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Crafting Virtual Connections to Support Inquiry-Based Science Learning

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Intent on building inquiry-based digital science learning experiences for K-5 students, this research study began with the formation of a tight partnership between state and local educational agencies, higher education, and university scientists and researchers. The primary focus of this partnership was to deliver high-quality, inquiry-based science education focused on alternative energies for K-5 students, primarily within a virtual context. The collaboration brought together a team of university academic departments, researchers, and faculty, in alliance with local suburban school districts, and affiliate rural private schools and districts. Qualitative data collection focused on the design and delivery of virtual visits between alternative energy scientists and participating K-5 students. Results suggest that the teachers' perceptions of the impact of the virtual visits varied depending on several contextual factors, and that they generally structured the virtual scientist visits in one of three manners. Lastly, this paper provides a summary of the strengths and weaknesses of these different approaches, including the challenges faced and lessons learned when structuring the virtual visits.

Keywords: virtual learning; science education; technology

INTRODUCTION

Digital learning tools have potential to provide rich, relevant, and situated learning experiences. Instruction situated within technology-rich learning environments that support this kind of learning is becoming more and more commonplace as teachers work

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toward active and engaged learning partnerships between students and teachers (Rosen & Beck-Hill, 2012). However, this landscape is continually shifting. Teachers are now expected to interact with new technologies in new ways to deliver appropriate pedagogy to meet the learners' needs (Kang, Heo, Jo, Shin, & Seo, 2010-11). This technology and pedagogy connection is often the source of scrutiny, and many argue a transformation is afoot with changes coming to the institution of curriculum-based instruction (Bidarra & Martins, 2010-11). These changes include shifts in the instructional focus to emphasize contribution, creativity, innovation, problem solving, communication, collaboration, and global awareness (Lu, 2011; AACTE & P21, 2010). As a result, teaching and learning practices are changing to accommodate these new perspectives and adapt to a world of digital natives (Funkhouser & Mouza, 2013). Further complicating matters is that teachers are now required to constantly negotiate new technical innovations and skills as current technologies and approaches become obsolete (Shieh, 2012). Despite these challenges, teachers still recognize that technology integration provides them certain affordances otherwise not possible like more instructional time for learning and exploration, increased motivation, engagement, and interest, and opportunities for students to more readily share work and collaboratively solve problems (Neiss & Gillow-Wiles, 2013).

LITERATURE REVIEW

LEARNING IN VIRTUAL CONTEXTS

The National Educational Technology Plan 2010 (U.S. Department of Education, 2010) suggests that new digital learning tools afford communication and collaboration for learning, and bring about a new way for students to interact in the learning environment with each other and the content. As a result, teachers are seeking technology-based pedagogies that support these learning processes. The integration of virtual learning environments is one way to provide the necessary technological support needed to bring about these changes.

Research indicates that the nature of learning within an interactive, virtual environment can be motivating for some students (Ketelhut, Nelson, Clark, & Dede, 2010). Neiss and Gillow-Wiles (2013) report findings that indicate teachers note that technology affords certain time-saving aspects, like immediate feedback for learners, that increase teachers' ability to incorporate more inquiry into the classroom. Other research indicates that technology can support the learning process by extending student-teacher conversations, and provide tools for students to collect data and test models (Sharples, Taylor, and Vavoula, 2007). Obara (2010) found that solving math problems in a virtual learning environment allowed learners to come up with different strategies to address problems, and advanced their ability to solve future problems more easily and more accurately. Learning in a virtual environment has also been found to be beneficial for low-achieving students. Moyer-Packenham and Suh (2012) report a significant gain in math achievement for those low-achieving students that participated in learning environment that included a virtual manipulative treatment. Even simple asynchronous communication technologies present in virtual learning environments have been shown to have positive effects on student learning and achievement (Pulford, 2009).

SCIENCE INQUIRY

Best-practice approaches in science education encourage a close alignment with modern scientific practice and the nature of science (NOS). Encapsulated in the broad term "Inquiry," the activities in which scientists engage are complex, flexible, and far more creative than may be commonly assumed (American Association for the Advancement of

Science, 1993). Inquiry then is a foundational principle in the NOS; it is both a way of thinking and a collection of practices that scientists use to develop and evaluate knowledge (Flick & Lederman, 2006). It is a reflection of constructivist epistemology where the generation of scientific knowledge is much more a result of successful conjecture than the archaic empiricist view of an accumulation of confirmed hypotheses (Carey & Smith, 1993). This development of scientific understanding then is an integrated and iterative effort of empirical investigation, critical evaluation, and imaginative explanation. Such is the NOS and complex reality of scientific inquiry (National Research Council, 2012).

Beyond an accurate understanding of the NOS, inquiry is also a central element in how students learn science (National Science Teachers Association, 2000). From the principles of scientific inquiry, successful instructional models have been developed to enhance student learning (Bybee et al., 2006; Llewellyn, 2007). Research across age groups has found significantly higher science content knowledge gains for students learning science through inquiry compared to control groups receiving more traditional science instruction (Chang & Barufaldi, 1999; Woslilait, Heron, Shaffer, & McDermott, 1998), as well as greater enthusiasm and engagement. Despite the benefits of inquiry-based science instruction, previous research suggests some shortcomings. For example, researchers have found that teachers to be challenged by sustained interventions to build connections between hands-on activities and science content, and the lack of quality inquiry-based activities in textbooks (Kracjik et. al., 1998; Roth et. al. 2006; Chinn & Malhotra, 2000).

TECHNOLOGY AND INQUIRY

In regard to technology support student inquiry, the integration of computer simulations and conceptual models in inquiry has demonstrated value in developing robust student understandings even in areas replete with misconceptions (Pallant & Tinker, 2004). Ketelhut, Nelson, Clarke, and Dede (2010) found that students who participated in virtual environment-based science inquiry curricula "show a stronger understanding of science inquiry than all other students" (p. 67). Further, interactive simulations provide learners with opportunities to engage in experimental practices, connect to prior knowledge, and use new technological innovations (Fan & Geelan, 2013). Other research indicates simulations and virtual labs that can be delivered via tablets, have potential to expand students' cognitive capacities, allowing them to experiment with more complex data, form hypotheses, and test those hypotheses in real time (Jenkins, 2009). Combined, these findings suggest that providing learners and teachers opportunities to engage in content in virtual environments holds potential to provide considerable support the integration of inquiry into the teaching and learning process.

PURPOSES AND RESEARCH QUESTIONS OF THE STUDY

Considering the potential positive influence of learning in virtual or technology-mediated contexts, combined with the benefits of inquiry-based science instruction, it would be prudent to investigate how technology and virtual interactions might be aligned with science inquiry to support student learning. Moreover, better understanding the potential influence of virtual interactions on science inquiry, student learning, and engagement, might inform how best to structure technology-rich interactions for learners across content areas, not just in science. Therefore, this study investigates the outcomes of a project that provided virtual connections between students and scientists to support inquiry-based science instruction. Further, this study investigates the factors that might have influenced student engagement and learning to understand if such virtual connections between learners and scientists are effective mechanisms for supporting science inquiry. More specifically, the researchers aim to study if building opportunities for elementary students to engage in virtual contexts with scientists can influence learning and the inquiry process, including students' interest and engagement in science. Further, we aim to study how the design of the virtual interactions themselves might influence student learning, inquiry, and engagement. As a result, the following four research questions will be used to guide the qualitative study:

1. How might virtual visits between students and scientists influence how students engage in science inquiry?
2. How might virtual visits between students and scientists support students' science learning?
3. How might virtual visits between students and scientists influence students' interest and engagement in science learning?
4. How does the manner in which the teacher structures the virtual visits influence student learning and engagement?

METHODOLOGY

PARTICIPANTS

The participants for this study were practicing K-8 teachers (*n* = 29) who agreed to engage in a professional development project in the area of science inquiry and content for teachers in grades K-8. Participants came from eight different schools in diverse contexts, ranging from very small rural districts, to larger urban districts. Of the 29 participants, 17% (*n*=5) taught 4th grade, 17% (*n*=5) taught 3rd grade, 14% (*n*=4) taught 5th grade, 14% (*n*=4) taught 2th grade, 10% (*n*=3) taught kindergarten, 7% (*n*=2) taught 1st grade, 7% (*n*=2) taught 6th grade, and 3% (*n*=1) taught 8th grade. There were several multi-grade classrooms too, including K/1/2 (*n*=1) and combined 7th/8th grade (*n*=2). Teachers interested in participating were required to apply for a position with the project, had to be currently teaching in grades K-8, and be willing to make a one-year commitment to participating in the project's activities. These activities included orientation meetings, integrating into their teaching four energy inquiry units per year, and engage in pre-post virtual visits with researchers studying emerging energy alternative technologies. In addition, participating teachers had to be willing to interact with instructional coaches on a regular basis throughout the school year in the interest of supporting the teachers' work in the energy inquiry units.

PROJECT OVERVIEW

The primary intent of the project outlined in this study was to pull together collaborators with backgrounds that spanned disciplines, university units, and K-8 schools to deliver high-quality science inquiry learning on alternative energies. This collaborative unit was compiled in an effort to design and implement the energy alternatives curriculum with an accompanying, integrated onsite and online professional development program. Technology played a critical role in achieving these goals. We relied on a series of digital tools to provide the mechanisms for supporting the virtual interactions that were key to the project. The use of these technology-based components was in an effort to connect scientists, engineers, undergraduate researchers, and K-8 students in an online environment as the students conducted the energy inquiries. As a result, the project was delivered primarily online with some face-to-face elements, and involved classroom teachers in grades K-8, school administrators, instructional coaches and teacher leaders, and science, engineering, education and Native American Studies faculty.

In terms of the science inquiry content and the professional development material, we designed and developed an energy alternative curriculum geared for K-8 students. Although we intentionally chunked the content so it was appropriate for specific grade bands (K-2, 3-5, 6-8), four total modules were designed and delivered. These included the following topics: wind energy, solar energy, biofuels, and hydrogen fuel cells. Each of these topics were selected for a number of reasons, most notably though because there are scientists, engineers, researchers and educators at the university studying each of them and motivated to share their research with younger learners. And finally, the project included the dissemination to students of Native American knowledge and the establishment of cultural connections to the energy principles that were being taught.

TECHNOLOGY OVERVIEW

Although this study focuses primarily on the impact on instruction and lessons learned from the virtual visits, an overview of the technologies used to support the visits is needed to establish a base understanding of how the project was designed and implemented. The use of these technologies changed the way the content was packaged and delivered; the instructional focus has shifted to emphasize creativity, innovation, problem-solving, communication, collaboration, and global awareness (AACTE & P21, 2010).

First, online technologies were used to support virtual scientist visits, the development and delivery of a virtual learning commons, deliver professional webinars, and support instructional coaching. Secondly, online synchronous videoconferencing software was used as the mechanism to deliver the virtual scientist visits with participating K-8 classrooms. Scientists on the MSU campus connected with the K-8 classrooms to answer questions related to the students' inquiry work, as well as share with students more about themselves and their careers as scientists. Third, the shared workspace, known internally as the Experiencing Emerging Energy Concepts (E3C) site, served as the communications center and clearinghouse for project information and resources. The aim was to create a virtual learning commons that would provide a communication and collaboration hub for the teachers and students. The inquiry modules were disseminated through this E3C virtual learning commons, and teachers and students used the web resource as the primary tool for sharing with the scientists their inquiry module data and observations. Fourth, project designers used the synchronous meeting software Adobe Connect to deliver an introduction webinar to all participants for each inquiry module. The webinars were used to deliver science content and cultural connections, as well as more depth and detail to the actual learning activities associated with that module. Lastly, coaches used email as one of the tools for communicating with and supporting participating teachers. The following sections will provide additional detail about how the different technologies served the project participants.

Virtual Learning Commons. First, as a central communication hub, we created a collaborative wiki to provide web access to all of the project's content. The collaborative site, created in Google Sites and coined the Virtual Learning Commons (VLC), gave teachers access to project components like the inquiry modules, assessments, and recorded webinars. Additionally, each teacher was given a private virtual classroom into which they uploaded student questions about the inquiries directed at the scientists, and student observations. The potential strength of this as a system to support collaboration was due to the platform and how it supports user control. Teachers had full access to edit the content within their virtual classrooms, and after a brief introduction on how to make page updates, most were able to successfully (and easily) make any necessary changes like adding their students' questions or inquiry observations.

Webinars. Secondly, to support the delivery of the content, we used Adobe Connect. This synchronous meeting platform allowed us to remotely deliver professional development content to the teachers located a distance. This meant that we could routinely provide the presentation and briefings on the inquiry modules to prepare the teachers to teach them, yet allowed teachers to avoid long distance travel for a face-to-face session.

Additionally, these professional development webinars were recorded and archived on the Google Site for those teachers unable to attend the virtual meetings.

Digital Communication. And finally, we used both the collaborative site and Google Video Chat as the mechanisms for delivering the virtual scientist visits. As they conducted the energy inquiries, K-8 students in participating teachers' classrooms posted progress and findings in a designated and secure area within the Virtual Learning Commons (VLC). This allowed an assigned MSU scientist or engineer or advanced student investigating the same topic to read and respond to the students' posts. Each classroom received at least one live videoconference visit per semester from an MSU energy researcher. Each videoconference was scheduled to coincide with a particular alternative energy unit being taught in that particular class.

This web-based videoconferencing program provided a relatively simply platform to connect the university scientists and engineers with the participating teachers and their students. Additionally, a Google Group discussion board was integrated directly into the Google Site. This tool provided a platform for asynchronous discussions between the teachers regarding the teaching of the inquiry modules. Teachers used this space to share ideas with one another about the successes and challenges faced when teaching each module.

PROCEDURES OF DATA COLLECTION

Although both qualitative and quantitative data were collected during the project, this paper focuses on the qualitative data as it relates to the virtual scientist visits and teachers' (n=29) reports regarding their interactions with the online communication and collaboration. All virtual scientist visits were recorded and later analyzed by the program evaluator to better understand the dynamics of how the visits are structured and how well they appear to work in different grade levels. After each virtual visit (mostly two visits per classroom) teachers completed the questionnaire regarding the impact of the visit on students' science learning and engagement. Additionally, the participating instructional coaches provided written narratives about their perceptions on the strengths and weaknesses of the program. This was valuable data because the instructional coaches had constant contact with the participating teacher. Further, despite a majority of the content being delivered online, and the majority of the collaboration and communication happening via online tools, it was important we met face-to-face with the teachers on a periodic basis. These face-to-face meetings served as impromptu focus groups, where teachers were given the opportunity to share what they perceived as the strengths and weaknesses of the program. And lastly, teachers were given a follow-up questionnaire after each virtual scientist visit that focused on the instructional impact of the event (see Table 1). Several team research team members used an open-coding approach to analyze these qualitative data. Procedures for establishing trustworthiness in qualitative inquiry were taken into consideration and implemented during data collection and analysis, including the use of multiple investigators and consensus building (Lincoln & Guba, 1985). Further, qualitative data was collaboratively reviewed with intentions to calibrate analysis efforts and generate consensus about codes and core ideas (Creswell, Hanson, Plano Clark, & Morales, 2007).

These findings, as presented here in this paper, is the result of critically analyzing these data in an effort to develop a better sense of what worked and what did not work with teachers' online interactions and work during the professional development experiences and delivery of the energy alternatives inquiry modules.

Table 1. *Virtual Visit Follow-Up Questionnaire*

Impact on students
1. Did the virtual visit inspired your students to ask different type of questions? If so, how? Why?
2. What was the impact of the visits on your students' science learning? Did the conversation with the scientist clarify concepts for your students? Why?
3. What was the impact of the visit on your students' science engagement? Did the virtual visit make your students curious about alternative energies? Why?
4. Do you or your students still refer to some aspects of the visit?
Effectiveness
5. Are the visits "cost effective" in terms of the use of school time and their impact on students?
6. Is the use of the video-conferencing technology effective in terms of the use of your time and the possibility to adopt this technology further in your teaching?

FINDINGS

The purpose of this investigation was to better understand the outcomes of building opportunities for elementary students to engage in virtual contexts with scientists. More specifically, researchers focused on examining if the virtual visits between learners and scientists influence learning and the inquiry process, as well as students' interest and engagement in science. In addition, this study aims to better understand how the design of the virtual interactions themselves might influence student learning, inquiry, and engagement. The following four research questions were be used to guide the investigation: 1) How might virtual visits between students and scientists influence how students engage in science inquiry? 2) How might virtual visits between students and scientists support students' science learning? 3) How might virtual visits between students and scientists influence students' interest and engagement in science learning? 4) How does the manner in which the teacher structures the virtual visits influence student learning and engagement?

Following data analysis, the resulting essential themes emerged: (a) influence of the virtual visits on inquiry-based science instruction, (b) influence of virtual visits on student learning, (c) influence of virtual visits on student engagement, and (d) influence of the structure of the virtual visits on student learning.

INFLUENCE OF VIRTUAL VISITS ON INQUIRY

Teachers were asked how the virtual visits might have impacted the types of questions students asked about the alternative energy content. All grade six through eight teachers reported about the benefit of the virtual visits as a way to stimulate students' questions, and deep thinking. As one teacher indicated "The 8th grade students learned that they could ask questions that I wouldn't know and really took advantage of that situation". Third through fifth grade teachers' perception of the impact of virtual visits on students' questioning varied, from not being beneficial (40%) to stimulating deeper questions (60%). One teacher suggested that the video-mediated communication prompted students' questions "because it meant they could see themselves on the computer/screen".

INFLUENCE OF VIRTUAL VISITS ON STUDENT LEARNING

Teachers were also asked how they perceived the virtual scientist visits might have impacted students’ science learning. The six through eighth grade teachers indicated that the virtual visits were beneficial to increase students' critical thinking and conceptual understanding. One teacher indicated, "The scientists were able to break down the concepts into something that is understandable for the students". Forty-eight percent of the grade three through five teachers emphasized the relevance of having the students interact with scientists "my class feels more comfortable asking questions. They were happy to have their questions answered by a real scientist". Fifty-two percent found the dialog with a scientist difficult to follow due to specific vocabulary, or complex concepts. Most of the early elementary teachers (K-2) indicated that was difficult for the students to follow the explanation of the scientist, either due to the complexity of the topic or technical issues. One teacher reported about the benefit of the virtual visits by stating, "We really didn't understand silicon before the visit and after asking tons of questions I think we do now".

INFLUENCE OF VIRTUAL VISITS ON STUDENT ENGAGEMENT

In terms of the impact on students’ science engagement, all grade six through eight teachers reported relevant benefits, either on their students' engagement with the topic. One teacher reported, "My students are still asking questions and wanting to know more. They are continually thinking about alternative energies and how to utilize them in the future". Further, teachers indicated the visits offered an opportunity for lower and middle achieving students to ask questions. One teacher commented, "The students that asked questions were not students you would think to come forward". Fifty-seven percent of the grade three through five teachers reported a positive effect of the virtual visits on students' interest in renewable energies, while 28% of the teachers were uncertain about the effect of the visits. One teacher reported poor outcomes due to technical limitations experienced during the virtual visits. And eighty percent of the K-2 teachers perceived the virtual visits as a great opportunity for students to be engaged and ask questions. One kindergarten teacher reported, "The students seem to become more engaged in the questions as the visit went on". These teachers also reported that wind energy was the topic that was mostly engaged young students.

Teachers were also asked if students continued to reference the virtual visits after the alternative energy units were completed. For the older students group (grades 6-8), the effect of the virtual visits continued beyond the visits itself either because students or teachers referred to the topics covered by the dialog with the scientists. Alternatively, grades 3-5 teachers did not report any follow up on the topics of the visits. Teachers of younger students (K-2) revisited some of the concepts presented in the virtual visits.

And finally, grades 6-8 teachers unanimously indicated about the great effectiveness of the virtual visits. Conversely, teachers of younger students (K-5) indicated that they would have, at times, preferred a live visit with the scientist. Teachers suggested this model have students visit a real science lab, or have a scientist visit the school. Teachers indicated this preference was largely due to periodic technical difficulties. These technical challenges reportedly made the virtual visits cumbersome for some of these teachers.

In summary, the impact of the virtual visits varied depending on the grade band, and the topic of the visit. Virtual visits seem to engage and enhance the science learning of middle school students. Regardless, many teachers shared that the visits were inspirational for students, and provided their students unique insight into what a career in the sciences would consist of, and in many cases, gave students a chance to consider careers in alternative energy.

STRUCTURE OF THE VIRTUAL VISITS

We also looked closely at the type and modality of instruction the teachers used to structure the visits. This was done through video analysis following the completion of each virtual visit. Qualitative data analysis and review of recorded virtual visits suggests that there were three primary modalities for how teachers and scientists structured these virtual visits. One interesting observation is that these modalities appear to fall on a continuum between a teacher-centered approach and a student-centered approach. These modalities and accompanying characteristics have been presented in Table 2.

Table 2. *Virtual Visits Dynamics*

Modality	Characteristics	Approach
Modality A	• Introduction by the scientist • Students show and tell and ask questions for 18-25 minutes	Teacher Centered
Modality B	• Introduction by the scientist about the research topic, work, and the role of MSU • Students ask questions for 10-15 minutes • The scientist asks questions back to the students (previously sent by the teacher) or probes students' understanding	Teacher/Student-centered hybrid
Modality B	• Introduction by the scientist • Students ask questions to their peers; if there is no response the scientist answer • Students ask questions to the scientist, and students ask questions to scientist	Student Centered

Analysis of these recorded virtual visits indicates some additional characteristics and results from the virtual visits, and how the different grade bands reacted to the online visit with the energy scientist and energy. In the K-2 classrooms, question asking stimulated more questions from the students. However, these younger students tended to rephrase and re-ask the same question repeatedly. For example, in one virtual visit with a kindergarten class and a wind energy engineer, the students asked numerous similar questions about how the visual affects the wind. For example, students asked, "Why does the wind blow off my hat?" and "Why does the wind make my jacket flap?" and "Why does the wind blow leaves?" and "Why does the wind blow paper?"

When analyzing the virtual visits from the grades 3-5 classrooms, the teachers appeared to be using more complex energy-related vocabulary, and as a result, the students tended to use the same vocabulary when asking questions to the scientist. Additionally, on interesting observation was that, regardless of the type of modality the teacher used to structure the virtual visit, both male and female students seemed to ask an equal number of questions.

Lastly, analysis of the recorded virtual visits with 6-8th grade students suggests that the students tend to associate the topic of the visit with other science concepts or social issues.

The students were much more capable of understanding, and consequently asking related questions to some of the larger societal issues connected to the scientist's area of research. For example, for the inquiry module on wind energy, many students wanted to know what kind of pushback the scientists had received from the public due to their research, and whether they have encountered any political barriers or problems due to their work studying wind energy.

DISCUSSION

STRENGTHS

One of the great assets of technology integration is how certain tools can provide students with the opportunities to experience things they would not otherwise experience. In this case, logistics would prevent the scientists from visiting every single classroom in a face-to-face capacity. However, we were able to exploit the affordances of the technologies and deliver the experience of visiting face-to-face with a researcher or scientist via the online format. And most importantly, students seemed to be quite affected by the virtual visits. Although many appeared to be initially captivated by the technology itself, the opportunity to talk to and ask question to a real scientist quickly became their focus. Anecdotally, the visits with the lower grade levels ran more smoothly when they were kept short, no more than 15 minutes in total length. But older students had sustained engagement and interest in talking with the scientists. In fact, in many cases, the virtual visits ran considerably longer than planned. Several lasted almost an hour, with students continually engaged and question asking.

Additionally, teachers were exposed to several technologies that are currently being integrated in classrooms all around the world. Since so much of the content was delivered digitally, and a majority of the interaction happened virtually, teachers also reported their involvement gave them a chance to work with technology in a positive manner. The teachers had hands-on exposure to Google Sites and Google Video Chat, both tools that could be readily further integrated into their teaching and learning beyond the scope of the project. In particular, and despite the technical challenges, the teachers appeared to have strong and positive experiences with the videoconferencing. Research strongly supports the concept that when teachers have positive experiences with a certain technology, they are more likely to integrate that tool into other aspects of their teaching. Videoconferencing offers many potential uses across the content areas. Considering the positive experiences the participating teachers had with the use of the tool, they might make further use of the tool in other areas of their teaching.

CHALLENGES

Although the technology was thoughtfully planned, teachers and the research team experienced several technical hurdles and challenges along the way. The Google Site required considerable backend management in terms of adding new users and setting up permissions to allow teachers to access and edit only their own virtual classrooms. Additionally, the Google Site was fairly restrictive in storage capacity. Considering the nature of the files we intended to share with teachers, including all the content to support the inquiry modules, space in the Google Site quickly became a concern. This was mitigated with the external storage of the files and linking to them within the Google Site. But that came at the expense of considerable time and energy managing the remote files and linking. And lastly, although much thought and care was put into how to best design and lay out the Google Site, it seemed as if many of the teachers were never truly comfortable with the internal organization.

As a research team, we consistently fielded questions from teachers regarding the location of content within the site. With this in mind, the use of a campus-wide course management system (CMS) platform would have streamlined this process and helped better organize and present the content. Of course this would come at the expense of teacher control; teachers would not have the ability to easily manage the content in their virtual classrooms. But these types of interactions could be accomplished differently in a CMS like using the discussion board feature or drop box tool as a way for teachers to submit student questions and observations.

In theory, Adobe Connect would be a very strong solution for delivering the webinars. However, the primary issue faced during the project was the variability of the web connections on the teachers' part. Some were connecting from rural locations where bandwidth was an issue. As a result, many would experience video and audio dropout during the webinars. There were technical issues as well, often beyond our control, with the recording of the webinars. Several different means of recording them were tried, and none were as successful as we would have hoped.

Google Video Chat was selected as the video conferencing platform to be using to connect students and the MSU scientists and researchers. In many of the schools in which participating teachers taught, Skype was a blocked program. This was unfortunate because many were familiar with Skype and new to Google Video Chat. However, the use of Google Video Chat as the tool was streamlined in some ways; teachers needed a Google account to access the Google Site, and therefore already had the necessary credentials to use Google Video Chat. A number of technical issues were experienced with the use of the software though. In addition, it required considerable time and resources to help teachers set up the program on their computer. Each live scientist visit required us to have a test video chat with each participating teacher. Considering the large number of visits for each inquiry module, this was very time consuming. And despite the careful attention setting things up technically for each teacher, there were technical glitches like dropped connections, incorrectly installed Google Video Chat plug-ins, and video and audio issues that were outside of our control.

LESSONS LEARNED

The challenges faced with the online components indicate several changes that could be made in order to more effectively support the virtual interactions between students, teachers, and scientists. First of all, project designers could build a model virtual visit for teachers to emulate/follow for the live visits. This model virtual visit could include standard protocols like introductions for both the scientist and class, as well as having students present to the scientists where they are at with the inquiry modules and what they have learned to that point. A virtual visit and webinar checklist could also be implemented at this point to ensure technical issues are kept to a minimum and teachers are adequately prepared for the online interactions.

Secondly, project designers should further explore a formalized content management system as the delivery platform in lieu of Google Sites. The use of Google Sites was intended to improve teachers' technological literacy, but it ultimately provided to be somewhat of a mitigating factor in regard to the success of their online interactions. So although there is much merit is having the teachers explore the inquiry modules via the Google Sites, and encouraging active and collaborative participation in the content development and site management, a formal content management system like the CMS already in place on campus, would streamline the delivery of the professional development content teachers. What would be important would be to consider ways for potentially integrating the Google Site with CMS-based material as a mechanism for teachers' further digital collaboration. A combination of a more rigid course site to provide structure with a more flexible tool like Google Sites could combine the necessary structure with end-user control.

There is also a need for more explicit curricular connections for the virtual components and inquiry modules beyond the science content area. Specifically, the virtual components could be improved if project designers provided more connections as to how the live visits and interactions on the VLC could be used to promote more than just science inquiry skills and knowledge. They also requested more support as to how the live visits and interactions on the collaborative site interface with the Common Core State Standards (CCSS).

Classroom management issues could exacerbate the challenges with the virtual visits. Scientists did not always interact in an engaging way with the students; alternatively, students did not always engage with the scientist. With this in mind, it was suggested that more training and preparation for the visiting scientist could improve this process. These trainings could focus on expectations and provide the scientist with a protocol or procedure to follow. Additionally, this would give teachers a model of a successful visit. Providing teachers with insight into ways to set-up their classroom appropriately for the live and best prepare their students for interacting with the scientist.

Finally, teachers, coaches and university faculty were all learning how to effectively use on line video conferencing. This technology was seen as a barrier to developing personal communication. However, as all the participants adapted to the technology, we found its usefulness in time saving and effective communication. For example, the next steps will be to practice online video skills between all participants, such that these important skills are developed prior to classroom interactions. As more and more PD opportunities are in the virtual realm, we will prepare teachers to effectively tap these resources.

LIMITATIONS AND FUTURE RESEARCH

It should be noted that several limitations of this study restrict the generalizability of the results. First of all, findings from this study and interpretations of those results are based somewhat on self-reported data. Although the determinations about the types of teaching modalities teachers incorporated to structure the visits were based on the observations and analyses of the research team, teachers were responsible for sharing their own perceptions of how the virtual visits impacted inquiry –based teaching and learning in their classrooms. Participating teachers could simply be responding to the questionnaire based on how they think we expected, or hoped, they would respond. Although the responses appear at face value to be candid and honest, it is important to note that as with any self-reported data there is risk that systematic bias could influence the participants' responses. Secondly, results should be triangulated with quantitative data on students' science content knowledge to determine if students experienced any quantifiable learning gains from the treatment beyond the teachers' observations about student engagement and collaboration. Teachers reported that, in certain circumstances, they witnessed changes in other aspects of learning like vocabulary used, engagement, inquiry and question asking. But determining whether or not the intervention impacted students' science content knowledge remains unanswered.

Based on these shortcomings, a primary recommendation for future research includes coupling analysis of virtual visits with analysis of students' science content knowledge to determine if any significant gains in science knowledge can be determined. Recommendations for further studies also include the development and integration of a valid and reliable instrument to study quality of the teachers' virtual collaborations. More specifically, it is suggested that project designers develop a comprehensive evaluation tool to study the teachers' online discussion board conversations and the work in the virtual science forums/classrooms. Further, we recognize the need to systematize the training of teachers to conduct assessment of their students' digital interactions with the scientists. An investigation into whether teachers who receive more formalized preparation and training for the virtual visits report being more or less prepared for the visits than teachers who receive no or less formalized training would be prudent. And lastly, studying how the curriculum could be re-engineered to more adequately support teachers as they make connections toward the CCSS would be beneficial. With this in mind, project designers could provide teachers more help analyzing how the virtual visits can be used to address other non-science specific competencies like communication and writing.

CONCLUSION

When originally planning the design and delivery of the project curriculum, we considered how technology could be used to serve the following goals: 1) Deliver high-quality inquiry-based science content; 2) Serve the remote/rural nature of participants; 3) Deliver high-quality professional development for teachers. At the project's conclusion, it was evident that the technology certainly helped serve these goals. First of all, despite the technical hurdles, we were able to conceptualize and build a shared workspace that supported communication and collaborative activities between university faculty, scientists, and researchers and participating teachers and students. Most importantly, this shared workspace provided the distribution method and collaboration point for the energy modules. Secondly, the technology afforded us the necessary means to connect with all participants, including those in remote areas representative of many of the rural schools and districts in the state. And finally, the technologies we employed helped us deliver the high-quality professional development that accompanied the inquiry modules on alternative energies. Combined, these tools provided the means to support asynchronous and synchronous interactions and collaboration between all involved, resulting in an exciting and appropriate manner to support teachers and learners.

Overall, findings from this study indicate that some reported the virtual visits did impact their teaching practices and students' learning, but this depended largely on contextual factors. More specifically, findings seem to suggest that teachers' perceptions of the impact of the virtual visits varied depending on the grade level of students and the topic of the visit. We also were able to determine that there was some consistency and structure present to the ways in which the participating teachers generally integrated the virtual visits. And further, each of the modalities provided affordances that strengthened the students' learning experiences. With further research and based on the lessons learned in this smaller study, the virtual-visits pedagogy holds considerable promise as a mechanism to support the delivery of high-quality inquiry-based science content, serving remote constituents in the process, while at the same time delivering high-quality, collaborative professional development for teachers in an innovative manner.

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