Maintaining Scientific Inquiry In Online Education

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Abstract

Teachers were given the challenging task of transferring their formal science classroom lessons to an online format at the onset of the COVID-19 pandemic. How were teachers able to recreate student-centered science lessons online? What challenges did teachers face in teaching science online? This study examined how a group of teachers, working to create a summer online science camp, were able to maintain a science inquiry-based learning environment in an online format. Teachers revealed positive attitudes toward producing a scientific inquiry-based learning environment online, new opportunities for creativity in teaching science, and different perspectives on how teachers interact with students.

Keywords: inquiry-based learning; online instruction

Introduction

Teachers are responsible for and strive to provide meaningful educational experiences for their students. However, at the onset of the COVID-19 pandemic, and as schools began closing, teachers were left to their own devices to determine how to provide similar meaningful educational experiences online. In addition to the sudden change to online instructional methods leaving school districts and administrations unable to provide adequate support to teachers and students, it also raised concerns about the effectiveness of teachers teaching online as many of them had little to no previous online teaching experience.

Students who spend more time in the classroom succeed academically at higher rates (Tinto, 2003). The student learning experience is enhanced not only by closer contact with teachers, labs, and classrooms, but also by in-person interactions with other students. Thus, disciplines that require a more hands-on, in-person educational experience have become a focus of concern, as students might not achieve similar learning outcomes in an online environment. Specifically, in science classrooms and labs where equipment and technology necessitate in-person

attendance, questions have been raised about how to emulate scientific inquiry practices in an online format.

This study investigates how a group of pre-service and in-service classroom science teachers sought to establish science inquiry practices in a week-long online learning science camp for middle school aged students. The challenges and shared experiences will provide insight for science teachers, and general teachers alike, looking to better prepare themselves for teaching in an online learning environment. Furthermore, the findings from the study will broaden the discussion of how best to implement science inquiry-based learning through an online learning format and examine what role might distance learning play in tandem with a traditional science classroom experience.

We sought to address the following research questions:

1. How were teachers able to maintain a science inquiry-based learning environment in an online format?
2. What barriers were presented and how were they addressed in creating a science inquiry-based learning environment in an online format?

Framework

The case study we examined in detail to answer these questions focused on a group of pre-service and in-service classroom science teachers teaching in an online learning science camp. These teachers taught in traditional classrooms at a variety of different middle and high schools in a normal academic calendar year, but due to COVID-19 were forced to move their instruction to online formats. The science camp, held after the school year concluded, was an opportunity for the teachers to collaborate, plan, and explore teaching online in a more informal manner. As we chose to focus this case study on these science teachers, we turned to inquiry-based learning as a framework for understanding how they created a scientific learning environment online.

Inquiry-based learning is a teaching and learning approach that emphasizes students' questions, ideas, and observations (Abdi, 2014). Furthermore, students working within an inquiry-based learning environment mimic behaviors displayed by those in the scientific community (Keselman, 2003) constructing scientific knowledge through a process of asking questions, conducting experiments, making observations, and formulating conclusions (Pedaste et al., 2015). With the recent focus shift to online learning, educators are curious to know how teachers can maintain an inquiry-based learning environment where their students are focused on being active

discovering knowledge that is new to them (de Jong & van Joolingen, 1998). How teachers recreated an inquiry-based learning environment online was investigated in this study.

Students engaged in inquiry-based practices of seeking explanations by asking questions, having direct interaction with the natural world, and collecting and analyzing data to explain scientific phenomena (HarlEn, 2013) report higher learning outcomes compared to students who experience more teacher-centered direct instruction lessons (Granger et al., 2012). Furthermore, students engaged in inquiry-based learning show increases in problem-solving skills (Avsec & Kocijancic, 2014), are more active in their learning (Zafra-Gómez, Román-Martínez, & Gómez-Miranda, 2015), and express more positive attitudes toward science and scientific oriented careers (Gibson & Chase, 2002). While student outcomes are not the focus of this study, establishing an inquiry-based environment that could possibly lead to these positive outcomes is.

In classrooms, educators seek to enhance the inquiry process and maximize student development of observation, measuring, experimenting, reasoning, and other science processing skills. It is presumed that similar efforts are sought after in online instruction. When COVID-19 pandemic appeared, teachers were suddenly faced with the issue of maintaining a similar classroom experiences, upholding expectations and standards, but through an online teaching medium. How were teachers able to maintain student-centered, inquiry-based learning in an online format? What strategies were used by teachers to maintain active, scientific knowledge construction in an online format? These are just some of the questions investigated in this study.

Methods

A qualitative case study analysis was used to explore and understand how a group of science teachers normally teaching in traditional classrooms were able to create an inquiry-based learning environment in an online setting (Stake, 1995). We searched for matching patterns between the teachers' shared experience and their students constructing scientific knowledge through asking questions, conducting experiments, making observations, and formulating conclusions, as is seen often in case studies (Yin, 2009). It is important to note that we, the authors, are former public-school teachers with experience teaching science and mathematics at the 6-12 grade levels. These experiences provided us with a working knowledge and understanding of inquiry-based learning. However, none of us had experience teaching online middle or high school science prior to this study. This status allowed for a more open-minded approach for considering the challenges the teachers faced in this study.

Participants and Settings

The purpose of the summer camp was three-fold. First, it provided out-of-school hands-on science and mathematics learning opportunities for middle school aged students. Second, it created opportunities for teachers to explore new pedagogical approaches and lessons of teaching in a more informal environment. Finally, the camp was used as a method of recruiting science, technology, engineering, and mathematics (STEM) undergraduate majors from a nearby university to be interns, with the long-term goal of incentivizing them, through scholarships, to enter the teaching profession. The camp attracted, on average, close to 150 middle school students each year, with 160 students participating in the online camp version.

The overall structure of the week-long summer camp, funded by a National Science Foundation NOYCE grant, had small groups of students rotating classrooms every hour where they were exposed to several science and mathematics lessons each day. A similar format was implemented during the COVID-19 year of this study. However, in place of physical rooms, online Zoom conferencing rooms were created. A series of four science and four mathematics Zoom rooms were established with each student visiting four science lessons and four mathematics lessons each day. Each Zoom room was led by four educators: a veteran in-service teacher, acting as the lead teachers, and combination of three novice in-service teachers, pre-service teachers, or interns. At the time of the COVID-19 pandemic emergence, the pre-service and in-service teachers involved in the camp had various years of experience teaching middle and high school science and mathematics ranging from one semester of student teaching to 21 years in the classroom. All interns were STEM undergraduate majors with no classroom teaching experience. The summer camp was normally held at a middle school located on the outskirts of a small city in a Gulf Coast state. Although the camp converted to an online version during the year of this study, the teachers and the majority of students resided in the same Gulf Coast state.

Concentrating on the science Zoom classrooms, as is the focus on this study, the science teachers and interns decided on designing science lessons around an outer space theme for their rotating classrooms. Mars rover landing, planetary ecosystems, water properties, and transportation were four lessons. The teachers and interns spent four weeks planning their lessons, meeting a couple times online as a whole group and several times online in their individual Zoom classroom groups. The Mars rover lesson involved applying chemical reaction knowledge to designing gear for a Mars rover landing. The planetary ecosystem lesson had students studying

various ecosystems on Earth and conditions on other planets. Students also studied properties of water and how its needed to sustain life on other planets. The fourth classroom had students studying physical aspect of motion as they designed a vehicle for transportation.

Data Sources and Analytic Approaches

Data were collected from one-on-one interviews of participating teachers the week after the online science and mathematics camp concluded. The four lead in-service teachers along with one first year in-service teachers and three pre-service teachers were interviewed for this study. This group of interviewees provided rich conversational data that highlighted efforts and challenges of creating inquiry-based learning environments in an online format (Polkinghome, 2005). The remaining eight educators were interns and were not included in this study. Pseudonyms were used for the names of pre-service and in-service teachers that participated in the interview process.

Interviews with teachers were conducted via online Zoom conference capabilities. Interviews were recorded and transcribed. The teachers were asked a series of open-ended questions beginning with the interviewee being asked to describe the science lessons their Zoom classroom group planned and taught. The interview continued by asking interviewees to describe how they created a science inquiry-based learning environment online, prepared for teaching online, and compared online instruction to their formal classroom instruction. The interview concluded by asking interviewees to give suggestions or advice to future instructors attempting to teaching science online. In addition, impromptu questions were asked to interviewees who shared tangential information or related experiences. These impromptu questions captured real time responses and reflections regarding their experiences attempting to create an inquiry-based learning environment online. Interview data collected was used to explain our research questions through our inquiry-based learning framework lens.

Our research questions and inquiry-based learning framework shaped how we coded for the teacher response and interview data. Coding resembled two factors that were the focus of this study: *creating an inquiry-based learning environment* and *challenges to teaching science online*. Coding for *creating an inquiry-based learning environment* involved combing the data for teachers discussing aspects of inquiry existing in an online format: students or teachers asking questions, conducting experiments and investigations, making observations, and formulating conclusions

(Pedaste et al., 2015). Coding for *challenges to teaching science online* involved combing the data that described challenges, barriers, concerns, or unforeseen outcomes in teaching science online.

Findings

The following section presents the findings from the pre-service and in-service teachers' responses during their one-on-one interviews. The findings refer to our inquiry-based learning framework to further explain the processes and challenges these teachers faced when attempting to teach science in an online format. The interview responses from coding for *creating an inquiry-based learning environment* and *challenges to teaching science online* revealed positive attitudes toward producing a scientific inquiry based learning environment online, new opportunities for creativity in teaching science, and different perspectives on how teachers interact with students.

Creating an Inquiry-Based Learning Environment

Two themes emerged from coding for *creating an inquiry-based learning environment*: ability-to-create and enhancing-inquiry. Through the emergence of the ability-to-create theme, teachers expressed positive attitudes toward creating an inquiry-based learning environment despite teaching in an online format. Jen, a teacher with 21 years of experience, said it directly:

> I just had a discussion with my principal about teaching science online. Yes, this can be done. We can still teach a student-centered lesson online and still have the same hands-on activities. Yeah, there's an obvious difference because you're speaking through a computer, but the lesson doesn't change much. The learning outcomes don't change.

All eight pre-service and in-service teachers were certain in their abilities of transferring their science lessons from a formal classroom to an online version. Many teachers acknowledged the initial uncertainty of teaching science online. One teacher went as far as saying, "*I felt like I was learning how to teach all over again*" However, most of them were surprised with the success they had as the online camp progressed throughout the week. The in-service teachers especially, more often than the pre-service teachers, expressed the ease in which they could incorporate almost all aspects of doing science activities in an online format. Asking questions, collecting data, making observations, and discussing conclusions were mentioned as being incorporated into their lessons. Scott, a pre-service teacher, shared his experience teaching science online:

> As I was performing my science demonstration, I was asking them (the students) questions and getting them to make observations as to what was happening. I had

> to make sure the camera angle was right so they could see, but it seemed to work. I kept trying to pull more and more students as to why things were happening by asking more questions much like in a regular classroom. It was weird at first but then I just got used to it.

Many of the teachers indicated the planning process took much longer than expected despite the overall ease of using inquiry based pedagogical approaches online. The teachers mentioned meeting with others, including with interns, several times to practice teaching their science lessons and rehearsing using the technological features of their Zoom conferencing online forum. Sara, a science teacher in her seventh year, said:

> Teaching online felt a bit more like a television production because you're using technology and you need to be aware of when and where to use it. Whereas in a classroom you can simply tell a group of students to gather over here or move things around because everything is right in front of everyone, online you have to use technology to create digital groups and plan or anticipate for students to have all the features in front of them.

The teachers in this study realized the distance and technical aspect of teaching online did not allow for immediate flexibility of moving lessons forward unless additional pathways and materials were planned for prior to the lessons. Although overall planning took longer than expected, their online science lessons were implemented successfully.

The second theme to emerge from coding for *creating an inquiry-based learning environment*, enhancing-inquiry, had teachers viewing teaching online as an opportunity to explore new ideas of teaching science. Several teachers shared a similar perspective that teaching online allowed for teachers and students to move beyond the classroom walls. Sara shared what she saw as a potential for teaching science online:

> We are breaking down walls of traditional classrooms and rethinking about all aspects of inquiry. It is not necessarily an official lab, but all aspects of inquiry can be explored and used in the outdoors or in students' houses. We might not be doing science the way science looks in books, but change is not a bad thing. It might be that we bring science into students' living rooms and kitchens. It might be that we have students out exploring more of their surroundings.

John, a teacher of 11 years, also expressed a similar view:

> Teachers who engage in hands-on science lessons don't always mean doing a lab experiment. Sometimes it's just investigating something or validating sources or making observations, and that could be anywhere. We don't have to be mixing test tubes in order to be 'hands-on' science. We can find different ways to do parts of inquiry outside the classroom.

Many teachers saw teaching science online or remotely as a potential for new student growth. For example, one teacher expressed having students create their own experiments at home could potentially lead to higher levels of interest and self-efficacy in doing science while gaining science content knowledge. Another idea shared was having students explore and investigate their own surroundings, or new environments, could possibly lead to students making connections between the real world and their education. Still another teacher said, *"Teaching science online is moving away from teaching science through worksheets."* Meaning that too often, teachers rely on worksheet handouts to do the teaching for them but teaching online or remotely required for more open communication between students and teacher asking questions, sharing collected data, and interpreting results.

Several teachers thought that new technologies and innovations could enhance the scientific inquiry process. Their sentiments were accurate as know that in natural sciences that new technologies allow those conducting scientific investigations to explore the natural world in different ways and make new discoveries (Novak & Krajcik, 2006). Analogously, as new technologies are developed in science education, teachers and students will find new ways to investigate scientifically oriented questions, develop and test hypotheses, collect and analyze various forms of data, and construct reasonable conclusions. Jen, the teacher with 21 years of experience, shared a new technology she used in her online science lesson:

> We had the students using a drawing tool feature on Nearpod. It allowed students to draw out what was happening to molecules in different phases of mater. It also allowed for students to share their work with others so the class could get an understanding of what others were thinking.

The pre-service and in-service teachers in this study shared positive perspectives of teaching science online. They expressed confidence in their ability of reproducing their more formal science classroom lessons in an online format. They mentioned having a successful

experience even though the time it took to plan their lesson was longer than usual. They viewed teaching online as an opportunity for new ideas and methods of teaching science.

Challenges and Barriers

Three themes emerged from coding for *challenges and barriers*: access, communication, and maintaining-scientific-integrity. Through the emergence of the access theme, teachers were concerned about students having access to both an online platform and the appropriate materials for the online science lessons. There were some concerns from the teachers in this study that students from low socioeconomic status (SES) families did not have internet access, personal laptops or tablets, or both to participate in the online classes. Mia, a third-year teacher, said:

> We want to make sure all of our students have access to education whether it's in-person or online. That's public education. I realize this week was a 'camp' and the students chose to be here, but it's more of a concern in the school year to make sure the students we have in our regular classroom are also in our online class. So, we need to check on computers and internet access.

To offset the potential new costs some families would incur from moving to an online education, some teachers suggested using public institutions, such as libraries, for access, asking to use hardware from their public schools, or seeking out grant funding from private organizations or companies to supply equipment to those students in need.

In addition to concerns about access to hardware and internet coverage, teachers were concerned students would not have the needed materials or additional technology to participate in certain science activities. Some teachers referred to this materials issue as a logistical issue making sure students were provided the needed items ahead of time, while some of the teachers indicated this was an addition cost issue as parents would be responsible for buying these items. Some solutions given to this issue were making sure parents knew about the materials weeks in advance, setting up a time at school for parents and students to pick up needed items, or planning lessons around using common household items.

The second theme to emerge from coding for *challenges and barriers* was communication. Most teachers were concerned about effectively interacting and communicating with their students through an online medium. Chad, another pre-service teacher, compared interacting with students in the classroom to interacting with them online:

> Social interactions are natural in the formal classroom because the students are physically right next to each other. That's not the case online. Teachers have to guide students toward interacting more in an online format because of the lack of proximity. Teachers need to be aware of how they frame their classes to foster discussion and interactions. Especially in science when you're comparing data or discussing results. If that's not happening in the lesson, then the lesson is all teacher centered.

Some teachers were concerned about losing the human aspect of education. *"What I miss is the student interactions in the hallway like giving a high-five,"* said John. The informal interactions before and after classes, in the hallway, and after school play into building community within the school. That lack of community building online has the potential of negatively impacting students and their interest toward their education. In response, a few teachers reminded themselves, and those going into online education, that in those moments before or after lessons to continue to ask students about their lives beyond the content being learned.

One specific habit that had a few teachers concerned was students turning off their cameras during the lessons. Jen described this concern:

> Some students would turn off their cameras and we kept reaching out to them making sure they were still there and participating. Initially we were worried that these students were not paying attention, or we had done something wrong. But it turns out the students were using the technology to engage at their own pace. They were still paying attention but would engage when they were ready.

The initial concerns from teachers were in regard to how students with social and emotional issues, including dealing with anxiety, would function in an online environment. As it turned out in the online camp, students were using the technology to engage when they felt comfortable and ready. However, from the teachers' perspective, it was difficult to interpret the students' blank screen.

The third theme that emerged from coding for *challenges and barriers* was maintaining-scientific-integrity. A couple of teachers were concerned about losing the integrity of doing science because of limited interactions that comes from online or remote learning. These teachers were concerned that other teachers would interpret online education as more of a one-way interaction, and avoid engaging students with questions, collecting and analyzing data, and constructing reasonable conclusions. Furthermore, they were concerned that other teachers would stick to more

teacher-centered activities or focus their science lessons on having a "wow" factor without going into depth of the nature of science. For example, interactive science demonstrations can have a positive effect on student emotional engagement and content learning (Milne & Otieno, 2007), but are often more teacher centered and focus on promoting inquiry.

There are usually new concerns when teaching through a new medium or with new technologies. The concerns expressed by the pre-service and in-service teachers were in regard to student access, communication, and maintaining the integrity of doing science. However, the teachers were either able to address these concerns in real-time or offer solutions to other, larger concerns beyond their online science camp.

Limitations

The qualitative nature of the pre-service and in-service teachers' interview response data represents perspectives after having participated in a week-long online learning science camp. The interview data were from 9 individuals, and their responses may not represent all pre-service and in-service teachers' views and concerns of teaching science online. Additional investigations of teachers' experiences using inquiry based pedagogical approaches in an online format are recommended.

Discussion and Conclusion

Many of the interviews led to discussions about the use of online science education when their students eventually returned to their formal classroom. A variety of ideas were shared on if and how formal classroom and online education could co-exist. Several of the teachers foresee online education having some role in education in the future whether that be continuing to move schoolwork beyond classroom walls, providing supplemental information and activities, or flipping classrooms (Tucker, 2012). Regardless of how online science education will look in the future or how it will be incorporated with formal classroom education, the small group of teachers had positive outcomes with their lone online science camp.

Concerns are raised when change is required. Although the concerns expressed by the pre-service and in-service teachers in regard to student access, communication, and maintaining the integrity of doing science, they were able to work through these concerns. Furthermore, the pre-service and in-service teachers in this study shared positive perspectives of teaching science online. They expressed confidence in their ability of reproducing their more formal science classroom lessons in an online format. They mentioned having a successful experience although the time it

took to plan their lesson was longer than usual. They viewed teaching online as an opportunity for new ideas and methods of teaching science.

References

Abdi, A. (2014). The Effect of Inquiry-Based Learning Method on Students' Academic Achievement in Science Course. *Universal journal of educational Research*, *2*(1), 37-41.

Avsec, S., & Kocijancic, S. (2014). Effectiveness of inquiry-based learning: How do middle school students learn to maximize the effi cacy of a water turbine. *International journal of engineering education*, *30*(6), 1436-1449.

De Jong, T., & Van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of educational research*, *68*(2), 179-201.

Granger, E. M., Bevis, T. H., Saka, Y., Southerland, S. A., Sampson, V., & Tate, R. L. (2012). The efficacy of student-centered instruction in supporting science learning. *Science*, *338*(6103), 105-108.

HarlEn, W. (2013). Inquiry-based learning in science and mathematics. *Review of science, mathematics and ICT education*, *7*(2), 9-33.

Keselman, A. (2003). Supporting inquiry learning by promoting normative understanding of multivariable causality. *Journal of Research in Science Teaching*, *40*(9), 898-921.

Milne, C., & Otieno, T. (2007). Understanding engagement: Science demonstrations and emotional energy. *Science Education*, *91*(4), 523-553.

Novak, A. M., & Krajcik, J. S. (2006). Using technology to support inquiry in middle school science. In *Scientific inquiry and nature of science* (pp. 75-101). Springer, Dordrecht.

Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A., Kamp, E. T., Manoli, C. C., Zacharia, Z.C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational research review*, *14*, 47-61.

Polkinghorne, D.E. (2005). Language and meaning: Data collection in qualitative research. Journal of counseling psychology, 52(2), 137.

Stake, R.E. (1995). The art of case study research. Sage.

Tinto, V. (2003). Learning better together: The impact of learning communities on student success. *Higher Education monograph series*, *1*(8), 1-8.

Tucker, B. (2012). The flipped classroom. *Education next*, *12*(1), 82-83.

Yin, R.K. (2009). Case Study Research: Design and Methods. Thousand Oaks, CA: SAGE, Inc.

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