the teacher and students discussed specifics about which the students wanted to learn. One student (Eric) stated that he wanted to know "how long does it take for a disease to pass on to someone else?" This is compared to a question asked by Rosario, who followed up with a question about the details of a specific disease. Rosario asked, "No matter what type of disease it is, I want to know about the different diseases, and the different time slots for different diseases or is it all the same?" Rosario continued to explain what she wanted to know and made specific reference to AIDS. Throughout the whole activity, Rosario referred to the period during which the badge showed no symptoms as *time slots*. These two students realized that there was an incubation period before the badges showed that they were infected. Both Eric and Rosario asked similar questions, but Rosario, showing a higher level of engagement (scored as high engagement), connected the simulation to the real world with the comment about wanting to know about AIDS. Both students raised worthwhile questions in regard to the content, but Rosario's question is particularly meaningful—it makes connections to a socially relevant and important disease. Rosario continued this interest with the real world later in the unit when she made reference to a TV show about herpes that she had recently seen and connected it back to the Thinking Tag activity. These different levels of questions demonstrate that students were engaged with the concepts and processes illustrated in the simulation.

Students were also able to connect their questions from one investigation to another. This was seen when several students wanted to investigate the concept of immunity to a disease. The students raised this issue because some of the students interacted between 15 and 20 times in the first trial and did not get sick. This type of connecting through questions to previous investigations shows a high level of engagement that was fostered by the Thinking Tag simulation. This ability to connect previous questions and investigations likely allowed students to stay focused on the activity.

Students rarely used the scientific language that would help explain the concepts that they wanted to investigate, but they were able to articulate and ask about complex science concepts, as is illustrated in the questions that Tommy and LaToya asked. In a discussion about what students would like to know, Tommy asked, "I would like to know why certain people didn't catch it." LaToya was able to articulate a similar question but used different language to do so and added a level of complexity that was not seen in Tommy's question. LaToya asked "why some people stayed clear, and had a large number of interactions, and some of the people that they interacted with went red." Tommy's question is a basic question about immunity, whereas LaToya asked about immunity and about the ability to be a carrier and not get sick. The language that students used was often in direct reference to themselves as participants to the simulations. This finding is similar to the finding reported by Colella (2000) and illustrates a personal engagement that is important to maintain.

When students carried out their disease investigation using Artemis, they were required to create questions about a disease due to the scaffolds present in the Artemis interface. These questions were meant to help support the students in collecting necessary information about the disease that they were investigating. To create the questions, students first needed to select a disease that they wanted to investigate. Following this selection, students created a driving-question folder specific to their question. This folder became a location for students to store notes and URLs they found during their investigation that pertained to their questions. In examining the students' folders, it became clear that only a few questions were written and answered by each student group. The data present showed that students tended to create simple questions that addressed a disease concept. Although questions initially appeared not to be meaningful, in fact they were to the students. When we examined the rationale students presented for selecting their disease to research, a rationale captured on videotape for several of the student groups, we were able to proceed with a more nuanced analysis. As illustrated in the conversation detailed below, the use of Artemis helped one student create a meaningful connection between science content and what he wanted to learn about later:

Andy: We already know . . . [what the flu is, he reads a list of flu symptoms from a sheet he had printed off].
Anna: The cold, flu, or pneumonia [reading as well].
Andy: Listen, let's study one of these [pointing to the other diseases on the list which include sexually transmitted diseases]; when you get older you might get one of these and you don't know anything about these.
Anna: I don't care.
Andy: . . . because from all of these you can die.
Anna: I don't care—you can die from pneumonia.
Andy: That's not very likely—one in a million.
Anna: I could be the one person out of the million.

They then decided on a specific straightforward question about pneumonia to investigate. The rationale for deciding on this disease was based on personal reasons, the possibility of dying from the disease. Andy showed a personal rationale for wanting to study a sexually transmitted disease that Anna is unwilling to address. This exchange shows how one student can affect another student and cause the level of engagement to change. Anna's level of engagement would be classified as midlevel, she is doing the investigation but is not investing anything more than she needs to do or what is expected of her. Andy is a mid-to-high–level engaged student, although he is convinced by Anna to do only what is expected of them.

These examples of the students' questions and interactions while using either the Thinking Tags or Artemis show that students are capable of generating questions that they can then investigate. The questions created for the Thinking Tag investigation were more complex. In analyzing the questions asked by the students when using either technology, student questions satisfied the worthwhile and meaningful criteria. Unlike previous studies into students generating questions (Krajcik et al., 1998), which identified a potential problem with students drawing too heavily from personal preference and experience and not from unit science content, these technologies allowed students to ask questions that connected the unit science content and real life to the investigations and technology used. An important potential difference between the two studies was in the type of science content that the students were investigating. The science that students were learning about in the "Can Good Friends Make Me Sick?" unit directly connected to their own health and body, whereas the science in previous studies was not as directly connected to the students' physical well-being, although students were still vested in the environmental science being addressed in the earlier studies.

FINDING INFORMATION: WORTHWHILE BUT WITH DIFFICULTIES

Thinking Tags was a technology that the students could easily master and use successfully, whereas Artemis remained difficult for the students throughout the entire disease investigation. The complexity of Artemis clearly was a factor, as is illustrated in the following conversation between Anna and Andy:

> Anna: [Looking at an Artemis note card] . . . it doesn't have anything to do with pneumonia—now you find something that has to do with pneumonia.
> [Andy tries to please her and does another search and finds additional sites.]
> Anna: You can't do that—see you can't do that [when Andy tries to go to another site from the search results].
> Andy: Do you still want to do pneumonia?
> Anna: Well we can't find anything on it. Well, why don't we do the flu, like I suggested in the first place?
> Andy: OK Anna, the flu. The flu is in there [pointing to a site in the Artemis interface].
> Anna: See, same thing [pointing to the results that they just got for the flu in comparison to the results for pneumonia].
> Anna: It won't go to it, I'm going to go back and try it again.

These students struggled with the complexity of the interface and the need to select multiple terms when doing their search. One term was required for the subject area and a second term was required for their keyword. Due to intermittent software problems, these two fields did not always work as they should have. This issue caused different searches to return the same results and is illustrated in Anna's comments about "see, the same thing" for both *flu* and *pneumonia*.

Regardless of the troubles that students faced in using Artemis, students did stay on task for a large portion of the period, making progress in initiating their investigation and selecting a disease to investigate. In addition to staying on task, students were able to find worthwhile information, specific to their investigations, reflected in the information presented in the final disease investigation presentations (see below).

DESIGNING AND CONDUCTING THE INVESTIGATIONS: CONNECTIONS AND CHALLENGES

The Thinking Tags allowed students to carry out meaningful investigations, although these investigations met with varying successes. As part of the Thinking Tag simulation lesson, students designed a series of investigations that addressed the issue of incubation period and traced the disease to the initial source. One student, Rosario, felt strongly that the simulation investigation would help her understand what had happened to her when she was sick with the flu:

> Rosario: Now listen to this, you all know when I was sick a couple of weeks ago, I had the flu, my parents had the flu but I never caught it, I caught it now—it was inside of me, but something inside of me was trying to fight it, but [when] it caught me, my resistance was still high but I caught it. How can we test this? Be quiet [Rosario tells the class]. How could we test this with the badges? When we did it [referring to the first simulation], it [the thinking tags] turned red 5 minutes later, did I have it exactly then? As time went on I caught it—so when did I caught [*sic*] it?

While using the Thinking Tags in their investigations, students showed strong connections not only to the real world, as is illustrated by Rosario's comment, but also to previous Thinking Tag investigations:

> LaToya: I think that you know how we had two groups yesterday and that the group over here wasn't infected until someone walked over here—I think that people should pair up and interact and then see what people get it.

LaToya realized that what happened the previous day helped her to see what would happen in smaller groups. She connected the previous activity with what they are trying to do now, and she wanted people to have the same badges from the previous day so that they could pick up from where they had left off. This connection supports LaToya's high level of cognitive engagement with the investigation and with the idea of identifying the source of the disease.

Although the students could make connections to the simulation and what it represented to them, they initially had difficulty in specifying exactly what they should do to conduct an investigation:

> LaToya: If I showed like how to do it, could you word it right? Cause I don't know how to word it right. You take one of them and like have them interact, have them interact with one and then wait to see if they get infected.

Students commonly had difficulties in designing the procedural components of their investigations. The issue of controls and changing only one variable at a time was difficult for them to understand. But once students became familiar with what they could do with the Thinking Tags and they settled in on a particular concept to address, they could design a series of investigations that allowed them to eventually identify the source of disease, although they continued to have difficulty following procedures accurately. One example of this that led to an interesting discussion happened when the class divided into communities and interacted only in these two smaller communities. Because of how the Thinking Tags were programmed, only one disease source was present in the whole class, but both communities became sick. Students eventually identified the problem and talked about how one Thinking Tag brought the disease into the second community.

Conducting investigations proved to be highly engaging for the students; they often asked if they could do the investigation again or if they could do a different one. Judging by the physical reaction to having a tag turning red, the students were amazed and horrified when it happened to them. Alycia reacted vocally when her badge turned red during one of the simulations: "I don't know who I got this from, but I'm very mad about this. Get away from me." When asked how they felt when they found out that their Thinking Tags were infected, the majority of the students did not like it. One student expressed his reaction as embarrassment and explained that he wanted to figure out "why I got it, who had it, where it came from and how they got it and how I could get rid of it."

DATA COLLECTION, ANALYSIS, AND DRAWING CONCLUSIONS: INVOLVEMENT AND NEXT STEPS

Students often did not do careful data collection or observation note taking while using the Thinking Tags in a simulation, even when they were given specific instructions. The videotapes show students asking with whom they had interacted and in what order the interactions had taken place. Students often found it difficult to identify the correct pattern of infection. This was one point in the investigation during which the high degree of engagement was actually a determinant to completing the goals of the investigation; the interaction was so compelling that students forgot to take notes and record the patterns as the infection spread.

In addition, students often did not apply all the information that they had available to make and state conclusions. One example was seen when Thomas went through his notes and talked about more students getting sick, showing a high level of cognitive engagement. By doing this initial analysis, he began to lay out who was sick first and then who got sick, but he did not complete this analysis before stating that "Maria is clean, she must have immunity. My conclusion is that LaToya is the source." His conclusion was not based on the complete data set of interactions; it is only after the whole class joined in the discussion that they realized that LaToya could not be the source of the disease.

As the students became more familiar with how the Thinking Tags operated and the data they would be getting, they began to draw conclusions that were supported by data and to design investigations based on the results of the previous investigation. Based on a whole class discussion, the students decided to continue with the general trend of the investigation to figure out the disease source. As the investigation began, the students engaged in the following conversation:

Maria: . . . if you get infected you can use the list to identify who got you sick and they can then use their list to trace it back even further. . . .

[Thomas decides to time for a 2-minute incubation—people will interact with one person and then not interact with anyone else for 2 minutes.]

Juan: Anyone turn red? [The students interact again.]

Someone: Did anyone turn red?

Students: Rebecca's is red—we have one red.

Teacher: Tell me your history.

Rebecca: Edward, Juan, and another student. [She is questioned about why there are three interactions when there should only be two interactions.]

Juan: I've got cooties, anyone else want cooties? [The class is trying to figure out whom Edward interacted with and whom Juan interacted with—they find out that Thomas had interacted with one of them.]

Students: Why didn't his turn red? He might have immunity. [The class next tries to isolate the Thinking Tags that were at the tables of Rebecca and Edward.]

Teacher: Should we wait longer?

Rosario: No, we need to do it over and see those two [Rebecca and Edward].

The students carried out another series of trials and eventually identified the disease source as coming from Edward's Thinking Tag.

When students were asked directly during the informal interviews about what they thought of the Thinking Tag activity, their responses indicate that they were highly cognitively engaged with the activity, in addition to enjoying the investigation:

Rosario: It was fun, you had to think about it—everyone was turning red and I was thinking how were you going to find out. You had to

> put your thinking caps on, because other[wise] you wouldn't be able to find out. People had to think together and we came with the idea of who had the disease.

Students enjoyed doing the investigations and reaching conclusions about the science concepts addressed. They struggled with the complexity of the design of the inquiry procedure and the successful completion of the multiple trials. Nonetheless, these examples show how the Thinking Tag technology can engage students in deep conversation and successful iterations as they learn core science process skills such as the design and implementation of an investigation.

PRESENTING AND COMMUNICATING FINDINGS: STRONG CONNECTIONS TO THE DRIVING QUESTION AND THE REAL WORLD

Both the Thinking Tag activity and the Artemis disease investigation allowed students to make strong, meaningful connections to their own lives. Students related to the Thinking Tags very personally—the Tags became an extension of themselves. At one point in a discussion following a simulation, someone in the class had to remind the rest of the students that the simulation was only a model of how disease could spread and that everyone should not take things so personally.

Students repeatedly related the Thinking Tag activity to real life and to the driving question. This type of connection can be seen in the example about catching the flu:

> Anna: Everyone in the class knows each other and it's like, something that could be compared in real life, like if someone had the cold and they talked to their friends in class, their friends could get sick.

Connections were often more personal in nature, as is seen in the example that Juan gave in his explanation about how the Thinking Tags can illustrate how he got chicken pox and spread it to his siblings. Or the connection could be more serious and address the more controversial topic in the unit, sexually transmitted disease.

This is seen in the comment made by one student during an informal interview:

> Eric: Herpes—yea it can, say example for sex can be an interaction with a female and a male, if one of [them] the male or the female have the disease genital herpes, say the male, if the male interacts with her, maybe later in a month or a week or the incubation time, it can flare up on her.

Although Eric is making the connections between the Thinking Tags and a particular disease, he is still uncertain about the details of the disease. In the disease investigation, students were to investigate diseases and present reports about these diseases to the class. Eric was able to report on the details of the disease during his presentation, but when pressed about the specifics of the disease herpes, he was unable to answer. All students who were interviewed were able to make a direct connection between their disease investigation and the Thinking Tag activity. During these informal interviews, one student volunteered a role that the Thinking Tags might have in the real world as a tool "for scientists that track diseases" to show people how a specific epidemic might have happened.

The final disease investigation presentation provided student artifacts as well as student behavior to judge student engagement. Students were highly engaged during their presentations, as they perceived themselves to be the experts teaching their classmates. Two presentations in particular were of interest because these groups chose to teach their classmates specifically about the dangers of the disease they investigated. One group instructed their classmates: "Do not have sex over the summer, if you do anything that you are not supposed to do, use protection and use it right." A second group, led by Rosario, told the class

> Like I was going to say, like how good friends can be infected, they can make you sick, I mean, before they are going to have intercourse, because it looks like they don't have a disease—like nothing is going to happen but once it happens, it happens [*it* here refers to infection]. I had to revise this over and over, know that once it happens, once you get infected, there is no cure for it. So know that once you are infected, you are infected. It is best to abstain from sex, period.

Rosario felt strongly enough about the content and the implications of the content that she wanted to give her classmates a small lecture about what they should or should not do. This was a direct result of Rosario and her group successfully finding information about their disease investigation using Artemis.

DISCUSSION

This article is a first step in the analysis of two novel learning technologies embedded within project-based science curriculum designed for urban students. The findings reported here show that these two learning technologies helped the students to ask meaningful and worthwhile questions, find information, and design and conduct simple investigations. In addition, students were able to begin discussing the ideas behind these questions and investigations in a manner that addressed scientific concepts in a meaningful and worthwhile way.

Findings presented in this article suggest that students can ask meaningful and worthwhile questions and have discussions about the scientific concepts aided by the learning technology without first having command of technical and scientific terms. This language is the next step for these students once they have mastered the idea of the concept. This transition is a challenge that needs to be addressed in the next version of the curriculum that supports the use of this technology and will be further explored. Using these two technologies, students were able to make strong personal connections between the science content and the investigations they performed. The personal nature of the communicable disease unit might help lend strength to connections that students create. This work supports the suggestion made by Kesidou and Roseman (2002) regarding the importance of designing curriculum materials with regard to learning goals. The finding illustrates the importance of matching technologies to curriculum goals to help scaffold students' inquiry activities. In examining the students' interactions and discussions concerning the lessons that used the two learning technologies, it is clear that students were engaged and interested in learning about the content addressed in the lessons through the interactions with the two learning technologies. In addition, students were making connections to their everyday lives and how they should act to be "safe." By making the content relevant to the students' lives, we were addressing a concern expressed by Barton (1998) regarding the importance of making urban science education relevant to the students' lives. However, the strong personal connections seen in the students' discussions about the disease investigation does not mean that all students will learn the content to the same depth. This was demonstrated in the lack of specificity that some students expressed when asked about the disease that they investigated using Artemis. This finding was similar to that reported by Hoffman et al. (2003). This lack of specificity illustrates the importance of in-class supports for the students as they carry out their online investigations to make certain that students learn the stated goals of the curriculum but still engage in the activity in the spirit that it was intended. Students needed additional supports to make meaning from the complex text that they were reading as they investigated their disease, especially for students who might be reading below grade level and reading from an unfamiliar medium, the Internet. It is with this type of support that the use of technology can be addressed and used to benefit a range of students (Atwater, 2000).

A similar concern was seen when students were engaged with the Thinking Tag spread of disease activity; students often had difficulty in using all of the information that they had collected about who might have been the initial carrier. This difficulty was seen in other studies examining students' initial attempts at inquiry (Krajcik et al., 1998). We found that students needed additional supports to successfully design and complete complex investigations and to fully understand the complex issues behind the pattern of disease transmission. The inquiry activities structured on the use of the Thinking Tags needed to be examined and restructured to allow students to master the creation and completion of complex investigations. In subsequent versions of the curriculum, additional lessons have been developed to help support the students as they engage in the spread of disease activity. We designed a series of investigations to engage students in inquiry through scaffolds provided by the teacher (Hug & Krajcik, 2002). Through the scaffolds included in the student materials, students have been able to design and carry out their own investigations that identify the initial carrier in the classroom. By providing the necessary supports for both the teacher and student, we have seen how an innovative learning technology can be used in an urban classroom in a manner advocated by the science education reform efforts. These findings provide an important lesson for materials designers who are interested in embedding learning technologies into curriculum materials. Specific supports need to be developed and inserted into curriculum materials to help students and teachers make meaning from use of the learning technology (Schneider, Blumenfeld, & Krajcik, 2002; Schneider, Krajcik, & Blumenfeld, in press).

The work presented documents student engagement with science content through the use of two novel learning technologies during the pilot enactment of a project-based science unit. The encouraging results from the 1st year's enactment led to the materials' being revised and used during subsequent school years. It is now possible to document substantial learning of science content aligned with the national standards, as well as the state and district objectives, in addition to the engagement shown in this article (Hug & Krajcik, 2004). It is with this type of curriculum material, which engages students in meaningful content and allows for learning of key science concepts, partnered with larger reform efforts, that districts can begin to address the inequities that have been seen in too many urban science classrooms (Atwater, 2000; Lynch, 2000; Marx et al., 2004).

NOTE

1. We refer to new technologies, in particular the use of computers, software, and various peripherals, that support students' learning as learning technologies (Krajcik, Blumenfeld, Marx, & Soloway, 2000).

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