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Using cloud-computing applications to support collaborative scientific inquiry: Examining pre-service teachers' perceived barriers to integration

Utilisation d'applications infonuagiques pour appuyer la recherche scientifique collaborative: examen des obstacles à leur intégration tels que perçus par les futurs enseignants

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Abstract

Technology plays a crucial role in facilitating collaboration within the scientific community. Cloud-computing applications, such as Google Drive, can be used to model such collaboration and support inquiry within the secondary science classroom. Little is known about pre-service teachers' beliefs related to the envisioned use of collaborative, cloud-based technologies. These beliefs may influence future integration. This study finds several first-order barriers, such as perceptions that these tools would take too much time to use. Second-order barriers include perceptions that this technology would not promote face-to-face collaboration skills, would create classroom management challenges, and beliefs that the technology does not help students understand the nature of science. Suggestions for mitigating these barriers within pre-service education technology courses are discussed.

Résumé

La technologie joue un rôle essentiel pour faciliter la collaboration au sein de la communauté scientifique. Les applications infonuagiques telles que Google Drive peuvent être utilisées pour donner forme à ce type de collaboration et pour appuyer le questionnement dans les cours de sciences du secondaire. On connaît pourtant peu les opinions que se font les futurs enseignants d'une telle utilisation des technologies collaboratives infonuagiques. Or, ces opinions pourraient influencer l'intégration future de ces technologies en salle de classe. Cette étude révèle plusieurs obstacles de premier plan, comme l'idée que l'utilisation de ces outils informatiques prend trop de temps. Parmi les obstacles de second plan, on note les perceptions selon lesquelles cette technologie ne promeut pas les compétences collaboratives de personne à personne, pose des problèmes de gestion de classe et n'aide pas les étudiants à comprendre la nature de la science. Des suggestions sont proposées pour atténuer ces obstacles dans les cours de technologie des programmes d'éducation.

Introduction

Science education reform documents call for students to learn and do science in ways that are similar to authentic scientific research (AAAS, 1993; Duschl, Schweingruber, & Shouse, 2007; NRC, 1996). Students are to engage in scientific practices through investigations in which students ask questions, make hypotheses, collect and analyze data, and create and defend conclusions (NRC, 2011). Within these guided and open-ended inquiry investigations (NRC, 2000), students are to collaborate and engage in conversations with their peers to create a community of discourse that participates in evidence based arguments (Duschl, Schweingruber, & Shouse, 2007).

Peer-based collaboration closely models the nature of science in which scientists work (NSTA, 1999; University of California Museum of Paleontology, 2011). Scientists work in collaboration in a variety of aspects of their work including the development of studies, the analysis of data, the building of theory and providing peer feedback. Collaboration can often take place at a distance. Information and communication technologies play an increasingly crucial role in facilitating such collaboration within science (Olson, Zimmerman & Bos, 2008). Technology helps facilitate the collaborative sharing and analysis of data (e.g. Biomedical Informatics Research Network) and for experiments to be run remotely (e.g. Upper Atmospheric Research Collaboratory). On smaller scales, groups of scientists use publicly available online tools for communication and collaboration.

Science education reform documents have long called for the use of technology not only to support scientific practices but also to model the distance-based interactions between scientists. For example, the National Science Education Standards call for the use of technology not only to improve investigations, but to also improve communication between students (NRC, 1996). Additionally, the National Science Teachers Association (1999) calls for the use of technology for networking to "emulate the way scientists work" (p. 1) and encourages collaboration with students over distances, thus, reflecting the nature of scientific research. More recent reform calls, such as the National Research Council's Framework for Science Education (2011) suggest that students should "use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables" (p. 63) to support learning of science concepts. Outside of science education, the NETS-S (ISTE, 2007) supports the call for the use of collaborative technologies for student learning through "us[ing] digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others" (Standard 2. Communication and Collaboration). Using collaborative technologies can help support collaborative inquiry within science education and can help model how scientists use technology.

There are a number of cloud-computing tools that can be used to support collaboration within and outside of science classrooms. Public cloud computing tools that can be accessed online anytime and anywhere through a central data center allow for the creation, editing, and storing of products online (Armbrust et al., 2009). There are several free cloud-computing office application suites that allow for online document, spreadsheet, and presentation creation (e.g. Google Drive, Zoho, and MS Office Web Apps). Many of these tools provide asynchronous and synchronous collaboration in which artifacts may be co-constructed, and offer online peer feedback and discussions features. These tools have the potential to afford collaboration not only within the classroom between students working on teams (e.g. seeing real time what others are discovering and to provide feedback on the discovery), but also collaboration beyond the classroom (e.g. between groups of students in different classes or outside experts). The use of cloud-computing tools can also help promote the development of a discourse community within the science classroom.

Barriers to Integration

Although technology holds great promise to improve student learning of science (Webb, 2008), the implementation of new technologies in the classroom has been met with hesitation by science teachers (Gerard, Varma, Corliss, & Linn, 2011; Guzey & Roehrig, 2009; Yerrick & Hoving, 1999). Some posit that barriers, both external and internal, have led to limited technology integration (Ertmer, 1999). Teacher education has been called upon to help mitigate these barriers.

Models of pre-service science teacher education have been developed to promote technology integration (Darling-Hammond & Bransford, 2005; Flick & Bell, 2000; National Science Teachers Association, 2003). Although these models have started to be implemented, they have shown limited success in helping pre-service teachers remove barriers to using technology, such as cloud computing tools, in their practice. Studies have shown that pre-service teachers are hesitant towards using technology with inquiry pedagogy (Friedrichsen, Dana, & Zembal-Saul, 2001), do not understand key concepts to appropriately implementing technology (Niess, 2005), and cannot envision new ways of using technology in their future classroom (Doering, Hughes, & Huffman, 2003).

Yet, little is known about pre-service teachers' barriers, beliefs, or envisioned use of cloud computing applications to support collaborative, inquiry-based pedagogy. Understanding beginning teacher's beliefs and perceptions will help inform methods courses in order to reduce these barriers to implementation and better prepare beginning teachers to integrate technology in meaningful ways (Hew & Brush, 2006). The purpose of this study was to identify pre-service science teachers' perceived internal and external barriers to using cloud-computing technologies to support inquiry-based pedagogies.

Theoretical Framework

The data from this study are framed by the literature on barriers. Ertmer (1999) posits that either first-order or second-order barriers can hamper meaningful technology integration. First-order barriers relate to external issues like lack of equipment, time, support, or training. Any number of first-order barriers must be overcome before successful implementation can take place as they can frustrate the teacher and prevent the use of technology in the classroom. Even if all first-order barriers are removed, the second-order barriers can prevent implementation. Second-order barriers are more internal and directly relate to teachers' beliefs about the role of the teacher, appropriate pedagogical practices, and the role of educational technology in their curriculum. These second-order barriers are more difficult to overcome due to their personal nature and may prevent meaningful use of technology.

Technology, Pedagogy, and Content Knowledge (TPACK) (Mishra & Koehler, 2006) also helps to frame this study. Teacher TPACK knowledge guides the use of particular technologies to teach particular science concepts using science pedagogies. The barriers related to the use of cloud-computing technologies within science education may be different than barriers related to other technologies used in science education such as probeware and simulations, and are likely different from barriers to using similar technologies in different content areas (e.g. Mathematics). Therefore, it is important to understand barriers related to the integration of cloud-computing applications from a content specific lens.

Study Context

The data for this study are derived from a technology integration course for pre-service science educators at a large midwestern university in the United States. Pre-service teachers are enrolled in a post-baccalaureate program, usually upon completion of an undergraduate degree in a specific science area. The course takes place in seven three-hour face-to-face sessions with additional online learning activities. This course is taught fall semester concurrently with a middle school science methods course and a field experience course in which participants observe and teach several lessons. In the following spring, the pre-service teachers student teach.

The course design is based on the technology integration model for science education (Flick & Bell, 2000). Flick and Bell's model suggests that technology used within methods courses should be introduced in the context of science, should take advantage of the unique features of the technology, should make scientific views more accessible, and should develop understandings of the relationships between science and technology. The objective of this course is to prepare teachers to thoughtfully integrate technology within standards-based science instruction to enhance the teaching and student learning of specific science content in specific contexts. The course asks participants to explore how, why, and when might we facilitate student use of educational technology to help support their deep learning of specific science concepts and processes? The broad goals of this course are to: 1) foster beginning teacher technological, pedagogical, and content knowledge (Mishra & Koehler, 2006); and 2) have participants justify the use of and thoughtfully integrate specific technologies within research-based science instruction to enhance student learning of specific content.

Each course module explores a different technology that can be used within secondary science education. Primary technologies include online simulations, concept mapping software, cloud-computing tools, online multimedia development tools, and probeware. Participants also develop a vision for integrating technology and integrate technology into a lesson within their middle school field placement (For more information on course design see http://edhd5007.sites.google.com).

Technologies in the course are taught using a learning cycle model: participants *Explore* the technology; *Extend* their knowledge through dialog, readings and develop authentic artifacts of practice such as lessons and assessments that integrate the technology in question; and *Reflect* on the use of the technology in their future practice.

The participants first explore technology by engaging in free investigation of the technology for a brief period of time. The instructor then models the use of the technology use within science education in a lesson designed for adult learners to prompt discussion related to implications for teaching and learning. In the case of the cloud-computing module, participants are engaged in an inquiry investigation in which technology is used to support synchronous and asynchronous collaboration. The lesson has participants explore scientific concepts related to seed dispersion. A paper helicopter (see http://www.nasa.gov/pdf/205711main_Rotor_Motor.pdf) is used to model a samara seed (i.e. maple seeds). Google Drive tools such as Documents, Spreadsheets, and Presentations are used. Google Drive tools were chosen as the modeled technology as many K-12 schools have begun to adopt the use of the Google suite of productivity applications.

Cloud-Computing Artifact - Google Drive Lesson

1. Title of lesson:
2. Describe **the context** in which you would use this lesson:
3. What class would you use this with?
4. What unit would you use this with?
5. What Academic Standards would be aligned with this activity? (Justify at least 2)
6. What NETS-S Standards would be aligned with this activity? (Justify)
7. Where in the learning cycle would this fit? (Choose 1 and briefly justify)
    a. Investigation Activity – Students explore the concept through a guided investigation
    b. Clarification Activity – Teacher leads instruction to make sure students understand concept
    c. Application Activity – Students use the concept in a novel situation
8. What science practices will lesson this support? Choose all that apply and justify at least 2.
    a. Asking questions
    b. Developing and using models
    c. Planning and carrying out investigations
    d. Analyzing and interpreting data
    e. Using mathematics, information and computer technology, and computational thinking
    f. Constructing and critiquing explanations
    g. Engaging in argument from evidence
    h. Obtaining, evaluating, and communicating information
    i. Applying and using scientific knowledge (i.e. engineering)
9. Briefly describe a lesson that uses cloud-computing tools (e.g. word processing, spreadsheets, presentation, drawing) that students use to work collaboratively (either synchronously or asynchronously) to support some component(s) of inquiry. The data could be student collected or could be generated elsewhere (e.g. historical or real time data sets). If you are using an existing lesson, please cite the source of the lesson. Include a sample Google Drive artifact.

Figure 1: **Cloud-computing Lesson Template**

Within the seed dispersion lesson, the participants first engage in an activity to explore the factors that influence how much time it takes for a paper helicopter model to land. Participants work from a single Google Document to brainstorm factors that they think would influence the time for the model to hit the ground in an instructor led, large group activity. Participants then use another Google Document within their cooperative learning base groups to develop questions, tentative predictions, hypotheses, and procedures to explore a variable they would like to investigate. Participants work from a single class document that has different table rows for each base group. This allows them to see other participant's study designs and to use the commenting tools to provide feedback to other groups as well as to receive feedback from the instructor. Participants then carry out the experiment and analyze data using the Google Drive spreadsheet application. Outside of class, students work asynchronously to develop a presentation that explains their results and prepare to present their work during the next class session. The activity and its implications for teaching and learning are also discussed during the next class session.

During the *Extend* phase, participants also read literature related to the technology and engage in face-to-face and asynchronous online group discussions. In the case of the cloud-computing module, participants read an article that explored how inquiry can be done using online data sets (see Bodzin & Cates, 2002). Also in the Extend phase, participants create an artifact that shows how they would integrate the technology to support the learning of a specific concept. In the cloud-computing module, participants develop a lesson that they could use within their practicum experience, student teaching, or future classroom teaching. In their lesson they design an activity that incorporates inquiry, cloud-computing tools, and peer collaboration to teach a specific concept (See Figure 1).

Cloud-Computing Reflection

1) Consider the affordances of using cloud-computing to support student learning in your specific content area. Provide examples on how this technology can:
- Support your teaching strategies
- Support student understanding of concepts and processes
- Support student development of digital literacy
- Support student engagement

2) Consider uses of cloud-computing to support student learning of particular concepts and/or processes. Provide examples on:
- How this technology could be used by individual students or groups of students
- How this technology could be used by you for whole class instruction

3) Consider the limitations of using cloud-computing. Provide responses to the following prompts:
- The limitations of using this specific type of technology
- The barriers you may face in integrating this specific technology and ways you might overcome these barriers

Figure 2: **Reflection Prompts**

In the Reflect phase, participants write about their experiences using the technology and begin to think about the how's, why's and why not's of using a particular technology. Figure 2 shows the questions that guide participant reflection. The cloud-computing module reflection pushes participants to think about the broad use of cloud-computing tools within their specific content area (e.g. Life Science, Earth / Space Science, Physics, and Chemistry).

Of particular interest for this study is the third set of reflection questions, which relate to the limitations and barriers towards integrating specific technologies.

Methods

This qualitative study uses inductive approaches for data analysis (Miles & Huberman, 1994) to explore the individual participant (n = 96) reflections from the cloud-computing module. Data for this study included cloud-computing performance task reflections from classes taught in 2007, 2010, 2011, and 2012. To begin the process of coding, reflections were read one at a time, focusing on statements that could be classified as first or second-order barriers. First-order barriers relate to external issues like lack of equipment, time, support, or training. Second-order barriers are more internal and directly relate to teachers' beliefs about the role of the teacher, appropriate pedagogical practices, and the role of educational technology in their curriculum. Later, sub-codes were developed when similarly coded items displayed nuances that elicited further refinement. As new statements were identified, internal consistency checks were performed to ensure statements continued to fit within existing coding structures. From coded data, quotations were selected as representative examples to provide greater validity and a rich description of the perspectives pre-service teachers have concerning technology integration. Additionally, analysis of final course papers, cloud-computing technology integration lessons, and group discussions within the online environment and within face-to-face meetings provided triangulation of data. Finally, both authors coded data and came to an agreement on code definitions to promote reliability.

Results

First-order Barriers

Data analysis identified pre-service teachers' perceived barriers to using cloud-computing technologies in their future classroom. First-order barriers are related to extrinsic beliefs that are perceived to be beyond the teachers' control. First-order barriers towards integrating cloud-computing tools included concerns that:

- cloud-computing technologies are not as good as other products;
- it is difficult in schools to get access to hardware and robust networks to use cloud-computing tools;
- it may be difficult for some students to access to cloud-computing tools outside of school;
- cloud-computing tools would take too long to use; and
- students would have different abilities in using cloud-computing tools.

Technology

Participants expressed several first-order beliefs related to the Google Drive technologies. Participants noted issues related to the usability of the Google Drive environment, in particular around synchronous and asynchronous collaboration tools. For example, one participant states:

> To be truly honest, I would not use this type of computing in my classroom. I found that it was easier to communicate with my fellow project team members in person than to try to contact them via computer. There are far too many places to leave messages within these forums, and the expectation to check these forums for messages in a timely manner is unrealistic.

Other participants noted “bugs” they found within the system such as challenges of “text jumping around” during multi-user collaboration. Participants were also concerned about formatting issues within Google Drive, especially when compared to commercial, non-cloud based tools such as Microsoft Office. Other participants expressed frustration that these tools were not as easy to use when formatting final versions of documents when developing or exporting.

Finally, many of the concerns of Google Drive technology centered on the spreadsheet tool and it’s lack of advanced data analysis features. One participant noted these limitations :

> For example, while we were making our graph we couldn’t put in a best-fit line with a slope value. It has limitations that could be critical when analyzing data. It should only be used for basic documents.

Many participants expressed similar concerns about the lack of the best-fit line features stating that other tools were far superior for science education use such as Microsoft Excel. Many students had used tools like Excel within their content area course work.

Context

The second set of first order barriers relates to contextual concerns associated with school hardware and network resources at practice teaching placements or envisioned at schools in which they would work someday. Many of these observations were grounded through classroom observations or practice teaching sessions. These concerns related to a lack of reliable computers or networks at the school site, a lack of computer labs to bring students to, or a lack of mobile laptop carts to bring into their classroom.

Participants expressed concerns relating to the reliability of the school network and computers. One participant noted that:

> The quality of the [school] resources may also pose a problem as they may not be able to allow the students to access their documents. A slow connection may cause problems when opening or saving documents. To overcome this, I would need to be sure that the computers are highly functional before I would allow the students to use them.

Similarly, another participant states: “I think we all have been in a situation where our Internet is down. It would be very frustrating to not be able to work on something because it is saved online and you have no other copies.” Generally speaking, participants noted concerns related to having quality Internet connections, especially when collaborating.

Many of the barriers related to a lack of access revolved around participant perceptions of a lack of funding for some schools. Participants were concerned about the availability of classroom computers or of computer labs to bring students to complete project steps such as data analysis. Some participants noted these barriers and posed potential work around options. For example, one participant noted that:

> Having at least one computer for each group is usually sufficient for completing tasks. However, if each student can have a computer available then student engagement will increase; they will each be able to contribute instead of one person writing everything that the rest of the group says.

Another participant response suggests that barriers related to the access to computers in the classroom might be mitigated by:

> Having students record their data the old fashioned way, with pen and paper, and then uploading all of their data at the end of the class period on a classroom computer can work around this limitation, however, the emphasis on the technology is greatly diminished.

Additionally, one participant noted the challenges of using this technology within a laboratory-based experience when they stated:

> The limitation that I see to this specific type of technology is the necessity for students to record data at their lab stations and then move to another area to submit it. Typically in most high school chemistry labs there is not an area for computers and it is not safe to have [computers] nearby due to the high probability of spills or accidents. Therefore students would either need to leave their station to input the data in a piecemeal fashion or submit it at the end of the investigation. Generally speaking, a limitation is access to this information in some school settings.

A perceived lack of school-based access was a limiting factor in teacher's willingness to use Google Drive within their classrooms.

Access

The third first-order barrier that pre-service teachers shared relates to student access outside of the classroom. Within this barrier, participants were concerned about the implications for student learning with assignments that require collaboration outside of the classroom. While many participants suggested ways to overcome these barriers by either focusing collaboration within classroom time, or getting students access to labs outside of school, or having them go to computer labs within libraries, they did note that this can be a burden on students and may be unfair. For example, one participant reflected on their current practice teaching placement and the use of an online textbook:

> While there are libraries with computers and a computer lab at school, students may not always be able to use these resources and we would then be punishing these students because they would not be able to participate in the group projects the other students are participating in. At the same time I realize that by not using technology with these students we are also making their lack of understanding of these tools worse, so I would have to weight those two sides of the issue.

Another participant noted that:

> While remote collaboration is one of the things that makes cloud-computing so valuable, it also presents a problem for those students who don't have a reliable Internet source outside of the classroom. I think that most students could probably find a location where they could get Internet time, the problem being that this takes away from the convenience of the technology. Whereas some students might be able to access the technology from the comfort of their bedrooms, other students will have to go out of their way to find the access to contribute. This is a tough situation to be in as a teacher. Before assigning homework involving the Internet I would have already had my students fill out an exit-slip on whether they have reliable Internet access. If it turned out that I had a student without it, I could either try and provide it at school, or only have the students use cloud-computing technology in school. The problem with the first solution is that it would take away some of that students free time. This doesn't seem like a fair solution to me. The problem with the second solution is that I don't think it emulates how students will use this technology in the future.

Participant beliefs related to a lack of outside of school access were a limiting factor in their willingness to integrate cloud-computing technologies.

Time

The next first-order barrier relates to concerns about the time it would take to use Google Drive. These barriers include perceptions that either teaching or using this tool may take away time from learning science content. For example, one participant expressed:

> Teachers mention a lot how there is never enough time to cover everything they want to during the school year - whether they teach just the information for the standards or include extra information and activities. Since I haven't really taught a full year before, I don't know if this will be the case for me, but I could see myself wanting to teach the content instead of teaching my students how to use these tools. However, if the students were taking a computer or technology class where they learn how to use these tools, then I would be more likely to have them use it because it wouldn't take time away from my life science curriculum.

Other barriers related to time include beliefs that other tools are more efficient. For example, one participant relayed that, "sometimes it is just more convenient to use traditional pen and paper," while another participant noted that giving time to use Google Drive tools in class "would also take more time away from teaching them life science content, and it wouldn't make using the technology any better than just having the students make a poster or PowerPoint presentation instead." Another participant expressed:

> It may seem like unnecessary use of technology if teachers are not creative about how it is used. For example, if students only use it to enter data, make graphs, and type up a paper individually, these same actions could be done by hand or using Microsoft Word products.

While time concerns were common barriers towards integration for many of the course technologies, these barriers highlight the value participants place on time spent on learning core science concepts.

Student ability

The final first-order barrier relates to concerns over students' abilities to use tools such as Google Drive. These concerns are related to beliefs that students will have varying degrees of digital literacy. For example, one participant noted:

> I think that it is important to recognize that while most students are computer savvy, not everyone is at the same level. Thus, it would be a barrier for teachers to assign a project using cloud-computing technologies and assume that every student knew what they were doing.

Other participants expressed the importance of assessing where students are at with their understanding of these tools before beginning. For example, one participant noted: "teachers must teach students the unique aspects of cloud-computing tools such as the synchronous collaboration, discussion, peer review, and publishing to add value to it."

Other participants noted that students with special learning needs such as a disability or English Language Learners would require additional accommodations. One participant indicated that, "for ELL students who struggle with English in the first place, having them manipulate a highly involved program such as Google Docs (and its sibling programs) will only slow their progress further, likely leading to frustration or disengagement." Participant understanding of student abilities is somewhat related to the barriers associated with time. For example, students without skills or requiring accommodations may call for additional support to fully integrate these technologies.

Second-order Barriers

There were several second-order barriers identified by the participants. Second-order barriers are intrinsic and are primarily based on beliefs about using the technology within classroom instruction. Second-order barriers for integrating cloud-computing tools include:

- cloud-computing tools limit student development of face-to-face collaboration skills;
- cloud-computing tools do not support the teaching of science concepts and processes;
- cloud-computing tools make the management of group learning difficult; and
- cloud-computing tools create classroom management issues.

Science content

Participants shared beliefs that cloud-computing technologies will not help support students in learning science content or support the understanding of the nature of scientific research. For example, one participant noted that, "I don't really see this actually supporting student learning of science concepts and processes, and other than the spreadsheet, it isn't really engaging them in authentic uses of technology within science." Other participants did not see the value of these tools within their particular content areas. One participant noted: “One reason I might consider not using the cloud-computing tools in my classroom is that they don’t necessarily directly pertain to the content I will teach in a life science classroom.” Other participants suggested that the tools themselves do not have merit to teach science. For example:

> Cloud-computing does not have actual scientific content itself. Thus, it must be used in conjunction with other activities, such as an experiment conducted by students. As a result, teachers must be purposeful in their use of cloud-computing as a tool to aid in the development of scientific concepts and students’ engagement with inquiry by keeping a clear goal in mind.

This second order barrier highlights that decisions teachers make when integrating technology relate to the value of the technology in supporting content area learning.

Face-to-face collaboration

Participants were also concerned that the use of cloud-computing technologies in their classroom would limit face-to-face collaboration. Some participants were concerned that this type of technology would limit student’s abilities to learn to work collaboratively in a group through verbal communication. For example, one participant noted:

> I think another drawback is that students are not working face-to-face with other students. This reduces social interaction time with group members, which is often an important factor for a group to work well with each other. Communicating through this technology does not allow for nonverbal communication, which is important when interpreting [and] perceiving the context of comments. This would be one of the major reasons why I might not use this technology in my classroom.

Another participant shares their fears of completely online instruction through the use of these tools:

> This technology starts to walk the scary line of becoming completely computerized. It might be easier, and possible, for a group to do an entire project without ever getting together face-to-face, but is that a good thing? Call me old fashioned but I still think there is a lot to be said for a student with good people skills.

This second order barrier highlights teacher beliefs related to their vision for collaboration within collaborative group inquiry.

Group management

Participants shared many concerns related to the management of collaborative groups. Within this set of barriers, concerns emerged that related to the structuring of group work, assessing individual contributions, and individual student effort. One participant captures these concerns by stating:

> Work done in this fashion is fairly opaque to the teacher. The teacher never really knows who contributed what to the conversations or to the actual products. Group work in class is much more transparent and on paper even more so as the teacher may recognize handwriting.

Another participant speaks to the concerns related to assessment of individual contributions when they stated:

> Social loafing is another issue that comes along with any sort of activity that involves collaboration. In collaborative groups--especially on digital projects that are turned in without recognition of who produced each piece--some students may contribute more to the final product than others.

This second order barrier highlights beliefs related to the pedagogical challenges of fostering healthy group collaboration within their envisioned science classrooms.

Classroom management

In the final second order barrier, participants express concerns related to classroom and student behavior management. In this barrier, participants were concerned about the potential distractions caused through the use of these tools, the potential for vandalism of other group member's work, and potential cheating. One participant reflects on the potential for distraction in the following comment:

> Another limitation that I foresee and have witnessed is that students may abuse the opportunity to use this technology in class. When I was student-teaching, the teacher provided laptops for the students to write an assignment via Google Docs. Rather than work on their assignment, the students shared the assignment with each other and were distracted by the chat feature during class.

Other participants noted that if groups are all working from the same document there is potential for inappropriate comments on other group's work. Participants expressed concerns such as:

> There could also be issues of students making inappropriate comments on the shared documents. I would want to keep comments anonymous to the students to encourage the quiet students to add comments, however, I would want to watch who is leaving which particular comments.

There was also concern around the potential for cheating. A participant noted the tension between collaboration and cheating when they stated: "It would be difficult to eliminate cheating using cloud-computing, when the very idea of this technology is collaboration." This set of second order barriers differs from group management and speaks to perceived barriers related to managing student behaviors while using collaborative technologies.

Discussion

This study suggests that there are several perceived barriers that pre-service teachers hold towards integrating collaborative cloud-computing applications in secondary science classrooms. The first-order barriers related to design issues such as bugs and a lack of critical features will potentially be lessened as cloud-computing applications continue to be refined with new features and enhanced usability. Infrastructure related issues associated with school and home contexts will also likely be mitigated over time as those venues and the technological tools therein become more robust and home access through mobile devices increases. Barriers related to the time for students and their instructors to learn and to use cloud-computing technologies may continue to be a challenge, as they have been historically, when facing integration of technology (Hew & Brush, 2006). To accommodate concerns related to time, methods instructors should help pre-service teachers think about the use of appropriate technologies in the context of particular content. In addition, methods instructors help facilitate conversations related to systematic use of chosen technological tools and to not view these tools as single use for a specific topic. These tools' potential can be realized when integrated throughout an entire course or as part of a scope and sequence in a school district where cloud-computing tools are used to support scientific collaboration in increasingly sophisticated ways.

Of particular interest in this study are the second-order barriers. The concerns related to how technology does not promote face-to-face collaboration indicates that pre-service teachers are not making connections to the collaborative work done by scientists that is facilitated by technology, or may not see value in modeling such practices in their classroom. To address this barrier, methods instructors should provide explicit experiences in the role that technology plays in modern scientific collaboration within their specific content area towards development and refinement of technological content knowledge. For example, participants could be asked to perform research in their particular content area around how technology is used for collaboration (e.g. Human Genome Project in Biology and the Large Hadron Collider in Physics). In addition, authentic science experiences completed prior to entering pre-service education programs in which they use collaborative technologies will help reinforce the development of technological content knowledge and will promote authentic practices within these future teachers' classrooms (Windschitl, 2003).

It is interesting to note, that for some participants, the use of these tools does not warrant replacement of low-tech approaches to collaborative inquiry despite the potential technological and social affordances of cloud-based tools that can promote collaboration (Kirschner, Strijbos, Kreijn, & Jelle Beers, 2004). Methods instructors should facilitate understandings of the social, educational, and technical affordances of cloud-computing tools to see how they can support collaborative scientific inquiry in the classroom and mitigate second-order barriers. However, it is as important to help participants to think about the potential group and classroom management challenges and ways that they may begin to think about structuring their classroom environment and expectations to help resolve these potential challenges.

It is also interesting to note that many of the barriers, although in the context of science, may be just as applicable to other content areas. Methods instructors should help pre-service teacher candidates focus their exploration of barriers from a TPACK frame. This will help them think more specifically about challenges they may face within their particular classrooms in teaching particular topics and how participants might address some of the issues before they arise.

Future research should explore the connections between teachers' domain (e.g. Life Science) and topic level (e.g. Cellular Structure) TPACK as it relates to perceived second-order barriers to identify if different domains have specific barriers. Additional research might explore how these perceived barriers change as a result of clinical experiences in which these teachers integrate technology into their middle school field experiences and within student teaching experiences. This practice would also be supportive of findings that suggest job-embedded professional development models for integration of technology that lead to higher rates of technology integration (Gerard, et al., 2011). Finally, web-based educative curricular resources that can guide teachers in selecting and adapting existing activities to integrate technology will help scaffold beginning teachers in developing and implementing instruction that thoughtfully brings collaborative cloud-based tools into standards and research-based science classroom practice (e.g. http://3Ring.org).

Conclusions

This research study identified first and second-order barriers to using cloud-computing technologies perceived by pre-service science teachers for the purpose of teaching scientific inquiry with collaborative tools. This study also suggests additional research and models for pre-service teacher education that will help mitigate these barriers. However, additional research that leads to pre-service instructional models that can help teachers thoughtfully integrate cloud-computing technologies by helping mitigate barriers, may ultimately be unsuccessful if teachers do not hold beliefs consistent to reform based science education (Ertmer, 2005). If teachers do not value the use of pedagogies that collaboratively engage students in scientific inquiry, nor see value in helping students understand the nature of scientific research, they may not value the use of cloud-computing tools to support these instructional approaches.

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