EVALUATION OF A HYBRID PD ON TECHNOLOGY ENHANCED INQUIRY BASED SCIENCE TEACHING

By

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Abstract

The Next Generation Science Standards (NGSS) were designed to revolutionize science teaching and learning. Because of the dramatic shift from learning through memorization to engaging in science as a practice, with the adoption of NGSS teachers will have to change approaches (NRC, 2012). At the same time that NGSS curricula are implemented in classrooms, the use of technology is more prevalent in schools (Dawson et al., 2015; Pringle et al., 2015). However, there is a discrepancy between the NGSS inquiry-based approach to technology and the way technology is being used in classrooms. Very little has changed toward technology and inquiry-based science teaching (Duschl, 2014; McLaughlin et al., 2014). PD has been shown to be an effective component of adopting new standards, and using technology (Campbell et al., 2012).

This study was a six-week hybrid PD on technology-enhanced inquiry-based science teaching with five 5th and 6th grade teachers. Using mixed methods, the study evaluated impact on teachers' beliefs and practices. Data was gathered using teacher surveys, student surveys, video recorded lessons, weekly learning journals, lesson plans, and a focus group. After data analysis, teachers were grouped into orientation profiles based upon incurred changes. The PD was effective at changing two first-year teachers' beliefs, but not practice. Two more experienced teachers had changes in beliefs and practice. One advanced teacher did not experience much change. Effective elements of the PD included convenient access and positive group dynamics. Implications from the study reveal that first year teachers need more support, elementary curriculum needs to be reevaluated, and advanced teachers need more rigor.
Keywords: NGSS, science, technology, beliefs, orientation, practice

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Chapter 1: Introduction to the Study

The Next Generation Science Standards (NGSS) were designed to revolutionize science teaching and learning across the United States. The standards were completed in 2013 and New Jersey adopted them in 2014, mandating that all schools align their curricula to the standards by the 2016-2017 school year for grades K-5, and 2017-2018 school year for grades 6-12. In 2017, the New Jersey Department of Education renamed the NGSS to the New Jersey Student Learning Standards (NJSLS), although the content of the standards remained the same in their entirety. The standards are built on frameworks that place an emphasis on learning science by doing science (NGSS Lead States, 2013). Different from previous science standards that emphasized memorizing a large number of unrelated science concepts, NGSS focuses on a much smaller subset of interrelated science content that builds throughout grades K-12 (NGSS Lead States, 2013, NRC, 2012). Under these standards, students will now achieve mastery by using inquiry-based science practices to generate understanding of science concepts in a similar way that scientists do. Because of the dramatic shift from learning through memorization to learning by engaging in science as a practice, the adoption of NGSS in New Jersey means that teachers will have to change their pedagogical approach in their classrooms (NRC, 2012).

At the same time that NGSS curricula are beginning to be implemented in the classroom, the use of technology is becoming more prevalent than ever in schools (Dawson, & Ritzhaupt, 2015; Kopcha, 2012; Lawless & Pelligrino, 2007; Pringle et al., 2015). Technology and science have continually gone hand in hand with one informing the other, a tradition that continues today. Science has gotten better because of technology and technology has gotten better because of science. Today's scientists are using technology to create advanced robots to perform surgery, generate models of complex structures such as the cholera toxin, and create enough data that physicists have been able to functionally maximize the storage on computers every eight or nine months (Hew & Brush, 2009).

It seems clear that in the coming years, technology and science will continue to become more intertwined. Scientific breakthroughs and innovations no longer involve a scientist working alone in a laboratory; quite the opposite, research projects now span the length of the globe. Scientists can collaborate across continents using technology devices, data collection can occur at multiple points on the Earth simultaneously, and simulation software and robotics has become so advanced that projects that used to take long lengths of time can now be reduced immensely. Students moving into the science fields will continue to rely on and innovate technology. At the current time where science skills have taken the forefront, and where technology is becoming ever more important, immersing our students within technology in a content area is the reality all science teachers are facing. This is particularly relevant to recent science education developments because technology is a critical part of being a scientist and technology has been shown to be a viable component of science teaching and learning under NGSS (Campbell et al., 2010; Campbell et al., 2015; Hug et al., 2005; Foley et al., 2014; Kim et al., 2007; Sinha et al., 2015).

However, there is a large discrepancy between the inquiry-based approach to technology use that NGSS calls for and the way in which technology is currently being used in classrooms (Duschl, 2014; McLaughlin et al., 2014; Pringle et al., 2015). The Substitution Augmentation Modification Redefinition (SAMR) Model is a hierarchical tool that can be used to describe specific approaches to technology use that align with or sit in opposition to effective approaches to NGSS teaching with technology. Consisting of four levels, the lower two levels of SAMR are characterized as “enhancement.” In these lower levels, sitting less in alignment with NGSS, technology use serves the purpose of replacing analog applications, but generates no other functional change (Hilton, 2015; Rommrell, Kidder & Wood, 2014). The upper two levels have the label of "transformation." Technology use in these levels is more aligned with the practice based learning at the core of NGSS, because the technology applications themselves enable a significant reconstruction of tasks, and makes tasks possible that were previously inconceivable in the classroom (Hilton, 2015). While the upper two levels of SAMR are more aligned to NGSS teaching, many teachers continue to use technology practices in their classrooms that either substitute or augment what they had done previously such as using the technology as a projection tool or for word processing (McLaughlin et al., 2014).

The following example provides a way of seeing how SAMR can be useful in seeing how science and technology are related to each other and therefore how it can be used to improve practice. In this example, technology is used for M and R applications, indicating a science classroom transformed by technology, is students working in groups to solve an authentic problem of earthquake readiness. With the goals of creating a house that can undergo the least amount of shaking as possible in a simulated earthquake, in this project, students used technology to watch videos of earthquake proof houses, create blueprints of a house, interact with students in a global community, built their house, and used an app on their phones to record data on how much shaking their houses underwent. The uses of technology in the task were also in line with the science and engineering practices of constructing explanations and designing solutions, developing and using models, and using mathematics and computational thinking. Throughout this project, technology completely transformed what students were able to do in the classroom, took on the form of multi-modes, and was used in line with NGSS inquiry-based practices. To begin the lesson, students watched videos of engineers performing a base-isolation tests and were able to see that when a house has a fixed base, it crumbles. Next, students logged onto a PBS website that featured a similar design challenge, and were able to view and comment on other students designs for earthquake-proof houses from across the globe via their ChromeBooks. After evaluating the strengths and weaknesses of some of the designs they viewed on the webpage, students used an online tool called Google Drawings to simultaneously collaborate with their group on a blueprint, many of which were inspired by some of the designs that were viewed on the PBS site. Finally, students constructed their houses and used the Google Science Journal App on their phones to record the acceleration of their houses as they were shaken on a table designed to recreate seismic waves. Afterward, students used that data to redesign and continue to test their design using the app as a part of the engineering design cycle.

During the assignment technology truly embodied the upper two rungs of the SAMR ladder, which allowed for significant redesign of the task, and allowed a previously inconceivable task to become possible. Technology also enabled students to connect with other students from across the globe via the PBS site, to authentically view the work of engineers, to collaborate on scientific blueprints in real time, and to collect data using technological tools in the same way that scientists would. This lesson was much more than enhanced by technology, it was made similar to the work of real scientists and authentic because of the role of technology. Students were not using computers to Google how to build an earthquake resistant house, they instead interacted with a community of their peers to create a design, and used data from a scientific tool to refine that design following the same engineering design process that all scientists go through. Technology both made this lesson possible and in the likeness of scientists because it embodied an M or R role in the classroom. The lesson was aligned high on the SAMR scale and contained many elements of the NGSS standards showing that technology and NGSS can be successfully forged together. If a teacher were to do this same lesson using an S or A level on the SAMR scale, he or she may have had students do things like watching a how to video on creating a house from school supplies and had their students follow the design exactly. Students may have discussed blueprints with their classmates instead of using the website to engage with a global community. Finally, students may have estimated damage done to the houses instead of collecting data using a scientific instrument. This lesson went beyond the enhancement level and through M & R usages of technology in the classroom propel students to not only use technology more effectively but also to engage in the practices in alliance with the nature of science more effectively.

While the success of the standards hinge upon students doing inquiry-based science as a practice as illustrated in the example above, recent studies have shown a contrast to the previous example, in that teachers continue to use technology in traditional, low level Substitution and Augmentation ways (McLaughlin et al., 2014). This may be as a result of teachers' beliefs about technology use which can be characterized as more traditional as opposed to more reformed-oriented (Campbell et al., 2012; Campbell et al., 2014). Teachers with traditional beliefs hold conceptions that align with enhancement and could typically be seen using technology to do things like replicating the textbook or using a search engine to answer a research question. Conversely, reform-oriented belief holders have ideologies on the purpose of technology for transformation and could be seen using technology to modify or redefine what can be accomplished in the context of a classroom, such as completing space simulations, building models, or contributing to global data collection.

Professional Development (PD) has long been shown to be an effective component of adopting new standards like the NGSS, and new teaching practices like using technology to support teaching toward NGSS and higher levels of the SAMR model (Campbell et al., 2012; Campbell et al., 2014). Often, the introduction of new standards without teacher development causes such initiatives to fail. PD can only be successful if it is ongoing, intensive, and connected to school goals (Darling-Hammond, Wei, Richardson, & Orphanos, 2009). However, lack of time and funding are two reasons why PD fails, often because districts cannot find enough time to make ongoing PD a reality, or they do not have the funds to sustain it (Blitz, 2013). One solution is to implement hybrid PD, where teachers meet both in person and online (Blitz, 2013). Hybrid PD has effective elements because teachers can log-on to online platforms at their convenience, and it often costs significantly less than more traditional PD offerings (Blitz, 2013). Blended in-person and online PDs may hold promise for districts that want to meet the ideals of effective PD but are having trouble finding time and resources to do so.

Problem Context

Spring Grove Middle School, a high performing middle school in central New Jersey, is experiencing problems using technology for student instruction in ways that address the NGSS. Similar to other schools, Spring Grove Middle School teachers are demonstrating a disconnect between the higher SAMR levels that match the way NGSS instruction calls for technology to be used, and the ways in which science teachers are using it. In this district, the curriculum has undergone a rigorous revision to align to NGSS over the past three years. Observations from the science supervisor have shown that teachers are working toward shifting pedagogies to align with NGSS best practices in their classroom. However, teachers are just beginning to integrate technology with the new curricula and have been using technology in ways that are aligned with the lower levels of SAMR. Additionally, administration has reported a downward trend science in marking period grades from grade six to grade seven. Many variables including the students, the school buildings, and teaching methods may have played a role in the decline. The issue of declining marking period grades was presented at a faculty meeting, however exact statistics were not made available. The school has acquired multiple technology tools including shared ChromeBook carts, iPads, and ChromeCast multimedia devices to be used for student instruction within the past two years. Additionally during the summer of 2017, the district added technology standards to the science curricula and identified effective technology integration as a PD focus for the 2018-2019 school year. The district has offered at least four one hour after school workshops on technology integration every year for the past three years.

Although there have been one-day PD workshops on how to design lessons more appropriately aligned with NGSS, and some training on how to use the ChromeBooks for student instruction, there has been no PD that merges the two: on how to use technology for inquiry-based student instruction in ways that align with the upper levels of SAMR and NGSS. Many science teachers in this building still employ student use of technology by traditional substitution and augmentation levels as evidenced by administrative walkthroughs and observations. Instead of fostering inquiry, teachers have continued to use technology to have students read websites and the textbook online and create PowerPoints, but are not using it to have students simulate labs, look at current scientific research, or design models.

Additionally, many teachers have formally and informally voiced their concerns about the lack-luster, one-shot PD in which they have participated. Notes from faculty council meetings have revealed that teachers feel dissatisfied with the one-day workshops that the district has been providing. Fifth and sixth grade science teachers and administrators alike would also like the opportunity for the group of teachers to formally meet and discuss ways they can bring continuity to teaching practices that will span both grades in an effort to reduce the marking period grade drop-off in grade 6. Fifth and sixth grade science teachers still have many questions about incorporating technology in inquiry-based NGSS ways, and would like the opportunity to participate in more training that merges them. The district has heard their concerns, and would like to act on them, however it has a very limited budget for PD.

Therefore, I have designed an intervention study focused on technology-enhanced inquiry-based science teaching merging the frameworks of NGSS with the best-practices for high level technology use in the classroom. The intervention will span six-weeks and will take on a hybrid format, whereby the first and final sessions take place in-person and the four middle sessions will be hosted asynchronously online. Designed to address the need for teachers to adopt new pedagogy as related to the NGSS and technology, and to bring some continuity between science teachers in grades 6 and 7, the intervention will capture teacher's beliefs and actual practices before, during, and after to evaluate its impact. Throughout the course of the PD, teachers will engage in experiential learning with different technology applications in the same way that their students will and will work with the other teachers in the PD in community to reflect and create new lessons blending science and technology together. The goal of the PD will be for 6th and 7th grade science teachers to begin to use technology with their students in more similar ways, and for all teachers to leave the last session having gained the skills to use technology in a more effective ways aligned with NGSS.

Research Questions

The following research questions will guide this mixed-methods study:

(1) How do science teachers' beliefs on using technology for inquiry-based NGSS teaching change throughout the course of a hybrid six-week PD course? (Qualitative)

(2) How does technology use in teachers' science classrooms change after participating in a hybrid professional development?

3) What evidence of alignment between technology use, M and R levels of SAMR, and components of NGSS are observed before and after participation in a six-week hybrid PD? (Quantitative)

Chapter 2: Literature Review

Twenty-first century expectations have put pressure on all schools and all content areas, including science, to revise curricula and change pedagogies to have an emphasis on technology. As we move further into this century, scientists have been able to use technology in ways that were unimaginable in the past, and our students are expected to gain the same technological aptitude throughout their time in school. At the same time that twenty-first century technology expectations have been put upon our students, the NGSS have placed an additional emphasis on the acquisition of skills over memorization so that students can become fluent with the nature of science during their time in school.

Locally, Spring Grove School District has been uprooted by the dual impact of the new standards and twenty-first century technology expectations occurring within the same time frame; the district adopted NGSS in 2014 and last year has added technology standards to the curricula of every subject. Teachers at this site are in need of PD blending technology and science instruction together; however, the district has a limited budget and time constraints on providing the quality PD needed to make a change. Therefore, this study will explore the impact of a hybrid PD on technology-enhanced inquiry-based science teaching. The following literature review will describe the current state of science education, technology, and the impact of the NGSS standards on teaching. Later, the literature will reveal how professional development has been able to make an impact on teachers' beliefs so that they are more reform-oriented toward technology use. The literature review will close with an evaluation of the implications of hybrid professional development as a possible means of viable PD and finally explore the SAMR Model, TPACK and experiential learning as the knowledge integration frameworks that will shape the content of the PD. The expectations of twenty-first century science students are not to just merely dabble in technology use, but to use technology in the likeness of scientists, for problem solving and critical thinking. All articles in the following literature review were peer-reviewed and most recent articles were given highest precedence, as the standards were adopted formally in all secondary schools for the 2017-2018 school year.

Science and Technology in the Twenty-First Century

In the twenty-first century, technology continues to be a more pervasive part of schooling. Technology can be defined as any digital or electronic tool used in teaching for the purpose of helping students learn (Campbell et al, 2012). Across classrooms nationwide, the presence of technology is drastically increasing, to a point where computer use in the classroom will become routine within the next few years (Foley et al, 2014; Pringle et al, 2015). Student lives are consumed by technology with readily accessed mobile devices and laptops outside of school, as well as access to mobile laptop and iPad carts, one-to-one computing approaches, and the mandate of online state testing for several states (Foley et al., 2014). Technology has become so pervasive in schools, that it has influenced nearly every socioeconomic bracket, and research has shown that using technology-based strategies in schools helps to address the needs of diverse learners (Campbell et al., 2015; Hug et al., 2005), increase student engagement (Hug et al., 2005), increase student motivations (Pringle et al., 2005), and create a more equitable environment for students (Hug et al., 2005; Pringle et al., 2015). Additionally, technology has changed the expectations for the upcoming workforce as today's students can readily communicate and collaborate using technology tools worldwide.

In recent decades, there has been an emphasis on preparing our students in the areas of technology and inquiry-based science (National Academy of Science, 2010). Recent studies have indicated the success that teaching science with technology can have for twenty-first century inquiry-based teaching and learning. On the whole, new instructional technologies have been found to support classroom inquiry by providing opportunities for students to experiment with simulations of scientific phenomena, engage in scientific modeling, and participate in scientific experimentation activities such as collecting data and conducting analysis using probe wear and scientific databases (Gerard et al., 2007). Technology has the capacity to enhance or make possible science learning that otherwise would not be possible within a school context. Learning tools including the Internet, modeling, and visualization software, can be used by students to extend their thinking and create multiple representations of their understanding while helping science teachers and students communicate, experience scientific phenomena, conduct investigations, and develop products (Hug et al., 2005).

Additionally, using technology in science classrooms has been found to be more effective than instruction without technology (Geir, Blumenfield, Marx, Krajcik, Fishman Soloway & Chambers, 2008; Lee, Lin,Varma & Liu, 2009). Repeating these findings, in a randomized study of two hundred seventy-one students in eight classrooms, Chang, Quintana, and Krajcik (2010) found that students' science learning gains on target science concepts were significantly greater when using technology enhanced innovations for chemistry, than when using typical textbook-based materials alone. Unique to each of these studies is that teachers have been participating in some form of sustained professional development while using the technology with their students.

In many cases, the PD itself was inquiry-based in nature, and teachers interacted with technology in the same ways as their students would (Gerard et al., 2011). There have been very few studies where a majority of teachers were already effectively using technology for inquiry-based instruction in the absence of PD. Overall, in the twenty-first century, students will need to learn both science skills, and how to use technology for science practices. Technology has proven itself to be a valuable tool to teach all subjects and has made specific links to science. As such, teachers will need to adopt new beliefs and pedagogy toward teaching science with technology and will need support in doing so.

NGSS Teaching and Technology

While technology has shown itself to be an operable tool for science teaching and learning, teachers in 2018-2019 face the additional pressure of adapting lessons to the inquiry-based NGSS. Born in response to global data from the "Era of Accountability," the NGSS were created to change science teaching from memorizing a large sum of unrelated facts, to doing inquiry-based science with content that builds on itself across the K-12 grade levels (Harris et al., 2017; Duschl & Bybee, 2014; Krajick, Codere, Dahsah, Bayer, & Mun, 2014; NGSS Lead States, 2013; Osborne, 2012). According to the National Research Council (2014), the NGSS "were intended to transform public K-12 science education so that it provides students with the proper skills and knowledge needed for college and career readiness." As such, the emphasis of these standards is directed toward:

i) integration of scientific and engineering practices to develop multiple learning core concepts; ii) sequential progression of knowledge at each grade level; iii) identifying accessible core concepts useful to develop a deeper understanding and application of content; and iv) incorporating engineering design into science education with emphasis on developing students' understanding of core concepts in engineering design and technology applications, all of which can be taught in conjunction with technology (NGSS Lead States, 2013).

Since their creation, eighteen states, including New Jersey, have adopted the NGSS as state learning standards with the expectation that districts will develop new curricula and new teaching methods in response (Haag & Megowan, 2015; NGSS Lead States, 2013). In effect, students will engage with science in the "same way that scientists do" including using technology (Foley et al., 2014; NGSS Lead States, 2013; Osborne, 2012). Specifically, the NGSS call for teaching to move away from covering isolated facts to a focus on a smaller number of Disciplinary Core Ideas and Cross-cutting Concepts that can be used to explain phenomena and solve problems by engaging in Science and Engineering practices in a new "three dimensional learning (Krajick et al, 2014; NGSS Lead States, 2013)."

Disciplinary-Core Ideas (DCI), Cross-Cutting Concepts, and Science and Engineering Practices are the three dimensions for building understanding in NGSS (NGSS Lead States, 2013). DCIs represent a much smaller subset of science content to be covered at each grade level including the explanations of phenomena that occur within each discipline (NGSS Lead States, 2013). Cross-Cutting Concepts are seven pattern-like intellectual tools that connect science learning to all disciplines (NGSS Lead States, 2013). Science and Engineering practices represent the eight multiple ways in which scientists and engineers describe the natural and designed world (Krakjick et al, 2014). Different from the earlier science standards, students will now avoid shallow coverage of many topics, and instead explore fewer topics in-depth to solve problems and explain phenomena, as skills build throughout many years in the curricula (Krajcik & Merritt, 2012).

The ubiquitousness of technology itself makes an argument for its usefulness within the classroom, and the recent reform in science education prompted by NGSS have made the incorporation of technology in the science classroom an important aspect of teaching and learning (Campbell et al., 2015). In an analysis of thirty articles on technology usage in inquiry-based learning environments published from 2008 onward, Donelly et al. (2014) found that there were four guiding principles by which technology was implemented to enhance the NGSS-like inquiry-based science classrooms including: (1) exploring meaningful and authentic scientific contexts, (2) using powerful visualizations to illustrate phenomena that are too small, fast, or vast for classroom experimentation, (3) encouraging collaboration with others, and (4) developing autonomous metacognitive learning practices. Overall, technology in the science classroom has the potential to increase students' ability to question, solve problems, reason, engage in conversation, make models, visualize phenomena, and interpret data (Hug et al., 2015).

Although there have been nearly no published studies that have researched NGSS and technology together, as the standards are very new for most districts, there have been several studies that have successfully used technology for inquiry-based teaching that align with the eight NGSS Science and Engineering Practices that serve as the backbone of the standards. The following describes ways that technology can be used to facilitate NGSS teaching and makes an argument for their connectedness. For example, online simulations have been shown to increase student engagement in asking questions and defining problems, (Hug et al., 2005) and to create authentic data sets which addressing two Science and Engineering Practices (Foley et al., 2014). Students have also used collaborative platforms to obtain, evaluate, and communicate information (Foley et al., 2014), and created virtual blueprints to argue from evidence, two more Science and Engineering Practices (Stegmann et al., 2012). Through the use of online math tools, students were able to represent different spatial arrangements related to using mathematics and computational thinking (Foley et al., 2014). Finally, students were able to use technology for modeling and carrying out their own investigations related to their models, a direct example of the principle on developing and using models (Krajcik et al., 2014; Yoon et al., 2015). Researchers have found that using technology in ways that align with the eight Science & Engineering Practices of NGSS engages students in doing science rather than passively accumulating facts. In each of these studies, the teachers involved were immersed in some form of sustained PD that impacted their student's ability to interact successfully with technology.

The work from these studies has given evidence that teachers can use technology in their classroom in ways that intersect with all eight of the science and engineering practices promoted by the NGSS. In most of these instances, teachers were developing lessons and using technology while immersed in a two-year (Foley et al., 2014; Krajik et al., 2014) or one-year (Yoon et al., 2015) PD that was aimed at helping teachers use technology for inquiry-based purposes with their students. Although in the above instances, a majority of teachers were able to leave the PD having used technology to foster inquiry, on the whole, while in settings removed from PD, science teachers have not made the connection between inquiry-based teaching and technology.

New Standards and Technology but Pedagogy has Remained the Same

Although twenty-first century expectations and NGSS call for teachers to move away from encouraging students to simply memorize scientific facts and to go toward inquiry, very little has changed in the past five years in terms of pedagogical methods toward technology and inquiry-based science teaching. Teachers left to synthesize the science standards and technology by themselves have not been able to effectively merge the two concepts into one way of teaching. In a sample of 28 teachers, researchers found that as recently as one-year ago, students were still learning science from technologies in similar ways that they would use a textbook, with limited to no regard for their understandings about the processes and nature of science (Campbell et al, 2010; Kopcha et al., 2016; Serapin, Philipoff, Kraupp & Vallin, 2012). None of the 28 teachers surveyed had participated in any form of PD. These traditional uses of technology are not aligned with the inquiry-based practices in NGSS and have also been shown to be detrimental to student performance on international assessments (Campbell et al., 2015; OCED, 2013).

In 2013, even after CCSS attempted to lessen the number of content standards to focus more on skills and created 21st Century Technology Standards to focus on the acquisition of technology tools, the United States still was behind in terms of international technological skills. The Organization for Economic Cooperation and Development surveyed 166,000 adults aged 16 to 65 in 24 countries on skills in three domains: literacy, numeracy and using technology to solve problems. The results showed that U.S. young adults ranked low in these skills compared with people of the same age from countries with similar development levels (OCED, 2013). Although the U.S. adults had scored poorly, young adults scored even lower in comparison to other countries (OCED, 2013). This is despite the fact that these skills were supposed to be taught and learned in school according to the technology standards that were a part of the 2009 CCSS. These data raise alarming concerns about the continued presence of traditional technology instruction. Therefore, there continues to be a pressing need for the U.S. to improve school-age students' fluency with and ability to use technology to solve problems (Wang et al., 2014). In other words, there is a need for our teachers to be trained in pedagogies merging technology and science so that their students can compete with those of other nations and be held accountable for teaching under the new rigorous standards.

Perhaps one reason that the United States has remained technologically and scientifically behind other countries, is that not much has changed in terms of how students interact with technology in science classrooms since the inception of the Internet. In a study of 1,060 students and twenty-four teachers in middle school classrooms who were not participating in professional development on using technology in science, Wang et al., (2014) found that from both the teacher and student perspectives, word processing and Internet search activities are still the most frequently reported technologies that students use in the classroom. These technologies reflect low-level integration and are not aspects of inquiry-based teaching or NGSS. Throughout the course of their study they reported that in classrooms where teachers had not received any PD, rarely did students have the opportunity to use tools such as blogging, editing, or movie production that could support creativity and productivity (Wang et al. 2014). These statistics show that students are continuing to use technology in the same unsophisticated ways they had decades ago, despite the exponentially increasing access to Wi-Fi connections and technologies available to them.

In order to align technology use to NGSS, and close the gap in global competition, teachers need to change pedagogies and move away from using technology to simply present information, to more inquiry-based methods such as building explanations of phenomena and proposing solutions to problems (Krajick et al., 2014). Instead of making PowerPoint slides, watching videos, or reading websites, teachers need to learn how to use technology to engage students in hands-on science (Foley et al. 2014). Engagement in technology can bridge the gap from science lessons with prescribed outcomes to more authentic NGSS-like science inquiry (Foley et al., 2014). A paradigm shift that aims to engage students in science and engineering practices will enable them to experience science as scientists do (Foley et al., 2014). Because this represents a substantial change in practice for many teachers, and positive outcomes have been found from teachers immersed in PD on technology integration in science, school districts in the United States are in a position of needing to train teachers to integrate technology effectively into classrooms in innovative and meaningful ways.

Teacher Beliefs

The majority of current science teachers have not received PD that couples science instruction and technology and thus continue to use technology for traditional as opposed to inquiry-based methods. One way to analyze trends in the wake of reform is to look at how policy impacts teachers' beliefs, and if a change in beliefs, in turn impacts practice. Even after the passing of NGSS and the rapid rise of technology, teacher beliefs continue to show that, when there has been no PD linking science instruction and technology, teachers think and execute lessons that embody methods using technology for traditional teaching rather than inquiry-based science. While other factors such as social environment, resources, and formal training of the teacher have impacts on teachers' instruction, beliefs have emerged as the primary factor influencing a teacher's behavior in the classroom (Gill & Hoffman, 2009; Pajares, 1992; Speer, 2005; Thompson, 1992). Essentially, if teachers have not viewed technology as a viable tool for teaching inquiry-based science like NGSS before the reform, then without training, they will continue to believe technology's uses are primarily limited to traditional uses after the reform of NGSS and the increase in technology.

Long-term, collaborative PD that has evaluated teacher's beliefs on the role of technology before and after the PD have largely been successful at getting a majority of those involved to go from holding more traditional beliefs before the intervention, to carrying-out more reform-oriented beliefs after the PD. Qualitative and quantitative studies have used teacher beliefs as a measure of how conceptions of technology use in the science classroom have changed after the implementation of NGSS. Documenting the misconceptions teachers have of technology use before participating in any PD, studies have provided evidence that before an intervention, teachers have not thought about how technology can be tied to NGSS and are comfortable using technology in traditional ways (Campbell et al., 2014; Yerrick et al., 2009). Furthermore, teachers are unaware that the way in which they are using technology is not aligned to inquiry-based NGSS science instruction (Campbell et al., 2014; Yerrick et al., 2009). The following chronicles specific examples of changing beliefs toward reformed inquiry-based technology use throughout the course of a PD.

A mixed-methods study situated within a five-year research plan funded by the NSF captured the beliefs of current science teachers in online journals throughout the course of an intervention (Campbell et al., 2013). In this study, Campbell et al., (2013) created three distinct technology belief orientation profiles that ranged from traditional, approaching traditional, to reform-based. The PD consisted of a two-week summer institute and ongoing meetings for the next five years where teachers would be given time to troubleshoot and reflect. I wrote three curriculum modules that incorporated technology that the teachers would experience first with their “learner hats” on as they played the role of students. After the learner hat phase, teachers would return to the “teacher hat” phase and discuss how the technology application would take shape in their classrooms. In later weeks, layers of scaffolding would be removed by the researchers as the teachers engaged in the last two modules.

Teachers beliefs in relation to the orientation profiles were measured before, during, and after the intervention. Data was collected using journals and classroom observations. Statements made in learning journals regarding teacher beliefs were found to be congruent with what was occurring during classroom observations. Findings revealed that out of the group of 10 eighth grade teachers, five in the beginning of the study held beliefs that were more aligned with traditional conceptions of using technology. After the one-year intervention, four participants had shifted their beliefs to be more aligned to the approaching standards reform profile (Campbell et al., 2013). Pre-intervention, a majority of the science teachers held beliefs that were mostly traditional in terms of using technology for science instruction, and after the intervention, a majority held beliefs that were either beginning to embrace technology for science, or were completely in synch with teaching inquiry-based science with technology. This study gives evidence that teachers beliefs can be impacted by professional development.

Other qualitative studies have similarly found that it is possible to successfully change teachers' beliefs on the role of technology in the inquiry-based science classroom from more traditional to more reform-oriented throughout the course of PD. In Lebak et al's (2010) one-year quantitative analysis of video from lessons and weekly collaborative PD meetings, all three teachers involved in the study changed their pedagogical approach from teacher-centered and textbook driven, to a student-centered, inquiry approach. As part of an action research project, the nineteen teachers involved in this study would video themselves and meet weekly over the course of fourteen weeks to critique each other's lessons and offer guidance on how to integrate technology more effectively (Lebak et al., 2010). Through this video-reflection format, three teachers stood out in making significant gains towards transforming their classrooms with technology (Lebak et al., 2010).

In another study, in a follow-up to their first study, during a two-year intervention of thirteen middle school science teachers, Campbell et al., (2014) found that seven out of thirteen science teachers beliefs aligned with more traditional views of technology use for student instruction before the intervention began. In response to the study, a one-year intervention was created that compared participants' initial and ending beliefs. The findings revealed that after the PD, seven out of eight teachers had moved from more traditional beliefs to more reform-based beliefs (Campbell et al., 2014). The PD was successful at changing all but one teacher of those who was formerly characterized as traditional, into adapting beliefs that were more reform-based (Campbell et al., 2014). Evaluated from multiple measures including lesson plans, online journaling, and classroom observations, these studies give evidence that PD has been successful at making a change in teachers beliefs toward technology use and in turn have positively impacted inquiry- based technology use (Campbell et al., 2014; Lebak et al., 2010).

Researchers have also used quantitative measures to evaluate the alignment of lessons to NGSS before and after an intervention. In a subsequent 2015 study, Campbell et al. continued their previous work and used the Technology Usage in Science Instruction (TUSI) instrument to measure how well-aligned technology use in teachers' lessons were to twenty-six indicators in alliance with NGSS before and after a one-year intervention. Throughout the course of the intervention, participants beliefs were evaluated using interviews. The PD followed a similar format as described above, where participants were introduced to a technology application over the summer and received lessening scaffolding throughout the year as they brought the technology into their classrooms and reflected on its applications with the research team. At the conclusion of the study there was a change in teacher beliefs to become more reform-oriented. In addition, Campbell et al., (2015) reported that all four participants lessons were more aligned to NGSS after participating in the one-year PD intervention. Evidence from the study has also shown that students were able to use technology in more sophisticated forms as a result of their teacher's participation in the PD. For example, the researchers captured students creating representational displays of science concepts using technology in ways that helped them formulate conclusions. As a result of the PD, participants' instruction more often integrated technology in ways that aligned with NGSS and teacher participants also had significant gains in science content knowledge (Campbell et al., 2015). Additionally, teachers were able to identify research questions, recognize information relevant to the problems, locate and manage relevant info, synthesize and produce information to answer questions, and communicate and share research findings with others after the intervention had concluded (Campbell et al., 2015). In summary these quantitative studies have given evidence that sustained experiential and reflective PD can play a significant role in shifting teacher beliefs and can help teacher's design lessons that use technology in ways that are more aligned to NGSS.

These studies support that teacher beliefs can serve as a basis for estimating teacher practice in terms of aligning technology and NGSS and can be used as a measure for developing teacher support. In conjunction with these data, in an analysis of forty-two studies from 1985 to 2011 on professional development in technology-enhanced science education, Gerard et al., 2011, were able to identify thirty-two studies where at least one-third of the teachers involved in sustained professional development were able to change beliefs and practices to enhance inquiry-based science learning. Overall, these studies show that sustained PD can have an impact on teacher beliefs, shifting them from more traditional to more reform-oriented, which in turn can impact teacher practice.

This research clearly shows how teachers' beliefs on technology use in the science classroom can go from more traditional to more reform-oriented throughout the course of interventions (Campbell et al., 2013; Campbell et al., 2014; Campbell et al., 2015; Wilkerson et al., 2016; Yerrick et al., 2009). However, these studies have been limited to collecting data on changing teacher beliefs in sustained PD, the shortest length of time being one calendar school year, and the longest being three years. Additionally, many of the current studies on changing teacher beliefs on the role of technology in the science classroom have focused on broad inquiry-based instruction only and so far, very few, (Campbell et al., 2016) studies have coupled NGSS, PD and technology together. All of the studies that were evaluated were in-person in nature. None took advantage of using hybrid methods for their teachers.

Professional Development

Professional Development has been successful at changing teacher beliefs from more traditional to more reform-oriented. Currently, without PD relatively few teachers use technology to support an inquiry-based approach to science instruction due to lack of training on technology tools (Foley et al 2014; Haag et al., 2015; Marshall, Smart & Alston, 2015; Sinha et al., 2015) and there is also lack of support in the form of access to PD for technology in the inquiry-based NGSS science classroom (Campbell et al., 2015; Pringle et al., 2015). Increases in technology tools and new reform documents specify that schools should train teachers to develop new pedagogy to address the influx of technology and the inquiry-based NGSS standards (Foley et al 2014; Gerard et al., 2011).

Although technology has been found to be a viable option for inquiry-based science instruction, it cannot stand alone. A recent meta-analysis of twenty-five studies investigating the role of computer-based technologies in student learning found that the teacher may play an even greater role in the students' technology-enhanced learning than the nature of the technology itself (Tamin, Bernard, Borokhovski, Abrami & Schmid, 2011). Across the studies, it was found that the effectiveness of technology depended on the teacher's goals, pedagogy, and content knowledge as opposed to the technology tool (Tamin et al., 2011). The role and knowledge of the teacher has more of an impact on students' ability to learn through technology than access to high-capacity technology. However, few pre-service science programs prepare teachers to use technology to enhance inquiry-based learning (Gerard, Varma, Corliss & Linn, 2011). As a result, the most common PD programs to introduce the goals and designs of technology interventions, and to cultivate science teachers' pedagogical content knowledge are in-service (Gerard et al., 2011). In order to change pedagogy to align with the current times, teachers will need support in the form of quality in-house professional development to change pedagogy from more traditional-based teaching to inquiry-based science teaching with technology.

However, teachers face many challenges in the adoption of technology and integrating them with an inquiry-based approach to science teaching practices (Campbell et al., 2015; Foley et al 2014; Sinha et al., 2015; Pringle et al., 2015). Barriers to technology implementation in the classroom include teacher beliefs, planning time, and training that lacks connection to practice or that focuses solely on the functions of technology instead of how it can be used during a science lesson (Kopcha, 2016). Technical difficulties such as lack of WIFI or training on the functionality of the technology without tech support can also hinder teacher's adoption of technology. In thirteen studies where PD only lasted one year or less, teachers most often abandoned the technology after the PD because of technical difficulties (Gerard et al., 2011). However, in eight studies, lasting two years or longer, all teachers were continuing to use technology for inquiry-based science instruction with their students because those leading the intervention were able to address technical difficulties and classroom management issues in the longer sustained PD settings (Gerard et al., 2011). Effective, immersive PD can equip teachers with skills and attitudes necessary to navigate and overcome the barriers of technology implementation (Kopcha, 2016).

Best practices to impact teacher beliefs and change teacher practice to effectively integrate technology in the inquiry-based science classroom throughout the course of a professional development have come about due to the work of other researchers. In working with teachers to make changes in regard to using technology for inquiry-based science, there are four main steps, part of the knowledge integration framework, that have evidence as being effective for supporting teacher change. In a meta-analysis of forty-two studies involving 2,350 teachers and 138,000 students on PD for technology-enhanced inquiry-science, Gerard et al., (2011) identified eliciting, adding, distinguishing, and reflecting on ideas about science and technology use as well as setting the foundations for inquiry, and community-based learning as the steps that have been most effective at making teacher change a reality. In each of the studies they identified, teachers were involved in an eight month to three year PD initiatives on using technology for enhanced inquiry-based science, and out of all of the compiled studies, only thirteen had results where fewer than one-third of teachers changed technology practice to enhance inquiry learning, while twenty-nine had greater than one-third of participants make changes after the PD (Gerard et al., 2011). PD has the ability to change teachers' practice blending technology and inquiry-based instruction, but only if it is done in accordance with best practices.

In order for PD to be most successful at making teacher change, teachers must be involved in inquiry learning of their own. This means that they act as the students and get to interact with technology while learning about its functionality and uses in the classroom. Inquiry investigation during PD engaged teachers in activities like comparing alternative forms of curricula and pedagogical technique, analyzing the range of students ideas and targeted subject matter, connecting students ideas to specific elements of instruction, and critiquing lesson plans in a mutually supportive teacher community (Borko, 2004; Franke, Carpenter, Levi & Fennema, 2001; Lawless & Pelligrino, 2007). By first laying the foundation for inquiry-based learning and creating a supportive community at the forefront teachers will then be able to engage in effective PD strategies.

Professional development initiatives whose design lent themselves to including all four options for teachers to elicit, add, distinguish, reflect, and integrate ideas were found to be more successful than those that included three or less (Gerard et al., 2011). In eliciting ideas, teachers were given the opportunity to think about and voice the repertoire of feelings they have about science instruction using technology. Effective PDs on using technology in the inquiry-based science classroom have elicited teachers ideas by asking for predictions, critiques of practices, and brainstorms of ideas so that existing thoughts may be inspected, analyzed, contradicted and refined throughout the course of the PD (Trautmann & MacKinster, 2010; Yerrick et al., 2009). After teachers pre-existing thoughts have come to the forefront, successful PDs have supported teachers in adding new concepts to their pedagogy. For example, Tosa & Martin (2010) enabled teachers to role-play students so that they could experience the potential problems that students may encounter. Watching video of other teachers using effective classroom practice had proven to be effective at adding new beliefs and practice toward technology use (Brunvard & Fishman, 2007; Lebak et al., 2010). Additionally, collaborating with peers on lesson plans and tying the new findings from PD tightly to classroom practice were other successful methods of adding conceptions to make a change in instruction (Borko, 2004; Grossman, Wineburg, & Woolworth, 2001).

After adding new ideas, teachers need time to distinguish between previous ways of thinking, new beliefs from the PD, and how both can be conceptualized in the classroom. For example, teachers participating in a PD on using technology for inquiry-based science may believe that students will be able to learn from simulations on their own, however, research suggests that students need guidance from teachers in order to link the simulation to key science concepts (Fishman et al., 2003, Spillane et al., 2002; Tal, Krajcik & Blumenfeld, 2006). The center of distinguishing ideas is all about teachers finding out how the new concepts presented in the PD will make sense in their classrooms. Finally, after distinguishing new concepts from the PD from prior individually held beliefs, in order for PD to have success at changing pedagogies from more traditional to more reform-oriented, teachers need time within the context of the PD to reflect and integrate new conceptions from the PD. Teachers need a formal way to make links amongst their prior knowledge, learning from the PD, and insights gained in the classroom. For example, Henze et al., (2009) found that more than two-thirds of the teachers that participated in his study, were able to change pedagogies to be more reform-oriented when they were given time to reflect on the implications of a computer-based model of a solar system versus a hand-made model.

Out of all of the studies that have been analyzed on teacher change for technology use throughout the course of a sustained PD, none have been on the impact of hybrid professional development on technology and inquiry-based science. Most of the studies followed a similar PD pattern whereby the participants would start their journey over the summer and meet many more times throughout the school year. Sometimes there was additional support in that the person leading the intervention was able to observe classes and give feedback on lessons. Many instances began the PD with teachers wearing their “learner-hats” and interacting with the technology in the same way that students would. Nearly all PDs included elements of formal reflection where the participants thought-over as a group or alone in reference to how they were using the technology. Most of the time, the PD was more successful it was sustained over a one-year period (Gerard et al., 2011). However, there were some instances where PD was successful short-term (Tan & Towndrow, 2009; Trautman & MaKinster, 2010; Yerrick & Johnson, 2009).

Although there is data to support that longer-term PD is more successful at making change than short term, there is also data that supports short-term PD can make an impact. Tan & Towndrow (2009), chronicled the transformation of one teacher from more traditional teacher-centered teaching to more inquiry-based reform student-centered teaching across three lessons. In this case, the PD involved was facilitated by the pairing of a researcher and the teacher. Together, the pair videoed the teacher's instruction and used a reflection protocol that was designed by the research team (see Appendix F) to debrief the practices that the duo observed in the classroom. By looking at video of herself and using the protocol, the teacher was effectively able to identify areas of her instruction that were more traditional and create a plan with the researcher to begin to infuse technology in her classroom for inquiry. After viewing two lessons of herself, the teacher created a lesson whereby students would also video themselves and critique their lab practices, instead of delivering a lecture on lab practices as she had done in the past. In this instance, re-watching video and using critical reflection helped the teacher to transform her classroom from more teacher-centered to more student centered.

In another short-term PD, Trautman and Makinster (2010) worked with a group of eleven teachers in fourteen meetings throughout the school year, eight taking place in the summer and six taking place on Saturdays to integrate Global Imaging Technology into their classrooms. The researchers also offered virtual office hours for support. The eight introductory meetings focused on learning the functionality of the Global Imaging tools, as well as developing lessons using GIT. The later six meetings were reflective in nature, as the participating teachers debriefed on their experience using GIT in the classroom and critiqued the lessons of the other teachers in the program. Through reflection and inquiry-based learning of the GIT tools, the PD effectively increased each teacher's TPACK as evidenced by end of the year surveys and observations (Truatman et al., 2010).

In a similar-short term intervention, eight teachers worked with researchers (Yerrick et al., 2009) on inquiry-based usage of laptops within science lessons. The eight teachers similarly began their journey exploring the laptops as if they were students, then met sporadically throughout the school year to reflect as a community and improve their practice. The end result of the study showed gains in student mastery of science practices from 48% in 2007 to 54% in 2008. Although none of these studies spanned the length of an entire calendar year, they each showed common elements of teacher exploration and community-based reflection (Tan & Towndrow, 2009; Trautman et al., 2010; Yerrick et al., 2009) and one example used video-reflections to transform practice (Yerrick et al., 2009). Together, these three examples had some promising impact either in making changes for teachers use of technology or impacting the student's overall success. Additionally, studies above have shown to be successful at making changes in teachers' beliefs in regard to how they think technology should be used. Based upon the viability of these studies, there is currently room to explore the impact that an online and in-person short-term hybrid PD on technology-enhanced inquiry-based science can have for teachers.

Hybrid PD

While studies on PD for using technology in the NGSS classroom have confirmed that PD can have an impact on teacher beliefs and teacher practice, schools that do not have the time or resources to sponsor a one-year or longer intervention may need to seek different forms of PD in order to sustain teacher change. Hybrid PD features a blend of in-person and online opportunities for PD (Graham, 2013). Districts are now beginning to turn to online learning and hybrid learning outlets to supplement PD that is offered face to and in accordance with PD best practices (Owston, Sinclair & Wideman, 2008). Overarching themes for effective PD is that it should be job embedded and include collaborative learning, active learning, facilitation of deeper knowledge of content, linkages across curriculum, assessments, and professional learning decisions in the context of teaching a specific content, and should be sustained over a long time period (Wei, Darling- Hammond, Andree, Richardson & Orphanos, 2009).

Blended hybrid teacher learning provides an opportunity to implement these practices through a cost and time effective avenue. Hybrid PD has been found to enhance PD experience through more effective teaching and learning, greater instructional flexibility and access to learning, and the possibility for more cost-effective instruction (Desimone, 2009; Graham, 2013; Ilaria, 2017). Because hybrid PD takes advantage of asynchronous learning opportunities online, participants have the freedom to log-in at their convenience, and the cost of utilities can be lower than traditional costs of professional development. These two factors can enable the PD to extend for a longer duration and adhere to PD best practices and are the leading factors in why districts may choose to adopt hybrid professional development instead of long-term options.

Although hybrid PD initiatives have been able to overcome the obstacles of cost and time effectiveness in the past, much of the empirical research on the effectiveness of hybrid PD initiatives to impart teacher change has been gathered through responses from participant surveys completed immediately after the PD ends and have had no consideration for long-term impact. (Dede, Ketelhut, Whitehouse, Breit &McCloskey, 2009). After an analysis of two hundred studies on blended learning in the past ten years, Dede et al., (2009) recommended that future studies on hybrid PD focus on "(a) research questions that address the impact of PD on teacher change; (b) research methods using both qualitative and quantitative analysis; and (c) extending analysis outcome measures across time to allow measurement of different stages of teacher change or teacher learning." There has been very little recent research on how hybrid PD impacts teacher beliefs or teacher practice in the classroom. Additionally, there are currently very few, if any, studies that have investigated hybrid PD to blend science and inquiry-based practices. Most methods of studies on hybrid PD have only looked at self-reporting from teachers. There is currently an opportunity to explore the impact that hybrid PD can have for technology-based inquiry science learning and how it may or may not impact teacher beliefs and practice.

SAMR - Knowledge Integration Framework

Through research, educators have been able to determine the best practices for PD on using technology to teach inquiry-based science. In addition to best-practices elements in used to design the hybrid PD in this study, teachers will also need a tool while immersed in the study to help them think about the different levels at which technology can be used in their classrooms. One framework that can facilitate this task is the SAMR model. In 2006, Ruben R. Puentedura created the Substitution, Augmentation, Modification, and Redefinition (SAMR) model as part of his work with Maine Learning Technologies Initiative. During the PD teachers will use the SAMR model as a knowledge integration framework to concretely visualize what level their current technology sits and see just how far their technology use can shift throughout the PD and after its conclusion. Although there has been very little research on how this tool has been used to change teachers' beliefs as part of a PD, the model was intended to encourage educators to significantly enhance the quality of education provided via technology (Rommrell, Kidder &

Wood, 2014). In this study, teachers will use the SAMR model to place their technology use prior to the study on the ladder and set goals for how to move up the ladder. Each week, they will be shown a technology use that sits within the M and R regions of the model. They will then interact with the tool in the likeness of their students, and work with the group to create and refine lesson plans that involve the tech tool of the week. Throughout the study, teachers will use the tool to reflect on how they can move their own technology use up the ladder, and how technology can be used to modify and redefine the limits of their classroom.

Since its creation, the SAMR model has become increasingly popular and has even been endorsed by Apple (Hilton, 2015). It consists of a four level, taxonomy-based approach for selecting, using, and evaluating technology in K-12 settings (Hamilton et al., 2016). SAMR is represented as a ladder and encourages teachers to move up the ladder from lower to higher levels of teaching with technology which will then lead to higher levels of teaching and learning (Hamilton et al., 2016). The ladder is divided into two lower levels of integration: enhancement, and two more sophisticated levels of integration: transformation (Hamilton et al., 2016). The bottom two layers are made up of Substitution (S) and Augmentation (A). Substitution occurs when digital technology is substituted for analog technology, but the substitution generates no functional change (Hamilton et al., 2016). When technology is exchanged and the function of the task or tool positively changes in some way, it is slightly more sophisticated and called Augmentation (Hamilton et al., 2016). S or A uses of technology are only classified as enhancement because they leverage technology to replace and/or improve existing tools in the learning task (Hilton, 2015). The upper rungs of the SAMR model are classified as Modification, whereby technology integration implies a significant redesign of a task, and Redefinition when technology is used to create novel tasks. M and R uses of technology are grouped as transformation because they provide new opportunities for learning that are not easily possible without technology (Hilton, 2015).

Teachers can use this ladder to gauge their technology integration and try to brainstorm ways to create lessons that reach the highest rungs. Many teachers may believe that any use of technology is good, but this model can give teachers a concrete way of seeing how challenging their technology integrated lessons are. It also helps teachers to vary their technology use to create lessons that go beyond the substitution and augmentation levels to truly transform a lesson. While participating in the PD, teachers will use the SAMR model to reflect on their own teaching and when designing new lessons that will be posted to the group for critique. Most studies have used the SAMR model to evaluate current practices existing in a school typically after a technology device was introduced into that school district (Hartmann & Weismer, 2017; Geer, White & Zeegers, 2017). SAMR has been used in the context of PD to help teachers think about their own level of technology integration. This gives us the opportunity to see if the tool can make an impact in changing teachers' pedagogies while using technology to go from more surface level to deeper reaching inquiry-based technology implementations.

TPACK - Knowledge Integration Framework

While the SAMR model is used to help teachers physically place their technology use in a hierarchy, The Technological Pedagogical Content Knowledge (TPACK) model will be used to help teachers in this study situate their new technology learning from the PD within their existing frameworks of pedagogy and content knowledge. As a knowledge integration framework, TPACK will be used so that teachers' can relate pre-existing knowledge with new knowledge and so that they may draw from their strengths in content and pedagogy and make relations to how that can intersect with teaching with technology. In order for teachers to use technology in ways that are aligned to the inquiry-based NGSS, they will have to increase their TPACK. A goal of the study will be for teachers to increase their TPACK. Conceptualized by Punya Mishra and Matthew Koehler in 2006, the TPACK framework is built upon Shulman's (1986) theory that effective teaching exists in a space between knowledge of pedagogy and knowledge of content (Hilton, 2015). The model for TPACK uses a Venn Diagram of three partially overlapping circles that represent the different knowledges teachers will have to draw from in order to integrate technology effectively. The model shows seven areas, starting with three main types of knowledges teachers possess: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK). It also covers crossovers of the three: Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK), with the middle of the model representing TPACK or the intersection of all of the different types of knowledges (TPACK). There is a dotted line around the model that represents the ever-changing contexts of technology integration and the many different classrooms this framework could apply to (Hamilton, Rosenberg, & Akcaoglu, 2016; Hilton, 2015; Khine, Ali, & Afari, 2017). In 2007, the framework was revised from TPAC to TPACK to demonstrate that TPACK is the total PACKage to help teachers improve student learning through intelligent integration of technology and teaching (Szeto & Cheng, 2016). The framework suggests that each of the domains functions individually as well as together and that effective teaching with technology requires the ability to craft learning activities that draw on all three areas simultaneously (Hilton, 2015).

Figure 1. TPACK Graphic Reproduced by permission of the publisher, © 2012 by tpack.org

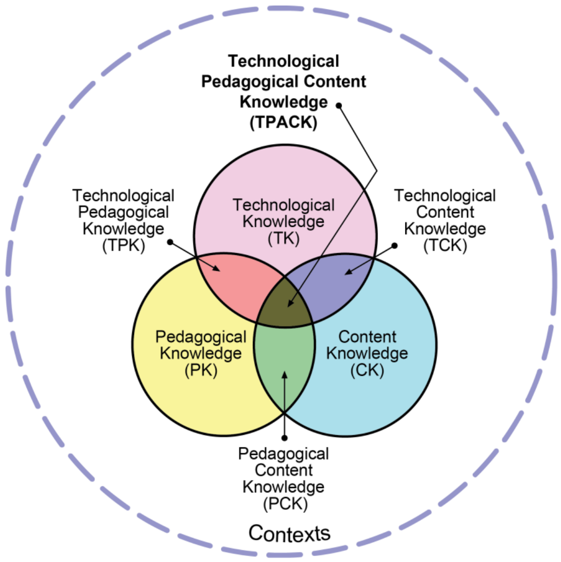

Figure 1. *TPACK graphic. Reproduced with permission from the publisher, ©2012 tpack.org*

TPACK has inspired teachers, teacher educators, and educational technologists to reevaluate their uses of technology to ensure that elements of good technology use, engaging pedagogy, and meaningful content blend together into more effective instruction (Hilton, 2015). For those still skeptical on using technology, the TPACK image will be used to show that when intersecting pedagogy, content, and technology learning can be stronger. The TPACK graphic will be used by teachers involved in the hybrid PD when creating new lessons that use technology to be critiqued by the group. They can map out the points of their lesson that use technology, pedagogy, or content alone and then find the best way to merge what they feel confident in drawing from in all three. In 2009, Schmidt et al., developed a survey for measuring the effects of TPACK's components through a pilot study of 120 pre-service teachers of early childhood and primary education, and found that nearly half of the participants had difficulty planning pedagogically sound technology-integrated lessons without using the framework. The framework has been found to be a useful tool in helping teachers plan and implement lessons incorporating technology in meaningful ways. Teachers need support in the form of PD to learn about and use this framework successfully (Liu et al, 2013; McNeil et al., 2016; Schmidt et al., 2009). This study will aim to increase teachers TPACK as they engage in inquiry throughout the course of the PD. While the structure of PD itself will be built around best practices for changing teachers beliefs on technology-enhanced inquiry based science teaching, the activities built into the PD will include having teachers use the knowledge integration frameworks of SAMR and TPACK to evaluate previous practices and elevate them by increasing TPACK and moving up the SAMR ladder.

Summary

In the year 2018 teachers have been called to adapt pedagogies to include technology and inquiry-based science methods. Teachers in Spring Grove school district have just added more physical technology, technology standards to the science curriculum, and in this upcoming school year, will be held accountable for effectively executing the next generation science standards. Using technology for science teaching has shown to be more effective than instruction without it. However, not all technology use is created equal. Teachers will need support to change beliefs from more traditional to more reform-oriented to change practice so that they may integrate technology in the inquiry-based NGSS classroom so that they can move beyond substitution levels of integration to more transformational applications. There is much evidence to suggest that long-term, sustained PD, where interventionists can support teachers can have an impact on changing a majority of teachers' beliefs on the role of technology in the inquiry-based classroom from more traditional to more reform-oriented. However, there have been some studies that have found success with shorter term PD. Interventions that included teacher inquiry on their own, video of lessons, and group reflections have proven to be effective at changing teachers' beliefs. While much of this data has focused on teacher inquiry with technology throughout the course of the PD, nearly all of the PD has been carried out in face-to-face sessions in the form of summer workshops and after-school meetings with only scarce opportunity to meet online. SAMR and TPACK are two knowledge integration frameworks that teachers will be able to explore throughout the context of the hybrid PD. There is currently room to explore the impact that an inquiry-based hybrid PD can have on imparting change on teachers' beliefs when they are able to access the training through technology at their own convenience.

Chapter 3: Methodology

For the purposes of this study, mixed methods were used to describe the experiences of participants before, during, and after, a six-week hybrid (online and in person) intervention on technology-enhanced inquiry-based science teaching. Mixed methods studies are characterized by the collection of quantitative and qualitative data and are thought of as strong studies because they rely on two-types of data collection (Creswell, 2014). With data coming from both qualitative and quantitative arenas, combining the two can overcome the weakness of close-ended and open-ended data alone to create a more reliable evaluation (Creswell, 2014). Specifically, this study used convergent parallel mixed methods, where both qualitative and quantitative data were collected at roughly the same time so that I then merged both types of data during analysis in order to provide a comprehensive analysis of the problem (Creswell, 2014). In this approach, I analyzed qualitative and quantitative data separately and looked at the results of each to see if the findings confirmed or disconfirmed each other to build a stronger argument in the findings (Creswell, 2014).

Quantitative data was evaluated in the form of recorded lessons from an unmanned video camera and student surveys before and after the intervention for all participants. This data was used to evaluate the impact of the PD on teachers' practice and on their students. Qualitative data was captured through recorded discussions during the in-person sessions, contributions to lesson plans and prompts on the asynchronous online meetings, as well as weekly reflective journals, and a final focus group interview with the participants that was held after the close of the study. This data gave insight into the status of teachers' beliefs on the role of technology and how they see the learning from the PD fitting into their practice. Convergent parallel mixed methods studies provide a deep look into the experience of participants, and this study will thoroughly describe the impact that PD will have on the members of the intervention by using multiple measures.

Logic Model

1) Problem
NGSS calls for students to learn science by doing science. The science field increasingly relies on technology in complex ways. Teachers use of technology for student instruction must be elevated to match the sophisticated uses of technology described by the goals of the standards and the current state of tech in the field .

2) Theoretical Framework: Experiential Learning
Because NGSS calls for students to practice science like scientists, experiential learning is being used as a framework for the intervention. Through experiential learning, teachers will be immersed in the technology and will be given the experience to use the technology in the same way their students and scientists would.

3) Context:
Many teachers are using technology for low-level substitution purposes. NGSS calls for more sophisticated uses of technology. Long-term PD blending technology and inquiry-based instruction together has shown to be successful, however, the district does not have the resources to support a long term initiative.

4) Intervention:
Because experiential learning coincides with NGSS, and the district does not have the money to support a long term PD, a 6-week hybrid in-person and online PD is going to be investigated for its ability to make a change in teachers' beliefs and practice for technology enhanced inquiry-based science teaching.

Research Questions:
The following research questions will guide this mixed-methods study:
(1) How do science teachers beliefs about using technology to teach inquiry based NGSS pedagogy change throughout the course of a hybrid six-week PD course? (Qualitative)
(2) How does technology use change in teachers' science classrooms after participating in a hybrid professional development?
3) What evidence of alignment between technology use, M and R levels of SAMR, and components of NGSS are observed before and after participation in a six-week hybrid PD? (Quantitative)

Figure 2. *Logic Model. Linear flow of thought of the study*

Intervention Design

The intervention was a six-week hybrid PD, where the first and last sessions were held in face-to-face sessions, and the middle four sessions took place in an online Google classroom. Once participants were selected to be a part of the final group, there was a total of five teachers. During the first meeting, participants experienced a technology tool that can be used for inquiry-based science teaching in the same way that students would, and the meeting closed with expectations for the course as well as the establishment group norms. The four online meetings generally followed the same format where first a technology tool was introduced via a mini video lesson and teachers had the opportunity to interact with the tool asynchronously. Midweek, one to two teachers posted a lesson plan on the Google Classroom that incorporates technology and the rest of the group commented on the lesson plan using a protocol. Finally, the week ended with an opportunity for teachers to reflect on the week's learning in an online learning journal. Week 5 of the intervention focused on NGSS, assessment, and technology and gave the participants an opportunity to discuss the impacts of NGSS and inquiry-based uses of technology on how we assess our students. This week also gave teachers a direct opportunity to discuss the discontinuity amongst the grade levels, evaluate if their assessments are aligned to NGSS, and comment on the skills their students will gain by using technology in more advanced ways. The closing in-person meeting had participants reflect on their experience via a protocol and participate in a demonstration of another technology tool. The design of the PD was be re-evaluated each week to ensure that it was meeting the needs of the group and was revised as necessary.

The PD was designed to incorporate successful practices for adult learning in face-to-face and online settings as well as successful practices for adults in a PD on technology-enhanced inquiry-based science teaching. In general, face-to-face PD has been more successful if it is of a longer duration, involves collective participation, a focus on content and pedagogy, and provides the opportunity for active learning (Garet, Porter, Desimone, Birman & Yoon, 2001). This PD incorporated many of these elements including a multi-week format, a focus on using technology in the content area, time for teachers to immerse themselves in the technology and the establishment of a community. The PD spanned a duration of six weeks, focused on using technology in a mini lesson each week, and used protocols and norms to establish a community that would have fruitful conversations. Similarly, online PD that gave participants the opportunity to interact in a community, included elements of active learning, focused on how students learn, and spanned a longer duration have been most successful at making a change in participants (Ostashewski, Reid & Moisey, 2011). Finally, specific to PD on technology and inquiry based science teaching, PD has been most successful if it engages teachers in activities like inquiry-investigations, comparing curricula and pedagogical techniques, analyze student ideas, and critique lesson plans in a mutually supportive teacher community (Borko, 2004; Franke, Carpenter, Levi & Fennema, 2001; Gerard et al., 2011; Lawless & Pellegrino, 2007; Lewis, Perry & Murata, 2006). Throughout the course of the hybrid PD, teachers were given the opportunity to engage in all of these practices as they investigated technology tools, reflected on approaches in learning journals, received feedback from students in surveys, and critiqued each other's lesson plans. Drawing upon the elements of PD that have been successful in both online and in-person environments and PD specific to technology and inquiry science teaching, this PD provided an opportunity to research if hybrid methods can be a viable intervention at imparting teacher change.

The six-week hybrid PD was structured around the adult learning theory of experiential learning. Within experiential learning, there are key components including experience as a source of learning and a stimulus for learning, critical reflection, and interaction amongst communities of practice, which will all be integrated into the PD (Merriam & Bierema, 2013). Kolb's image of the experiential learner is a reflective person who learns as a result of proactively responding to repeated transactions that she experiences over the course of life (Taylor, Marienau & Fiddler, 2000). Therefore, through experiential learning, an adult's life experiences generate learning as well as act as resources for learning (Merriam et al., 2013).

In the beginning of each online week and the introductory meeting of the PD I presented mini lessons on how to integrate technology into inquiry-based science teaching. Participants then used the rest of that week to interact with the different technology interfaces in the same way that their students would. These online learning weeks and first meeting enabled teachers to experience learning from a different perspective other than their own and served as the first step Concrete Experience in Kolb's learning cycle as they experience learning through the lens of the technology-user (Merriam & Bierema, 2013). In Kolb's learning cycle, a concrete experience is a time where adults experience something new from which they are able to reflect on later. As teachers engaged in technology in the same way that their students would, they gained a new experience that enabled them to later relate better to their students. They were able to draw from this experience when structuring lessons using the technology tools.

After the introduction of new technology tools each week, teachers took part in critical reflection throughout the sessions online and in-person through the use of protocols journaling. This enabled them to reflect on practice, as they began to imagine how to situate new technology tools in their classrooms, sending them into the next stage of Kolb's cycle-- Reflective

Observation (Merriam & Bierema, 2013). The third stage of Kolb's cycle is Abstract Conceptualization whereby participants use theories to make decisions and solve problems (Merriam & Bierema, 2013). While in this phase, teachers interacted with each other online to create and refine lessons that were based upon their changing beliefs as a result of participating in the mini-lessons, the online community of practice, and journaling.

Communities of practice, like the community in the small-group PD have been shown to unite members in a shared community of change (Merriam & Bierema, 2013). Teacher's changing beliefs on the role of technology in the classroom were collected as evidence to confirm that they had developed new theories on the role of technology. Finally, when the PD concluded, teachers entered the fourth stage of Kolb's learning cycle Active Experimentation, where they filmed themselves trying out new lessons that integrated the frameworks they had developed from the experiences in the PD (Merriam & Bierema, 2013). Experiential learning was the foundation of the structure and elements of the PD.

Setting

New Jersey passed the inquiry-based NGSS as state standards in 2013, with a mandate for all middle and high schools to align curricula to the standards for the 2017-2018 school year (NGSS Lead States, 2013). Spring Grove Middle School aligned its curricula to the standards during the 2014 - 2015 school year, and also received an influx of technology in the form of twelve ChromeBook carts, two iPad carts, eight ChromeCast devices, and online subscriptions to virtual sites such as Gizmos science simulations in the years following. Additionally, Spring Grove school district added technology standards to all science curricula during the 2017-2018 school year and made technology integration in the content area a professional development focus throughout the same year. In the wake of these initiatives, there is now a heightened focus on using technology for inquiry-based teaching and learning in science in the district. The hybrid PD for this study took place with fifth and sixth grade science teachers throughout the Fall and Winter during the 2017-2018 school year. The PD occurred during six, one-week sessions. The first and final PD took place in a face-to-face meeting in a science classroom at Spring Grove Middle School. The middle four sessions took place in an asynchronous Google Classroom, and followed the same format each week as described in Appendix A. Spring Grove Middle School is a high performing middle school located in central New Jersey. The district is diverse and has higher than average reported family income. About fifteen percent of students receive free or reduced lunch.

Participants

All sixth-grade science teachers from Spring Grove Middle School and all fifth-grade teachers from all eight elementary schools in Spring Grove school district were invited to participate in the intervention. There is one middle school and eight elementary schools in the district. There are six sixth grade science teachers and about sixteen fifth grade science teachers, so roughly twenty-two people were invited to participate in the PD and the study. Fifth and sixth grade science teachers were identified by the science supervisor and the Director of Staff Development, Evaluation and support as in need of a joint PD on technology and inquiry based science teaching because trends in science marking period grades over the past three years have shown a decrease from grade five to grade six. Because grades typically decreased in sixth grade, and are higher in fifth grade, fifth and sixth grade teachers have been selected as needing PD so both grade levels can work together to lessen the marking period grade drop off between the two grades. A PD on technology-enhanced inquiry-based science teaching has the potential to unify some of the teaching strategies between the two grades. In effect, this PD had the potential to lessen the negative trend in marking period letter grades that has been on the rise in the past years. It also had the potential to increase the rigor of each class and the teaching strategies that take place in them.

The Director of Staff Development, Evaluation and Support used a recruitment email to invite all fifth and sixth grade science teachers from each school to participate in the PD. Once invited, teachers indicated if they would like to participate in the PD by signing up via the online PD portal already in use by the school district. All teachers that signed up via the online portal were automatically enrolled in the hybrid PD. All teachers and I were compensated for their participation in the PD monetarily at a rate of $113 per hour via Title IIA monies. All teachers who registered to participate in the PD received consent forms to participate in the study and authorized collection of data in the forms of pre/post video of lessons, lesson plans, dialogue from the in person and online sessions, and online journals that are posted to the online community. They also received consent forms for their students to participate in the pre/post student survey. Five teachers participated in the PD and the selection process ensured a range of skills, are represented in the final group of the PD and the study.

All teachers in the district received a ChromeBook for personal use during the 2017-2018 school year or later, so all participants in the study have some experience related to technology use as the district hosts several online-only platforms including grading, paychecks, and the evaluation system. Beyond the required online systems, teacher experience with technology for inquiry-based science teaching was diverse. Some teachers opted to attend previous workshops on technology applications and use technology in their classes regularly, while others had limited experience beyond personal use. Teachers ranged in length of years teaching from first year teachers to many years of teaching. Additionally, some teachers have taught science at a different grade other than fifth or sixth grade previously. General descriptors about teachers were collected using the table below once the final group was selected.

Participants Name	Years of Teaching	Grade level teaching	Home School	Reported level of technology usage (beginner, novice, intermediate, advanced)
Rachel Augustine	4	6	Spring Grove Middle School	Intermediate
Lori Campbell	15	6	Spring Grove Middle School	Advanced
Teresa Flynn	22	5	Spring Grove Elementary A	Intermediate
Amber Jackson	First year	5	Spring Grove Elementary B	Intermediate
Samantha McDonald	First year	5	Spring Grove Elementary B	Intermediate

Figure 3. *Demographic information. Collected on all participants.*

Goals

Teachers met and interacted face-to-face or online frequently throughout the course of the hybrid PD. The overall goal was for the PD to change teachers' beliefs regarding the role of technology in the inquiry-based science classroom, increasing TPACK, so that they may in turn change their practice and begin to use technology in the science classroom for transformative teaching. Meeting this goal was achieved through giving teachers an initial experience with a type of technology and then asking them to reflect and collaborate with the group on how that type of technology can fit into their teaching. Additional sub goals include:

- Providing teachers experience of interacting with technology in the same way their students would.
- Teachers reflecting on video of expert teachers.
- Teachers evaluating technology use using the SAMR scale.

- Teachers critique/ collaborating on lesson plans that use technology via an online platform.
- Teachers reflecting on how technology can fit into their own practice via weekly-journals.
- Teachers evaluating results of a survey from their students on how technology can play a role in the science classroom.

Data Collection Procedures

In this study convergent parallel mixed methods were used to collect close-ended quantitative data related to teachers' practice and student opinions, and qualitative open-ended data on teachers' beliefs. In this type of mixed-methods study both qualitative and quantitative data will be given equal weight in the interpretation giving a better understanding of the impact of the intervention (Creswell, 2014). Figure 1 depicts the sequence of data collection and analysis in a typical convergent parallel mixed methods study.

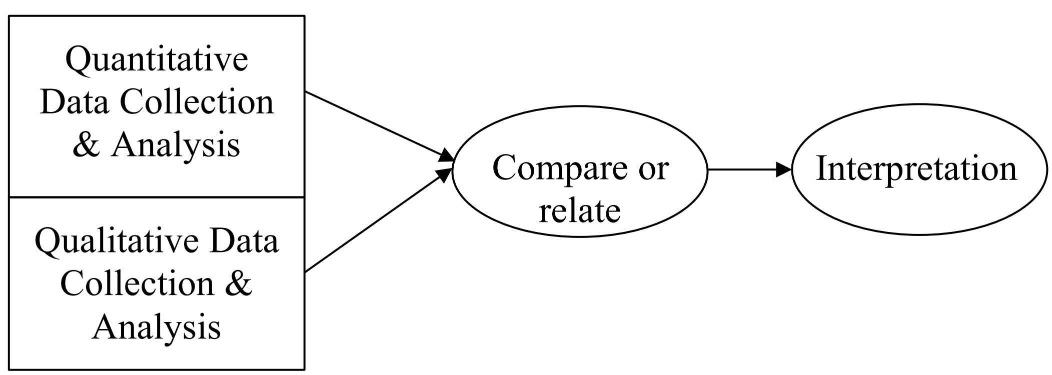

Figure 4. *Description of Convergent Parallel Mixed Methods. Data collection and analysis description of convergent parallel mixed methods. Image adapted from Creswell, 2014*

As qualitative and quantitative data was collected to describe participants' experiences and change over the course of the study, the following table describes the relationship of the research questions to the data collection methods. After the table, the data sources for quantitative data collection will be described in detail first followed by a description of the data sources for qualitative data.

Research Question	Data Sources
How does technology use change in teachers' science classrooms after participating in a hybrid professional development?	● Pre/Post TUSI scores from video recorded lessons ● Pre/Post student surveys ● Lesson plans
How do science teachers' beliefs about using technology to teach based on the NGSS change, change throughout the course of a hybrid six-week PD course?	● Weekly Reflective journals ● Video-recorded in-person sessions ● Weekly dialogue on the online classroom ● Weekly critique/collaboration on the lesson plans in the online classroom ● Focus Group Interview
What evidence of alignment between technology use, M and R levels of SAMR, and components of NGSS be observed before and after participation in a six-week hybrid PD?	● Pre/Post TUSI scores from video recorded lessons ● Pre/Post student surveys ● Lesson plans ● Focus Group Interview

Figure 5. *Research questions aligned with data sources.*

Quantitative data collection. Quantitative data was collected to concretely compare the impact of the PD on teachers' practice as well as student perceptions of teachers' practice from before the PD to after the PD. Quantitative data is collected to examine the relationship among variables that are typically measured on instruments (Creswell, 2014). Results of quantitative data are quantifiable and were used to interpret the effect that variables can have on a population (Creswell, 2014). In this study, the variable that was evaluated included effects of the professional development on the sample of teachers in the study. Data was collected using video recordings of lessons, and a student survey.

Video recorded lessons measured by the TUSI. All participants in this study first video-recorded themselves in a science lesson that used technology using an unmanned SWIVL video camera two times total. First, within the time span of one month before the intervention and again a second time within the time frame of one month after the intervention concludes. The data from the lessons was scored using the Technology Usage in Science Instruction (TUSI) instrument that measures the extent to which technology is integrated into science instruction in ways aligned to content foci and pedagogical practices as highlighted in current reform documents like NGSS (Campbell et al., 2012). The individual items contained in the TUSI can be found in Appendix B.

The TUSI was created in six distinct stages to ensure that it was both valid and reliable including: (1) developing five areas to focus on consistent with technology use for science instruction (2) establishing item content validity with both national and international content experts (3) refining of the item pool based on content expert feedback (4) piloting testing of the instrument (5) checking statistical reliability and item analyses and (6) subsequently refining and finalization of the instrument (Campbell et al., 2012). Throughout piloting and finalization, the instrument was found to have internal consistency and concurrent validity (Campbell et al., 2012). The instrument was also used to measure the change in individuals after an intervention in Campbell et al., 2013, 2014, and 2015 studies. In this study, during data analysis the scores from pre-intervention was compared to the scores post-intervention to see if the PD had an impact on practices. The TUSI instrument was also used in developing codes for qualitative data. Some of the language from the TUSI was used to create codes as a way of looking at collected qualitative data especially lesson plans.

Student survey. Teachers administered a survey to their students on their perceptions of their teachers use of technology. The survey was administered twice, first in the span of one month before the intervention began and again one month after the intervention concluded. The survey was on a Google Form and was anonymous. Containing seven items total, the survey consisted of two demographic questions, two Lickert scale questions, and three open-ended questions. The survey itself is contained in Appendix C. Fifth grade teachers had around thirty students that participated in the survey, while sixth grade teachers had closer to one-hundred students that participated in the survey. Survey research can provide a numeric description of trends, attitudes, or opinions of a population by studying a sample of that population (Creswell, 2014). Additionally, by surveying students, I obtained a large amount of data from a small population of participants (Fowler, 2009).

Qualitative data collection. Qualitative data was collected to examine teachers' experience throughout the course of the PD and gave a look at how teachers' beliefs in regard to the role of technology in the inquiry-based science classroom changed over time. Qualitative research is a means for exploring and understanding the meaning groups or individuals ascribe to a problem (Creswell, 2014). In this study, the problem that was evaluated was that science teachers were not using technology to its full potential in the inquiry-based science classroom. Each week in the PD teachers received one mini-lesson on a technology tool, critiqued/ collaborated on one lesson plan as a group and responded individually to a reflective journal prompt. Qualitative data collection methods included reflective journals to directly evaluate teachers' beliefs, lesson plans as evidence of teachers' learning, dialogue as a means of looking into teacher collaboration, and a final focus group interview for teachers to discuss the overall process.

Reflective journals. At the conclusion of each week throughout the six-weeks of the PD, teachers responded to an online reflective journal prompt that was related to the content covered in that week. In total, participating teachers responded to six journal prompts. The journal prompts focused on how the teachers saw themselves using or not using the technology tools in question. The prompts also asked teachers to elaborate on their beliefs on the role of each technology tool in their classroom. Responses were asked to reach a threshold of two-hundred words or more. The journal prompts were posted Thursday night, and teachers had until Saturday night to respond. Data collection of written documents such as journals enabled me to obtain language and words of participants in a setting that was not face-to-face with so participants may be more open (Creswell, 2014). Journal questions were piloted in science department meetings with seventh grade science teachers not participating in the study before the study began and were revised as necessary. Several studies including Campbell et al., 2013 and Lebak et al., 2010 have used learning journals as a way to measure teachers' beliefs throughout the course of an intervention on technology-enhanced inquiry-based science teaching.

Lesson plans. Each online week (weeks 2-5) one to two teachers posted their own individual plan of a lesson that incorporates technology for the group to review. All teachers in the PD posted at least one lesson plan before the conclusion of the PD. The "presenter" each week posted their lesson plan on the Google Classroom no later than Tuesday for the group to evaluate. All other members reviewed the plan and responded to it using the Four A's protocol. The presenter had the opportunity to respond to the comments and revised the lesson plan as necessary. Artifacts such as lesson plans represent data to which participants have given attention to incorporating themes from the PD and can be useful in identifying how the PD is being interpreted into practice (Creswell, 2014). Several studies including Wilkerson et al., 2016, Krajcik et al, 2016; and Pringle et al., 2015 have used lesson plans as a part of evaluating the effects of a PD on technology-enhanced inquiry-based science teaching.

Dialogue. The entire PD will be hosted via a Google classroom. On the Google classroom, participants responded to various question prompts, and interacted with each other. All of this dialogue was captured on the Google Classroom and gave additional evidence into the changing constructs that the participants adopted. A benefit of capturing online dialogue is that it is already transcribed and easily accessed (Creswell, 2014). Additionally, the in-person sessions (sessions 1 & 4) were video-recorded via an unmanned video camera and then transcribed so that all dialogue was captured and can later be analyzed.

Focus group interview. At the conclusion of the PD, a focus group interview was conducted with participants to ask them about their overall experience throughout the PD, how they felt they changed or did not change throughout the PD, and to address any questions I had about responses on the Google Classroom. Focus groups bring together a small number of people who have had a similar experience so as to raise comfort and discussion level and to provide a greater understanding of the attitudes and perceptions of the participants (Merriam, 2009). The focus group interview will take place in a closed classroom in Spring Grove Middle School and lasted approximately one hour. The focus group interview was audio-recorded via an app on a passcode protected iPhone and was transcribed by a private company. The focus group interview used the semi-structured protocol as listed in Appendix D. The questions in the protocol were piloted with seventh grade science teachers not participating in the study during a science department meeting before the interview and were revised as necessary.

Participant survey. Participants took part in a seven-question survey before the first session of the PD, and after the last session of the PD. The survey asked participants to rank their perceptions of their own technology use, their primary beliefs on the role of technology in the science classroom, and to elaborate on the methods by which they felt comfortable using technology with their students. Containing seven items, the survey had four demographic questions, two Lickert style questions, three open-ended questions, and two where participants selected all options that applied. The survey was not anonymous and was posted to Google Classroom via Google Forms. The survey itself is in appendix E.

Data Analysis

In convergent parallel mixed methods, both the quantitative and qualitative data must be merged together before the interpretation takes place. This study used a side-by-side approach to compare the qualitative and quantitative data. In a side-by-side approach, I first presented the quantitative statistical results and then discussed the qualitative findings (Creswell, 2014). I then looked at the results of each to evaluate any confirming or conflicting findings and provide a rationale as to why. In this study, the results from the pre/post TUSI scores and student surveys were evaluated first, followed by the results of the analysis of the dialogue, lesson plans, and journaling. Interpretation is presented during the findings and discussion portion of the final paper. Data analysis was used to interpret how teacher's technology use changed throughout the course of the study, and how their ideas on NGSS changed throughout the study.

Organizing the Data Set

The data was primarily organized by participant using a color-coding folder system in a passcode protected Google Drive. Within the Google Drive Folder for each participant, data for each participant will be placed in separate documents labelled with a date and organized chronologically by week. For quantitative analysis, the results of the TUSI scores and the student surveys were analyzed using Excel and Google Sheets. For qualitative analysis, dialogue, lesson plans, journals, and focus group responses were color coded by code and a summary sheet on each participant organized chronologically was created.

Quantitative Analysis

Quantitative analysis was used to describe how participants' use of technology, and student perception of their teachers' technology use in the NGSS science classroom changed from before to after the study. Quantitative data was looked at for each individual participant and the group as a whole. Analysis of the survey results and the recording of their individual lessons before and after the study, helped to answer how individual teachers' practices changed from before to after the study as well as if their technology use became more sophisticated on the SAMR scale. Looking at the data on the whole group helped to indicate if the PD had any significant changes on practices from before to after and if the practices became more sophisticated on the SAMR scale.

T-test. General descriptive statistics was run on the pre-data and was compared to the post data for both the TUSI scores and the student surveys. Afterward, a t-test was run on the pre group of data to compare to the post group of data to test for any significant difference in the data sets. Statistics were run and figures were created in Excel. The statistics were run for all individual teachers.

Qualitative Analysis

Qualitative analysis described how participant's opinions and actions related to the role of technology in the NGSS classroom changed throughout the course of the intervention. Data from dialogue, journals, and lesson plans, focus group interviews were transcribed and organized to create codes and later themes about individuals, and the group as a whole. Qualitative data was used to help answer questions about how teachers' beliefs have changed throughout the course of the PD.

Coding/ themes. Analysis of the dialogue, journals, and lesson plans, and focus group interviews centered on the creation of themes surrounding teacher beliefs on the role of technology for instruction after NGSS. Thematic analysis is a qualitative approach that is a method for looking at patterns across interview responses (Merriam, 2009). The main purpose of coding is to link similar data across the interviews. Links amongst the interview responses were identified and grouped so that the data set was described in rich detail.

After transcription of all dialogue, a codebook was developed to create larger themes amongst the data. Merriam's (2009) was used as a guide in reducing the text to create meaning. Codes came from the text organically, in inductive coding after reading over the transcriptions several times. Inductive codes included: examples of technology use, beliefs on the role of technology, beliefs on how technology can be used for science, fears on technology use, and how the PD helped. Codes also came deductively from the literature. Deductive codes also included language from the TUSI instrument to evaluate how well-aligned teachers' language and described practices are during conversations on the in-person sessions and in lesson plans posted to the Google classroom. A code for each of the 8 NGSS Science and Engineering Practices (asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, and engaging in argument from evidence) as well as the 7 Crosscutting Concepts (patterns, cause and effect, scale proportion and quantity, systems and system models, energy and matter, structure and function, and stability and change) were developed. Additionally, any qualitative data that discusses technology was coded according the SAMR scale. Google docs was used to tag the data according to codes. Dedoose was not used because collected video data was not compatible with the program. Google Docs allowed me to look at the data across individuals as well as the group as a whole. Codes were then grouped together to create larger categories (Merriam, 2009). Last, multiple categories were grouped together to create themes (Merriam, 2009).

Creation of Orientation Profiles

Following the initial coding procedures described above, teachers were then grouped into three different orientation profiles based upon their primary methods of technology use after the PD had concluded. The characteristics of each of the profiles stemmed from the orientation profiles created in Campbell et al., 2014 and Campbell et al., 2015. The profiles were tiered to describe the level and approach which participants were aligning technology and NGSS in high SAMR levels in their practice. Additionally, the participants in each of the orientation profiles experienced various levels of change as a result of the PD.

In order to group participants into the three profiles, first, the quantitative data was evaluated. Those participants that had similar average TUSI scores were initially placed into the same orientation profiles. For example, those that had scores within the 40-50 range were placed into the same profile, and those that had scores within the 60-70 range were placed into a different profile. Looking further into the quantitative data, all of the lesson plans and video data were coded according to the SAMR scale and NGSS Science and Engineering Practices and placed into a summary table. Those teachers who had similarities in terms of overall technology use, SAMR numbers, and counts of Science and Engineering Practices remained in the same profile. For example, those that had high counts of S&A approaches to technology use were grouped in the same profile. These data points confirmed the initial groupings based upon quantitative data as the participants had similarities in terms of their beliefs and instructional methods qualitatively.

To build on these initial quantitative similarities, qualitative data was then used to round out the profile and shuffle the participants into new profiles if necessary. First, all of the weekly learning journals were coded and put in a summary table chronologically to evaluate how beliefs and practices had changed. Next, participant survey data and responses from the focus group interview were coded by week to show how participants changed over the progression of time. Finally, I read over each of the summary sheets for each participant and evaluated if final beliefs had changed from initial beliefs and if stated beliefs matched up with practice. Data from student surveys were also used to evaluate if practices had changed from before to after the PD. Following this analysis, it was determined the primary means by which each of the participants is currently using technology in their classrooms and the level of change they experienced. Teachers were finally grouped into profiles because of their similarities in quantitative practice and qualitative beliefs.

Timeline

Date	Events
Early October 2018	● IRB Approval ● Piloted Journal questions, focus group questions, and student survey during science department meeting ● Proposal Defense ● Director of PD invited all fifth and sixth grade science teachers ● The hybrid PD was posted on the district portal ● Participants had a one-week window to sign up for the PD
Mid -Late October 2018	● Participants received consent forms ● Participating teachers video recorded themselves teaching one lesson that uses technology ● Participating teachers administered the student survey

	• I scored the initial lessons using the TUSI instrument
Mid November	• The first in-person session of the PD took place in my classroom
November - early December 2018	• The four online PD sessions were held via Google Classroom
January 2019	• Final in-person session of the PD was held in my classroom • Teachers administered the student survey • Teachers video recorded themselves teaching one lesson that uses technology • I scored the video recorded lessons using the TUSI instrument
January 2019	• One final focus group interview was held with the members of the PD participating in the study
February - August 2019	• Analysis & Writing
Late September/ October 2019	• Defend

Figure 6. *Timeline. Events of the study listed chronologically.*

Chapter 4: Findings

The following section will reveal the findings of the study as they relate to the research questions. First there will be a description of how data analysis was used to organize participants into orientation profiles based on their beliefs and practices on the role of technology in the inquiry-based science classroom, and the level of change that was incurred during and after the PD. Next, the participants' experiences during the PD will be described for each orientation profile. Descriptors will include the practices, general beliefs, beliefs on the role of technology for science, and fears on the role of technology within each profile. Afterward, the profiles will close with a summary of the main findings for the participants in each profile. Finally, the format of the PD as it relates to changes in the participants will be discussed.

Teacher Profiles: Emerging Teacher Practice & Beliefs

After the PD concluded an analysis of teachers' learning journals, videos of their lessons, lesson plans, comments on others lesson plans, individual teacher surveys, and student surveys were used to create profiles to describe the impact of the PD for each participant as detailed in chapter three. Profiles describe each teacher's primary usage of technology at the close of the PD and the changes they exhibited in beliefs practices throughout the length of the PD. Two teachers were found to have beliefs and practices that are aligned with using technology primarily as a means to show what students know, one teacher used technology primarily as a tool for deeper learning, and two teachers drew from both perspectives. The following chronicles the evidence of alignment to each profile as collected from the data of the PD. The goal of the PD was to shift teacher beliefs and practice to make technology use more aligned with NGSS, and all participants showed some elements of change at the conclusion of the PD. As will become evident in what is to follow, some teachers still need more time and practice to make a connection between technology and science, while others were able to capitalize on the connection between the two and use technology in the highest levels of SAMR in lessons that embodied many of the NGSS Crosscutting Concepts and Science and Engineering Practices.

Teacher Profile 1: Technology used for information transmission

Teachers in this profile consistently had students use technology as a means to gather research and to report what students learned from the research and made little change in practice throughout the PD; however, they exhibited a change in beliefs to be more in line with technology-enhanced inquiry-based instruction at the conclusion of the PD. In alignment with the SAMR model, in their practice, these teachers continually used technology for enhancement or the lower Substitution and Augmentation levels of SAMR. Although some aspects of lessons showed elements of the upper SAMR levels, these teachers' practice struggled to make a connection between technology and inquiry and missed out on the opportunity to use science with their students in the same way that scientists would. As far as the Science and Engineering Practices, teachers in this category most commonly used technology in ways that aligned with "Obtaining, Evaluating, and Communicating Information" and passed up opportunities for things like "Planning and Carrying Out Investigations."

These teachers had the two lowest Technology Usage in Science Instruction Scores, Ms. McDonald averaging 44 out of 104 points, and Ms. Jackson representing 49.5. Collectively, they used 23 types of technology, so their struggle was not with overall technology use, it was instead the methods by which it was used. These teachers had the highest counts of the lowest SAMR rankings of Substitution and Augmentation technology usages, with Ms. McDonald coming it at 5 counts of Substitution and 15 counts of Augmentation and Ms. Jackson coming in with 5 examples of Substitution and 10 examples of Augmentation respectively. Student surveys revealed no significant difference in technology tools used before and after the PD.

Because these teachers did not bridge the gap from "enhancement" to "transformation" on the SAMR scale, and mainly used technology to research and report their findings instead of doing investigations in alliance with the NGSS Science & Engineering Practices, they have been classified under this profile. However, these teachers did not remain stagnant throughout the PD. As the weeks passed in the hybrid course, inklings of change towards beliefs in the role of technology for enhanced-inquiry-based instruction became evident in the ways the teachers talked about technology use in the classroom and pointed out some of the flaws in the practice of their earlier lessons. Although these teachers did not experience much change in terms of practice, the PD did impart a positive change on the teachers' beliefs. The following chronicles the two teachers journeys throughout the PD including excerpts from their video lessons, learning journals, and lesson plans. The profile description will close with a look at signs of change in beliefs and practice toward more sophisticated uses of technology-enhanced inquiry-based teaching as well as a discussion of possible explanation for why the teachers have been placed in this category.

The Teachers

Two fifth grade teachers Amber Jackson and Samantha McDonald consistently designed lessons and shared beliefs aligned with using technology as a means for students to gather information and report what they know about a topic. Instead of asking students to design solutions to problems, or pose their own questions about a topic, the teachers facilitated lessons that asked students to do things like watch videos or look at websites to find information on phenomena and then use a platform like FlipGrid to create an expert video on what they now know about a topic. These teachers rarely asked students to make predictions and use evidence to be immersed in or explain phenomena and instead showed videos explaining how a phenomenon happens and asked students to take information from the topic and repeat it in their own words.

Interestingly, both Ms. Jackson and Ms. McDonald are first-year teachers. Ms. Jackson holds a bachelor's degree in Journalism/ Media Studies and a Graduate Degree in Elementary Education. Ms. McDonald has obtained a bachelor's degree in STEM Education, and a Master's in Special Education. The teachers received their respective degrees from different colleges and neither of the teachers has done graduate coursework focused on science education. In the next paragraph, the examples of how the teachers used technology as was revealed in videos of lessons, learning journals, and dialogue will be discussed.

Examples of Tech Use

Throughout the PD, this pair of teachers most often structured their lessons so that technology could be used as a tool for students to view digital sources and then report back on their findings from the sources as to what they knew about a topic. The lesson would typically take on a format where the teachers would give the students media on a particular topic, including books, articles both in print and online, and videos, and had them look into the content for an allocated length of time. Afterward, the students were tasked with reporting the main ideas from the media resources as if they were an expert.

Samantha McDonald. For example, in her first recorded lesson, which was submitted before the PD began Ms. McDonald demonstrated her approach to teaching science via technology in a lesson that centered on learning the basics of levers and pulleys. To begin the lesson, she invited students to post anything they knew or a question they had about levers and pulleys on a virtual Post-Its website called Padlet. She then led the class in reviewing the various postings from the students. Afterward, she explained that students were going to spend the day becoming experts on levers and pulleys, while she scrolled through a list of Google classroom resources the students were to review in order to become experts.

In this lesson, students used a subset of teacher-selected digital resources including videos, weblinks, and a digital book to learn about levers and pulleys posted to Google Classroom for the students to peruse and obtain pertinent information from. Working in predetermined partner pairs, the videoed lesson revealed that students were thoroughly engaged in the topic. One pairing even remarked that they were "...surprised elevators use pulleys" to lift heavy loads. As a closure to the lesson and to assess the students understanding, Ms. McDonald asked the students to create a video on FlipGrid asking a question they still had about levers and pulleys. Afterward, each student was responsible for answering a question from another student in a second FlipGrid video using the evidence gathered from the online resources. FlipGrid videos enable students to record a short video and post it to a location where the rest of the class can access and respond to it.

While this lesson engaged students with many technology resources its use is not particularly sophisticated or in alliance with the NGSS Science & Engineering Practices or ideas presented in the PD. The engagement was superficial and did not ask students to explore or collect data on phenomena on their own. The uses of Padlet and Google Classroom were more in line with Augmentation in the SAMR Scale and most in line with the Science & Engineering Practice of "Obtaining, Evaluating, and Communicating Information." While the use of FlipGrid was evaluated at a Modification level, the lesson could have been transformed to more elevated uses of technology and more alignment to inquiry-based practices if Ms. McDonald had driven the lesson from student questions, they posted in the FlipGrid. The process evident in this lesson whereby students learned from the sources in the technology instead of using the technology to engage in describing and understanding a phenomenon, places all of the control on the teacher, and does not enable the students to delve into discovery.

Not all technology use is created equal. In this lesson it is very evident that students had used the technology to summarize what the main ideas of the digital sources to show what they know instead of acting like scientists and engaging with the material through discovery on their own, with the teacher taking the role of the facilitator. Because this lesson took place before the PD began, it reveals Ms. McDonald's understanding of how technology and science can be merged together. She had not yet engaged with any of the material the PD would cover, and this initial lesson shows very little understanding of using technology for enhanced inquiry-based instruction and instead demonstrates comfort with using it have students find answers by summarizing sources that can be found online. Students made sense of the phenomena of levers of pulleys by reading about how they work instead of designing experiments or building levers and pulleys to test their functions.

In Ms. McDonald's week three lesson plan students were again confined to the same lesson set up of posing a question, looking through teacher-selected resources, and then summarizing what they knew on the topic using a technology tool to demonstrate understanding. In this lesson, the objective was "Students will be able to create an expert video answering focus questions on a specified Trashpower topic." This teacher repeated terminology similar to the first lesson and set her students up to engage with the technology in the same way. The low levels of SAMR and low alignment with NGSS Science & Engineering Practices come not from the objective, but the approach to how students collected data and interacted with technology to obtain that objective.

In this lesson, students were assigned a topic, then browsed through various teacher-selected media including websites and videos, and finally were asked to create a video as if they were an expert on the topic that would be shared with the class. Assigning students to groups of two or three, in this lesson titled "trashpower" Ms. McDonald gave each group a different type of renewable or nonrenewable energy resource to become an expert on. She then described where students could find resources on the topic on her Google Classroom page which included Brain Pop videos, Ed Puzzle videos, and various weblinks. To capture what students had learned about a topic, she asked them to create a FlipGrid video listing the facts they had obtained from looking at the teacher-selected resources. As a closure to the lesson, students were asked to watch another group's expert video and post either a question or comment in response.

Although this lesson again used many different technology tools, the technology use itself ranked low on the SAMR scale in the Augmentation range. Because the teacher assigned students the topics they were to learn about and provided all of the resources they obtained the information from, the lesson remained very teacher-driven and technology was only able to mildly enhance what could be done without it. This lesson did not give students the opportunity to explore the phenomenon of using trash for power but instead had students summarize their readings from the list of teacher-compiled resources. In terms of the NGSS Science and Engineering Practices, this lesson drew heavily from "Obtaining, Evaluating, and Communicating Information" because students did not ask their own questions and did not have the opportunity to try and make meanings of phenomena on their own.

At this point in the PD, teachers had been introduced to Google Science Journal, Google Tools, and Flip Grid. She could have worked from these sources, using an inquiry-based approach, and taken the lesson in a different direction. Some of the comments left by other teachers on the lesson plan had even pinpointed that students should have been able to ask their own questions. In this lesson, as the weeks progressed, Ms. McDonald still continued with her same approach of primarily using technology to show what students know, but she did begin to incorporate some elements of inquiry-based learning.

In a last example during week five in the PD, Ms. McDonald started to show minor elements of change, and by departing from her typical lesson structure, was able to incorporate higher-level SAMR approaches and more of the NGSS Science and Engineering practices. With a focus on levers and how they work, Ms. McDonald asked students to use Google Drawings to create a model of a lever. She then had the students record a video explaining where the fulcrum and load was in their drawings, and what would happen if you moved the load closer/ farther away from the fulcrum. Beginning the lesson by showing students the basic functions of Google Drawings, Ms. McDonald had students work independently to draw their models and record videos explaining their functions. The usage of Google Drawings in this instance was classified as Augmentation because the online features of Google Drawings only have minor upgrades from doing it on paper. Similarly, the use of ScreenCastify was classified as Augmentation on the SAMR scale because students could have achieved the same results if they were to do a presentation on their levers. Both technology applications aligned with the Developing and Using Models, and Obtaining, Evaluating, and Communicating Information elements of the NGSS Science and Engineering Practices.

Although the technology used in this lesson did not bridge the gap from Augmentation to Modification, Ms. McDonald is beginning to show some elements of student-inquiry. Instead of asking the students to view a video on levers and then make a model based on the video, she designed the lesson so that students made predictions on what would happen if they changed the location of the load based on data from experiments carried out in class. Different from the first example, Ms. McDonald has given some control to the students by asking them to make models on their understanding from the data they collected. While this example shows inklings of change toward technology-enhanced inquiry-based teaching, the lesson could have been elevated with a few tweaks.

In this final example, Ms. McDonald departed from her typical format of giving students resources to look at and summarizing what they had learned from those sources by having them create an evidence-based model. While this approach represents a drastic change from all of her other submitted lessons, it was the only lesson where students had the opportunity to "Develop and Use Models" via technology in all of the examples that were gathered as part of the PD. It was also the only instance where students had control of their creations and used evidence to back up claims. She remains in this category of using technology to primarily show what students know, because even after the PD had ended, she submitted a final lesson plan where students demonstrated understanding by looking at sources she had posted on Google Classroom and then created questions and answers for a Jeopardy Game that would be used as a class review. Because her post-PD recorded lesson on levers showed some inclinations toward change, but it remained alone as an example of technology-enhanced inquiry-based instruction, the PD had a mild effect on her technology usage, but it did impart some change in practice for at least one lesson.

Amber Jackson. The second teacher classified under this profile; Ms. Amber Jackson had a similar experience with technology for science use throughout the PD. Many of her lessons mirrored Ms. McDonald's in that students were given a topic, used teacher-selected resources to gain knowledge about the topic, and then used technology to recap what they had learned about the concept. The following will give an in-depth look into a few of Ms. Jackson's lessons and their relationship to SAMR, the Science & Engineering Practices and technology-enhanced inquiry-based teaching, as well as one lesson where components of the PD were present in her teaching.

In her initial lesson plan, posted before the PD began, although the topic of the lesson varied from Ms. McDonald's, Ms. Jackson's lesson followed the same exact format. This lesson targeted students becoming experts on the Greenhouse effect. The lesson began with a partner-pair-share activity where students discussed what they knew about the concept of the

Greenhouse Effect or a question they had about the Greenhouse effect. Next in order to obtain information on the Greenhouse Effect, Ms. Jackson explained that students would be rotating through four centers for the next 60 minutes. Each of the centers had an artifact for the students to explore including textbook pages, Brain Pop videos, YouTube videos, and pictures. As a culminating activity, students were asked to create a FlipGrid Video that explained one key fact they learned about the Greenhouse effect and how it impacted Global Warming.

The technology uses in this lesson had very little to do with scientific practices, and more to do with gaining the main idea from different resources. Students were not asked to design models or experiments, or collect evidence to make claims from, instead, they were given many different Substitution and Augmentation digital media sources that stated a multitude of ideas about the Greenhouse Effect and were tasked with summarizing the main ideas from these sources. Students were not acting as scientists, but more like good readers, as they pulled out compelling details from the sources they were given.

Four weeks later in the PD, not much had changed in terms of Ms. Jackson's approach to technology use. In her week four lesson plan posted to the group to comment on using the 4 A's protocol, the topic of the lesson was on renewable and nonrenewable energy sources. Even though the focus of the lesson had shifted, she took a nearly identical approach to using technology in this lesson as the lesson above, and to Ms. McDonald's week three lesson plan. Students were placed into predetermined groups and the teacher explained that students would be cycling through six centers on different types of energy sources. The centers had various information on the energy sources including print, picture, BrainPop Videos, Wonderopolis Articles, and YouTube videos. Wonderopolis is a technology tool that sends articles to students on their own reading level. Four out of the six stations had information that was presented via a technology source, which ranked low on the SAMR scale. As students cycled through the stations, they recorded their learnings on a foldable graphic organizer. This time, students did not use a technology tool to report out what they knew, instead the foldable was collected as a formative assessment. The focus of the lesson was on collecting facts and the only Science and Engineering Practice that the lesson aligned with was “Obtaining, Evaluating, & Communicating Information.”

This lesson clearly had many missed opportunities for technology-enhanced inquiry-based instruction. Another teacher in the group even commented on the lesson plan suggesting there could have been more interaction with science and technology than simply reading. Lori Campbell commented on the plan questioning “Can a STEM component/station be added where students "design" a type of alternative energy and create a model? It can be anything, but it would be a way to get them thinking about problem-solving for alternative solutions.” At this point in the PD, teachers had been introduced to Google Tools including Google Drawings, Science Journal, and Gizmos Science Simulations. The teacher could have drawn from these ideas to create a STEM design challenge or used simulations to make evidence-based models. Even while being immersed in the PD for four weeks, very little had changed in Ms. Jackson’s approach to using technology in the science classroom and there was nearly no opportunity for inquiry-based instruction.

In her final lesson, submitted after the PD, Ms. Jackson still held tight to her format of the lesson plan and her usages of technology, but she began to show minor elements of change. Throughout the six weeks of the PD, teachers had been introduced to using technology for design challenges, how to create evidence-based models, implementation of technology for skills-based assessments, and although the changes were slight, there were small components of these technology-enhanced inquiry-based instruction techniques evident in the plan.

The lesson focused on the topic of levers and was a review before an assessment. Once again, the students moved about the room in centers. This time, there were four stations, and each of the stations involved a type of technology tool. Station one tasked students with creating a FlipGrid video explaining what happens to the effort if the effort was moved away from the fulcrum and what would happen to the effort if the load was moved away from the fulcrum using evidence. Station two had students create a Google Slides presentation with five examples of real-life levers and to label the effort, fulcrum, and load. Asking students to watch a video on how to read a graph, and then to interpret one on a worksheet, Station three used technology to replace the teacher, and this approach ranked low on the SAMR scale. The final center, Station four, asked students use a Google Slides presentation to define a term from the levers unit. In this station, technology was used in the way it was mostly used throughout all of the examples she shared during the PD: to show what students knew.

Although this lesson did not depart far from the other lessons described above, there were some minor improvements in practice that can be linked back to the PD. For example, when students created the FlipGrid video, they were not only asked to just describe facts that they knew about levers, but they were to provide evidence of what they knew. This relates back to Week two's mini-lesson in the PD where it was demonstrated how technology could be used to make evidence-based models. Although the use of technology is still centered on having students tell what they know, it now has evolved to include one of the Science and Engineering Practices of Engaging in Argument from Evidence. In station two, students were able to connect their learning inside the classroom to real-life levers, a component of week five of the PD, and the parts of the levers as if they were a model. This use of technology aligned with Augmentation on SAMR and Developing & Using Models in the NGSS Science and Engineering Practices. Ms. Jackson was also able to use technology to bridge the gap from the classroom to the real world by asking students to explore real-life examples.

However, in Station three, Ms. Jackson made very little connection between science and technology. Students watched a video and then used what they learned in the video to read a graph. This usage of technology ranked in the Substitution range did not align with the NGSS Science & Engineering Practices and did not represent a change for Ms. Jackson. Station four, where Ms. Jackson used a Google Slides presentation for students to define vocabulary terms, also ranked low on the SAMR scale in the Augmentation range and saw Ms. Jackson relying on her most familiar technique of using technology to show what students know.

Throughout all of their examples of technology use that were shared during the course of the PD, both of these teachers used technology as a tool to show what knowledge students had gained from the activity. In each lesson, the teacher controlled the sources that students were to evaluate, and technology was not used for designing prototypes or experiencing simulations to make conclusions but was instead used to dispense information and have students repeat it in a technology-assisted form. Nearly all of their lessons ignored the way in which technology was presented in the PD for STEM design projects, creating evidence-based models, and skills-based assessments. Students most often interacted with technology to "Obtain, Evaluate, and Communicate Information," which is only one of the eight Science and Engineering Practices. Technology use in the classroom rarely was used in the likeness of scientists in the Modification Range. However, there were some inklings of change in both Ms. McDonald's and Ms. Jackson's lessons near the latter end of the PD; Ms. McDonald in the form of using technology to "Develop & Use Models," and Ms. Jackson in the form of "Arguing from Evidence." Although both teachers demonstrated minor changes throughout the PD, the examples they submitted in lesson plans and videos demonstrated that their primary practice of using technology in the science classroom is to obtain information and show what students know.

Beliefs

Throughout the PD the teachers expressed their beliefs on the role of technology in their weekly learning journals and in the focus group interview. While much of these two teachers' practices did not change significantly during the PD, it seems the PD was more effective at changing their beliefs toward a greater understanding of technology-enhanced inquiry-based science teaching. In the beginning, their beliefs were more in line with the practices from the lessons described above, but as the weeks progressed, they were able to communicate ideas that showed they believed technology could play a significant role in the science classroom. Eventually, their beliefs departed from the lesson format described above where the teacher was largely in control and technology was used as a tool to summarize what students knew, to demonstrating an understanding of how technology can be used for inquiry. On the whole, both teachers' beliefs centered around the fact that technology can increase engagement, immerse students in critical thinking, and can be a tool for guided discovery. The following will explore the teachers' changing beliefs throughout the six weeks of the PD.

At first, the teachers demonstrated a limited understanding of how technology could enhance engagement, critical thinking, and guided discovery in terms of acquiring science skills, but as the weeks moved on, they were able to express confidently that technology could and should be used to enhance inquiry-based science instruction. In terms of beliefs, there was even a break-through moment where Ms. McDonald and Ms. Jackson realized that they hadn't been using technology for science at all but rather to review. The paragraphs to follow will show that, seemingly in response to elements in the PD, teachers beliefs moved from a basic understanding of why technology was a "good" tool to use in their classroom to a more advanced understanding of how technology can enhance scientific literacy. The later beliefs of these teachers reveal more advanced understanding on how technology can be connected to science, however, as evidenced in the lessons above, they have not yet made the transition from belief into practice.

Throughout the span of the PD, both teachers began to praise technology for its ability to engage students in the elementary classroom. This was a belief that was unwavering throughout the PD and grew in strength toward science inquiry as the weeks went on. At the beginning of the PD, in her week two learning journal, Ms. McDonald wrote "Technology keeps students organized and engaged. Throughout this video, every student was determined to making their water filtration system work and the use of the technology played a major role in their enthusiasm." In week two of the PD, participants watched a video of a design challenge whereby students had to create a water filtration system, and technology was used in every step of the way including planning, creating, testing, collecting data and evaluating. In her comment, she missed the mark on how technology was used to aid in the science behind the design challenge but does see the value in that technology can increase the overall engagement of the students.

Later in the PD, she noted that technology can increase engagement in the activity while also increasing the engagement in science skills for the students. Leading up to week four of the hybrid PD, the course had focused on using technology for science in design challenges, simulations, and modeling. In her week four learning journal, Ms. McDonald made a connection between some of the ideas in the PD and how technology can be used to increase both engagement and science skills. She wrote “Google tools including science journal can definitely be beneficial for an inquiry-based science class. Students love opportunities to explore scientific experiments on their own. To do this using a technological tool is something my fifth graders love.” Whereas in her prior statement Ms. McDonald boasted of the engaging factors of technology very vaguely focusing on organization, in this statement she is clearly able to articulate how technology can increase engagement in science. She alludes to the fact that through inquiry, students are able to explore and question in the likeness of scientists and use technology to gather evidence to back up their claims using a tool like Google Science Journal. She was not, however, able to provide a concrete example.

Like Ms. McDonald, Ms. Jackson too had always believed that technology could be an engaging tool for her students, and as the PD continued, she was able to articulate more specifically how technology can be engaging for science. In her week two learning journal, she responded: “I believe technology can greatly increase engagement and learning in the NGSS classroom, I hope to increase my toolkit of technology resources.” Focusing on how students can use technology to show what they know instead of how it can be used to increase engagement through focusing on science skills, at the beginning of the PD, Ms. Jackson did not have strong beliefs on how technology can be implemented to enhance science learning. She believed technology can enhance the classroom overall because students are more engaged with showing what they know on multiple sources instead of just the same platforms all the time. While this strategy can enhance engagement in a topic it has a weak connection to how technology can increase excitement in developing science-specific skills.

Building upon this notion of engagement, weeks later in the PD, Ms. Jackson was able to see how the increased engagement in technology can be applied directly to an increase in students' attainment of science skills. In her week six learning journal she points out flaws in her previous methods of using technology and lists the inquiry-based ways that she now believes will engage her students more and also develop their skills for doing science. She wrote,

> I often used technology as assessment previously but have gained insight into using technology to introduce concepts, provide...instruction, assist students in gathering data, and simulate or supplement experiments.

In this statement, she is describing ways that technology can be used to draw students in specifically for science through gathering data and simulating experiments. By contrasting these methods with the previous methods by which she used to teach, she is demonstrating new beliefs on how technology can be implemented to impact the science learning of students. She now sees that using technology with students is not enough and believes that engaging approaches to technology can purposefully impact science learning.

Moving from engagement, in terms of critical thinking, both teachers experienced a similar change in beliefs over time. When the PD began, both felt more generally that technology can be used to increase overall critical thinking amongst their students, and demonstrating change, near the end of the PD their beliefs became more specific as to how technology could enhance scientific critical thinking for their students. Critical thinking refers to student use of analysis and evaluation to draw conclusions on more open-ended issues as opposed to learning prescribed facts. In Ms. McDonald's week two learning journal, she expressed vaguely that "Technology can change the way students use their critical thinking and reasoning skills." With this blanket statement, she believes technology can enhance instruction but isn't quite sure how it can be implemented to develop science skills. She clearly believes technology is a beneficial tool but cannot describe how it will improve the science classroom.

Yet later, near the close of the PD, in week four, Ms. McDonald built upon her previous statement and made a connection between technology, critical thinking, and science instruction for her students. She wrote in her learning journal

> Science simulation tools can play a positive role in the NGSS science classroom. It opens up opportunities for students to explore concrete formats that scientists actually use. Not only will they be able to make connections among different sets of data, but it allows for students to become active participants where they ask high-level questions and make worthwhile predictions.

In this statement, Ms. McDonald voiced that technology-based simulations do more than enhance students to think critically, they also help students to make predictions and collect evidence in the same way that scientists do. Whereas many of her other statements on the role of technology were about how technology can assist the teacher primarily, in this excerpt she described how technology can be used to reinforce the science first. This demonstrates an understanding of more advanced beliefs as Ms. McDonald is beginning to believe that technology can be used to enhance science skills, and through increasing science skills, critical thinking can also be enhanced.

Similarly, Ms. Jackson began the PD vaguely believing critical thinking can be enhanced by technology and ended the PD with specific beliefs on how technology could make a difference. In her week three learning journal she described how technology can increase the critical thinking of students by asking them to complete different types of tasks and can assist the teacher by making formative data collection more efficient. She responded “Technology gives us more opportunities to assess students and collect data on student learning. This allows me to...benefit both the student in practicing with different types of tasks like speaking, writing, designing... and myself as the teacher." Centering on how students' critical thinking skills can be tested on multiple forms of assessment, Ms. Jackson elaborates on how technology can enhance critical thinking without touching on how it can be expanded to science. With this lesson, she is more focused on assessment than learning. She described technology as a tool that will challenge her students and enable her to collect more data but does not delve into how critical thinking can be expanded for science through technology.

Although Ms. Jackson's first beliefs on critical thinking in her week three learning journal made a limited connection to technology and science skills, she was later able to draw from elements of the PD to show an increased understanding of how technology can be used to increase critical thinking in developing science skills for her students. In her week five learning journal, the week after simulations were the main focus of the mini-lesson, she described a scenario where she used simulation to simultaneously increase critical thinking and science skills for her students

> I used a Gizmo last week with levers. Students had done the work on their own model levers in class, but using one in the simulation allowed them to think more about the real world - for example, if I wanted to lift a pig, how much effort would it take, where should I stand on the lever, etc. They can begin to inquire and actually test out their wonderings in a way they cannot on their classroom lever.

Unpacking her words, in this response, there are many indicators of changing beliefs as to how technology can enhance both critical thinking and science skills. She first explains how the simulation was able to expand on models they had created in class, which is an example of using science skills for critical thinking. Scientists often develop models to test out the real world. She also describes a sequence of events where students can make predictions, test those predictions, and make conclusions about concepts by gathering data that is collected in the simulation. This describes using critical thinking and implementing a technology tool to have students do science instead of learning about it using teacher-selected resources. This reflection gives a clear depiction of how Ms. Jackson's beliefs on technology now encompass that it can be a tool for both critical thinking and inquiry.

Finally, the biggest change in beliefs as a result of the PD came from the teachers' point of view on how lessons should be structured. Near the conclusion of the PD, both teachers were able to pinpoint weaknesses in their initial teaching methods because they weren't using technology to enhance science specifically, but rather to enhance reading skills or for classroom management. Although their practice did not change much, their beliefs did. Both of these teachers who primarily use technology to show what students know were able to verbalize that technology should and can be used to enhance science skills and came to the realization that their prior practice was falling short of doing so.

In the focus group interview, Ms. Jackson elaborated on her prior practice of using technology and in a different learning journal is able to elaborate on how that practice needs to change. She said

> How I was using it before was mostly for, I would say, assessment or even just as a closure activity. So a lot of it was letting them make a Flipgrid, showing what they learned and kind of more of an open-ended thing. I wasn't really using it for the bulk of the learning like where they would actually be receiving information.

This statement indicates her prior belief that technology could only be used for formative assessment and as a means for students to show what they know instead of as a teaching tool. With this statement, she is also showing a maturation in the approach to how technology should be used for science. By recognizing that implementing technology as a tool to show what students know is not enough, she is showing that her beliefs have changed on how technology should be implemented in the science classroom.

When reflecting on her earlier lesson as part of the focus group interview, Ms. McDonald reiterated this notion, realizing that she hadn't really used technology for science but more as a tool for students to show understanding or for review. She stated

> I would use it for closure. We used Flipgrid at Central. Yeah, centers, so we would do different centers and they would rotate on the computer. But we didn't really do it, yeah as a teaching tool. We just did it as a tool to, honestly review, or just assess.

Before the PD neither teacher had thought about how technology could be used to support inquiry in science but instead through of it more as a tool to collect formative data on their students to inform their teaching. As the weeks went on, these teachers began to believe in various ways technology could be used to support science.

In a week 4 learning journal Ms. McDonald summarized how technology can be used for science. She wrote:

> Often times students feel compelled to memorize and cram knowledge in their heads that they end up forgetting in a few days anyway. What's great about NGSS is that they work to create assessments that are high-quality scenarios that focus on the big picture or problems we face in the world. Not only has my tool kit expanded, but I can recognize the need for inquiry-based learning.

Ms. McDonald contrasts her prior methods of teaching against the new ones she has learned in the PD and sees that implementing technology for inquiry-based instruction is more important than how she previously used technology. She speaks for both teachers who have developed more advanced beliefs and understanding of how technology can be used to develop science specific skills.

Although neither of these teachers' practices seemed to be highly impacted by the PD, their beliefs on the role of technology in the NGSS science classroom continued to evolve as the weeks went on. Initially, both broadly thought technology was a good thing to have in the classroom but could not articulate how or why it mattered for science instruction. However, over time, not only did their feelings on the importance of technology continue to grow, they were able to state specific ways and applications of technology that could be used to enhance science skills. The most telling piece of evidence that these teacher's beliefs exhibited change as a result of the PD, came from their own realizations near the closure of the PD that they weren't using technology with their students in the likeness of scientists at all, but rather to collect formative data. Largely, this PD was able to shift these teachers' beliefs from relying on it as a tool to show what students know, to a tool to enhance the development of scientific skills such as modeling, data collection, and student-led questioning and discovery that dominate science outside the classroom. This shifting of beliefs from technology as a formative assessment tool to technology as an enhanced inquiry-based instruction tool, show a more developed understanding of how technology can connect to NGSS instruction.

Technology for science. Building upon these changing beliefs, throughout the course of the PD, these teachers were confidently able to articulate benefits that technology has for science teaching. Specifically, Ms. McDonald and Ms. Jackson valued technology for its role in science instruction because of the value added to learning that came from virtual simulations, its ability to bridge the gap from the classroom and give students the opportunity to explore real-world issues, and most importantly that technology could be an important factor in student's engaging in guided discovery. These science-specific beliefs contradict many of the methods of using the technology they demonstrated in their lessons yet show an enhanced understanding of the many science-specific ways technology can be used to build skills similar to those of scientists in the classrooms. These statements are more in line with the NGSS Science and Engineering Practices and higher levels of SAMR and show that both teachers were able to internalize some of the instructions from the PD into their own belief subset. The following will delve into the teacher's science-specific beliefs as evidenced by their weekly learning journals, videos, lesson plans, and focus group interviews.

One method whereby technology can enhance science instruction comes from online simulations. Gizmos science simulations were a main focus of the PD in week four, where all teachers were given the opportunity to explore this online platforms and search for simulations via content, DCI standard, or grade level. Because of their ability to engage students in trial and error and enable them to create and test predictions in real-time, virtual simulations were an example of technology that was included in the PD as a way for students to gain science skills through almost game-like interactions. Out of all of the applications that were highlighted by the PD, simulations were the one tool these teachers latched onto and were most impressed by throughout the six weeks.

Both teachers felt that science simulations made a difference for students because of their ability to make things possible that could have never occurred in a classroom setting. In Ms. Jackson's week two learning journal, which she wrote before simulations were introduced in the PD, she described, "Another benefit for students is the increased access to things they can't see or go normally, by way of interactive field trips or videos." She followed up on this idea in her week four learning journal after simulations were introduced "They can allow students to perform experiments or investigations without having complex or dangerous materials available…" Noting that simulations enable students to gain skills without the constraints of danger or time for travel, Ms. Jackson points out that virtual simulations are a way to connect science learning and technology. Ms. McDonald agrees with this sentiment and in her week four learning journal, she wrote, "it's a great tool to show an experiment that would normally take weeks to complete in a matter of one class period." With these statements, the teachers articulated that simulations are valuable for science because they allow students to engage in skills that scientists would use unhindered by limiting factors that would constrain physical experiments from taking place inside their classrooms.

The teachers also pointed out the value in simulations for their ability to integrate instruction across content areas and to make connections to real-world phenomena. Ms. McDonald responded in her week four learning journal:

> however, it is such an important tool to help integrate across subject areas. I think it is a positive attribute that the science simulations also use mathematical tools/graphs. That connection is such a major step in showing students that subject areas overlap all the time.

She believes that by using simulations students will be able to transfer their skills gained from the technology tool to other subjects such as math. Directly in alliance with the NGSS Science & Engineering Practice of "Using Mathematics & Computational Thinking" a component of week two in the PD, this connection shows an enhanced understanding of using technology in science to focus on transferable skills rather than memorization of facts in science.

Ms. Jackson also notes that simulations enable students to test real-world elements in a way that other hands-on labs may not. In her week four learning journal, she elaborated

> A baking soda volcano, for example, can look like a real volcano but students don't actually form connections to real volcanic activity like they would if they engaged in a simulation where they adjusted the environmental constraints to cause a volcano to erupt.

With this statement, Ms. Jackson is bringing into focus the NGSS Practice of "Interpreting & Analyzing Data" and linking back to ideas presented in week four of the PD. Through interpreting data produced from lifelike simulations, she described students were able to gain access to their own understandings on how phenomena such as an erupting volcano can take place that may have been limited or caused misconceptions had physical labs taken place. In this description, Ms. Jackson is articulating a Modification example of technology because the simulation allowed for significant task redesign in how her students learned.

Overall, the teachers believed that simulations played an important role in the development of science based-skills for their students. They recognized how simulations gave students access to supplies, events, and designs that would not be possible within the classroom due to limiting factors such as time, space, or danger. As simulations enabled students to make predictions and manipulate variables to test those conclusions in real-time, the use of these in the classroom aligns with the NGSS Science & Engineering Practices, higher levels of SAMR, and components of the PD. The pair was also able to relay the importance of simulations to connect with other subjects and to make connections to real-world phenomena. Through these statements, the pair show an enhanced understanding of the benefits of simulations for science learning drawing from elements presented throughout the PD. Although both of these teachers were able to articulate the benefits of simulations in terms of science learning for their students, only one teacher, Ms. McDonald submitted a lesson that used simulations throughout the PD.

Again, the PD seems it was able to impact only beliefs but that those beliefs had yet to be extended into practice.

In addition to describing the benefits of simulations, Ms. McDonald and Ms. Jackson saw technology as a valuable tool to connect students with elements of the real world as a way to enhance their development of science skills. Both teachers repeatedly mentioned technology's ability to connect students with experts in their field and also to collaborate with students from around the globe. In the week two mini lesson, teachers watched a video where students were immersed in a design project and Skyped in with a scientist who worked at a water filtration plant. Then, using some of the elements from the discussion, the students built or modified prototypes of a water filtration system and gathered data on how successful their device was in the likeness of the scientist they had talked to. Both teachers were inspired by this interaction and penned in their week two learning journals their take on how technological interactions with scientists can enhance learning for students. Ms. McDonald wrote, "in addition, it will open up technological connections with people outside of just their classroom walls." Similarly, Ms. Jackson described "they were able to Skype with someone who actually does related work professionally...one of the biggest benefits of technology in the Science classroom is the ability to connect students with real-world uses for the knowledge they are acquiring." Both teachers feel it is important to connect their students with a professional, and Ms. Jackson was able to make a connection on the importance of students learning science concepts that are rooted in the real world. Additionally, in their post-PD survey, both teachers checked off "simulations" as one of the tools they would feel comfortable using in their classroom, while neither teacher had selected this tool prior to the PD.

Continuing on the previous trend, however, neither teacher submitted a lesson throughout the PD that engaged their students with a professional via technology. Their acknowledgment on the importance of this concept shows their beliefs shifting toward a greater understanding of technology-enhanced inquiry-based learning, but their practice still has not changed. Had these teachers created a lesson similar to the one shown in the video, their technology use would have been elevated to an M or even Redefinition on the SAMR Scale and their students would have been using technology in line with the NGSS Science & Engineering Practices of “Planning & Carrying out Investigations”, and “Analyzing & Interpreting Data.” It seems these teachers’ beliefs are making changes before they are able to bring to life new lessons that will impact their practice.

Finally, the largest and most important change in the teacher’s beliefs was their realization that technology can be used as a means for students to learn science skills from guided discovery. In this method of using technology, students would be “doing science” with the technology, instead of learning about science from a technology tool. This use of technology would reach the highest levels of SAMR and engage students most thoroughly in nearly all of the NGSS Science & Engineering Practices as well as components of the PD. Ms. McDonald described how using technology for guided discovery in her classroom would make a difference in the way students obtained science knowledge.

> I feel like a lot of our classes are 80% us talking ... I learned this somewhere ... 80% us talking, 20% students talking, and I feel like it (technology) will alleviate us being so much of the main person in the classroom, whereas the kids now have more of a voice, and it's less of us guiding them, and more of them guiding themselves.

In this statement, Ms. McDonald is giving evidence that she has developed an understanding of what giving students independence in science learning toward guided discovery is all about. She is drawing from elements that were reinforced in each week in the PD to help teachers see that technology does not have to be used as a tool for students to read about science, but a tool that students can engage with science. Her notion of students being able to guide themselves and use their own voice shows she is developing an understanding of students acting like scientists to collect data and make conclusions. With these statements, she has demonstrated that she believes it is possible to use technology to give students more autonomy in her classroom and for students to engage in the Science & Engineering Practices to explore their own questions and come to their own conclusions.

This statement shows the complete opposite method of teaching to the lessons that the teachers in this profile submitted throughout the PD. In nearly every instance of technology use, they asked students to learn about a phenomenon by reading digital sources or watching videos and picking out important facts from the media. Whereas in guided discovery, Ms. McDonald said it best, students use technology to guide themselves through the working of phenomena by either building models or using simulations to collect data on the happenings they are engaging with and making claims on those phenomena supported by the evidence they collect. Students are able to take ownership in their learning, as they use technology tools to guide themselves to "Ask Questions & Define Problems," and "Construct Explanations & Design Solutions," two of the Science & Engineering Practices. Interestingly enough, although Ms. McDonald was able to articulate exactly how technology can be used to support guided discovery, the Science & Engineering Practices above were the two least used throughout both teachers experience in the

PD. As was common throughout the PD, the impact on these two teachers' beliefs was not yet materialized into their practice.

Throughout each of these statements, the teachers demonstrated an enhanced understanding of how technology can be beneficial for science-specific learning. Many of their statements were in line with the higher levels of SAMR and gave a concrete reference to the Science & Engineering Practices. The teachers were able to articulate exactly how technology could enhance the learning of their students and enable them to do science in the likeness of scientists instead of just learning about phenomena. However, throughout the lessons submitted and examples of technology use described throughout the PD, there was little to no evidence to suggest that these beliefs have been put into practice. It seems that the teachers' beliefs have been drastically impacted by the PD, but their practices have yet to make a change. Overall, at the PD's conclusion both of these teachers were able to describe that technology is an important tool for students to use for enhanced-inquiry-based instruction.

Fears/ Resilience

While both teachers were able to state the benefits of technology for instruction, they were not able to transition their beliefs into practice and one reason behind this may lie in some of the fears the teachers had. Their fears did not center on how technology can be used for science, but just general functionality of the technology tools. The teacher's fears stemmed from their lack of experience in using technology and their belief that their fifth-grade students weren't mature enough to interact with technology. On the whole, these teachers were not successful in practicing technology in the classroom in high levels and their fears may have been a relevant factor.

Both teachers used the same familiar applications in comfortable ways during the PD. Throughout the six weeks, both teachers most often used FlipGrid, a short video recording tool, Ms. Jackson three times, and Ms. McDonald 2 times to record “expert” videos on the science facts they obtained while looking through teacher selected digital resources. Their lack of diversity in technology tools, and their unwillingness to expand into new tools may be due to their feelings of inexperience with technology. In the focus group, Ms. McDonald expressed her anxieties with teaching science in general as a first-year teacher, let alone integrating technology in science. She stated, “[I] think as a first-year teacher, I feel like I have so much to learn. I know every teacher feels that way and it’s a constant thing of always learning more but, first year...I was nervous to teach science.” Her fear of teaching science may have prevented her from taking a risk in trying to integrate technology into this subject area.

Additionally, both teachers felt as though they had to master technology tools before using them with their students. Ms. Jackson wrote in her week two learning journal “I believe teachers definitely need to weigh the costs and benefits of technology use before relying on it in the classroom. I definitely don’t want to implement technology in my classroom unless I have completely mastered its use myself.” She fears that if she has not learned all of the inner workings of a technology tool, then she will not be able to use it effectively with her students. This fear may have prevented her from using some of the tools presented in the PD because of the time it takes to master technology applications, and many were introduced throughout the six-weeks. Ms. McDonald expressed a similar sentiment in the focus group. She remarked “I don’t feel like I would’ve felt as comfortable doing it if I didn’t have the background...with doing certain technologies and doing certain applications.” She feels she must have a good background in using technology tools before trying out the applications with her students. Both teachers had a fear that they would not be able to use technology successfully unless they were masters in using the tool themselves.

Another initial fear that both teachers had was that their students may not have been mature enough to be trusted with using some of the tools from the PD, however it seemed that fear had lessened as the PD moved forward. Ms. McDonald stated in her week two learning journal, “my hope is that my students can correctly use technology in a meaningful way...and there are some that really still struggle with just logging on to Google Classroom.” She fears that her students may not be able to use applications in the way she intended and notes that at this age, some students have difficulties carrying out basic functions. Ms. Jackson notes a similar fear, citing the amount of time it takes just to get students to the applications she has set out for her students in the focus group stating,

> the first thought that comes to mind is timing - it feels like it takes forever for students to get ChromeBooks, log on, go to Google Classroom, and then once they get where they’re going, they forget directions. I think the fact that students are still learning this often takes up time.

Again, describing the developmental appropriateness for her students, it seems Ms. Jackson is afraid to try more advanced technology applications because her students still take a lot of time to perform even the most basic functions.

However, later in the PD, both teachers were able to champion the fast rate at which their students picked up technology tools. In week five, Ms. McDonald elaborated “The students have surprised me in all the best ways when I have introduced technology in a lesson and had them navigate and explore on their own terms.” This realization that their students can and will use technology may help them in the future to integrate more of the technology tools with their students in the ways they were demonstrated in the PD and that coincided with their beliefs. These teachers were not very resilient in overcoming their fears; however, they did begin to show an understanding and belief in their students' ease at navigating technology tools. In the future, they may be more inclined to use PD in alliance with their beliefs described above as their confidence grows with the technology tools themselves and with the capabilities of their students.

Summary

Although these teachers primarily used technology throughout the PD to have students show what they know about a particular topic, they did show some elements of beginning to shift their pedagogy toward more instances of guided discovery and using technology in ways more aligned with the NGSS Science and Engineering Practices. Ms. McDonald had a breakthrough when she asked her students to use ScreenCastify and Google Drawings to make evidence based models of levers and pulleys, and Ms. Jackson was able to show enhanced understanding of technology and science when she also had her students make evidence-based models of levers as part of a stations activity. While these teachers showed small changes toward guided discovery in terms of their practice, the real transformation came in terms of their beliefs. These teachers not only demonstrated that they believed technology could be an effective tool in their classrooms, but by the end of the PD they were able to articulate just as to how technology would make the difference for the acquisition of science skills in their classroom. Although the teacher's practices may still be lagging behind, their belief system shows comprehension and thorough understanding of how technology can be used in advanced SAMR ways in accordance with the NGSS Science & Engineering Practices. It may take additional training to change practices in the classroom, but these teachers have developed an understanding of the connection between science and technology that may not have been possible without the PD.

The teachers were able to sum up the changes they experienced throughout the PD in their own words during the final in-person session where they participated in an "Up & Down the Mountain Protocol." Ms. McDonald voiced "I used to think and use technology mostly for assessment and closure but now I can use it a lot more for delivering content and instruction in science." She now sees that technology can be used for more than just formative assessment and that students can learn through enhanced uses of the technology to develop science skills as opposed to learning from the technology to deliver science facts. Building on this notion, Ms. Jackson elaborates on how she has developed a confidence in her students to successfully navigate technology to gain understanding of content. She summed up her learning in the following statement, "I used to think that the kids needed a lot of guidance with using technology but now they are really quick to figure it out on their own…" Both teachers voiced that they have a trust that technology can play a great role in their students' science understanding and are developing more trust in their students to engage in elements of making conclusions on their own toward guided discovery. Although these teachers' practices have a way to go before being completely in line with high levels of SAMR and the NGSS Science & Engineering Practices, they have shown a great change in terms of beliefs that can hopefully one day be translated to more effective practice.

Teacher Profile 2: Shifting Toward Discovery

The second teacher profile moves away from those who use technology primarily to show what students know, to a middle ground where it was mostly used for guided discovery but at times was used as a formative assessment tool. These teachers fell in the middle of the group in terms of instructional strategies and beliefs for using technology for guided discovery or as a tool to demonstrate what students know. More importantly they also exhibited changes in both beliefs and practice over the course of the PD. At times these teachers asked their students to use technology to review teacher selected digital resources to learn facts about science, and at other times, students could be found engaging in design projects where they developed science skills by doing science in technology-enhanced inquiry-based teaching. Technology has become a well-developed tool in each of these teachers' classrooms, and after the PD, the implementation of technology in alliance with the NGSS Science & Engineering Practices and high levels of SAMR was strong. Their beliefs on the role of technology show a deeper understanding for its place and benefit in the science classroom after the PD had concluded. The hybrid course had the most impact on these teachers by introducing new tools that they could integrate into their schema.

Overall these teacher's quantitative data scores placed them into them middle range of the group. Ms. Rachel Augustine had the second highest TUSI score average of 63.5 out of 104, while Ms. Teresa Flynn was in a similar range with an average of 61. Interestingly, Ms. Augustine's TUSI scores increased by 33 points after the PD, while Ms. Flynn's dropped by 12. These teachers did not have the highest or lowest SAMR ranking throughout the PD but had more examples of technology use that fell into the "transformation" range than the "enhancement" range. Ms. Augustine had eight technology usages that fell into the "Modification" range of SAMR, while Ms. Flynn had seven examples. They each had very few instances of technology use that aligned with the lowest level of SAMR for a total of three each. Submitting examples of technology that aligned at least once with all eight of the NGSS Science & Engineering Practices, these teachers' videos, lesson plans, and focus group data revealed a well-rounded approach to integrating technology in their classroom for inquiry-based instruction. Between the two teachers, the most common practices they implemented were "Asking Questions and Defining Problems," "Analyzing & Interpreting Data", and "Developing & Using Models."

Throughout the PD these teachers demonstrated that they had the knowledge and ability to implement technology for guided discovery, but at times, they also used it as a means for students to gather information in low SAMR ways. The following will introduce the teachers and define some of their examples of technology use in terms of SAMR and the NGSS Science & Engineering Practices. Later it will delve into their beliefs on technology and how it can be beneficial specifically for science, and finally will close with an analysis of their fears. Throughout, the participants' feelings on how the PD aided them in changing their practice and beliefs to be more aligned to high levels of SAMR and the NGSS Science & Engineering Practices will be discussed.

The Teachers

Ms. Rachel Augustine and Ms. Teresa Flynn have been categorized into this teacher profile because of their similarities in instruction, beliefs, and elements of change throughout the PD. The two teachers have different backgrounds in terms of careers as science teachers. Teaching for 22 years, Ms. Flynn was the veteran teacher of the group. Graduating with a dual major in Early Childhood and Elementary education, and a master's degree in Education, Ms. Flynn is a 5th grade science teacher in Spring Grove School District. Ms. Augustine currently teaches sixth grade science and previously taught 7th grade science. Ms. Augustine received her bachelor's degree in Biology and Education. She has been teaching for the past five years and is certified to teach K-8.

Although these teachers come from different backgrounds, and currently teach different grades at different schools, they had similarities in terms of their instructional practices and beliefs on the role of the technology in their science classroom. Both teachers considered themselves at an "Intermediate" level when it came to technology use with their students and Ms. Flynn even considered herself "Advanced" at NGSS instruction. The following paragraphs will offer an in-depth look into some of the examples of the teacher's technology usages in relation to SAMR, NGSS Science & Engineering Practices, and the elements presented in the PD.

Examples of Tech Use

Throughout the PD, both Ms. Augustine and Ms. Flynn used many technology tools with their students. More often than not, these teachers used technology in high level SAMR ways to transform the science learning that went on in their classrooms. Students engaged in science through using Virtual Reality headsets, changing variables in simulations, and making sense of phenomena through the development of technology-assisted evidence-based models. In a majority of these teachers' technology examples, tech tools were used for much more than a substitution for physical resources and were purposefully implemented to make a connection with the development of science skills in their students. While these teachers did primarily use technology for guided discovery, there remained some instances where the tool was not being used to enhance science learning but rather to collect science facts. The following will demonstrate a look into submitted lessons to gain insight into their teaching strategies and how their practices may have been impacted by the PD. Although the pair of teachers developed an understanding of how technology can be used for the development of science skills, they did not always implement it in the same ways presented in the PD and that is why they have been placed into this middle category. Overall, these teachers had advanced beliefs and the PD was able to impart change into some of their practice. The following will chronicle the examples of the teacher's practice in a continuum of integration for technology-enhanced guided discovery.

Teresa Flynn. In her first submitted video, from week two in the PD, Ms. Flynn not only drew heavily from the ideas presented in the PD, but also showed resilience and confidence in trying out a new technology tool with her students. During the lesson, many students initially struggled with the use of the technology tools, however, she worked alongside them to troubleshoot small issues and closed the lesson by giving them the opportunity to voice their opinions in relation to the pros and cons of using the technology tools. This vignette demonstrates her ability to use technology for inquiry, and her realization that technology is a worthwhile tool for science was shared with the class.

Ms. Flynn began the lesson by reflecting on the previous day's work which included installing the Google Drawings add-on to Google Chrome on the ChromeBooks, and practicing taking pictures of physical models students had built of levers using the ChromeBooks. In this day's lesson, students worked in predetermined partner pairs on a collaborative Google SlideShow which would sum up all of their learnings from the levers and pulleys unit including individual slides for: a picture of a lever they built in the classroom, a slide on the definition of levers and pulleys, a Google Drawings Model of a lever and pulley, a labelled picture a real-life lever and pulley found on the Internet. Specifically, in this lesson, students were going to focus on creating a Google Drawing model of a lever and pulley and take a picture of the levers they had previously built in the class. As she gave the instructions, she even had a mis-step when trying to insert a picture into a document, but simply kept going and then tries again. She even tells the students "it's okay if you have questions because this is new."

After the introduction of the flow of the lesson for the day, the students began working and Ms. Flynn circulated the room. Right away students had issues using some of the technology, but Ms. Flynn was able to address their concerns and helped find a resolution immediately. One student can be heard saying "why can't we just do this on paper, it would be SO much easier" in reference to creating a model of a pulley using Google Drawings. A different student chimed in a few minutes later "this was hard, but it got easier later." Students continued to collaborate on the Google Slides activity despite their frustrations. For having been introduced to the technology tool only one week earlier, Ms. Flynn was very resilient in terms of using the technology with her students and was able to articulate why the technology was so important to use in the science class. After the students had worked on perfecting their digital models of levers and pulleys and had taken pictures of the physical models they had built, Ms. Flynn wrapped up day one of the lesson by asking students to voice the pros and cons of interacting with the technology tools throughout the lesson.

Cons came in from students in the form of "sometimes the picture was blurry...too much light," in regard to using the ChromeBooks to take pictures, and "sometimes it was hard to figure out what stuff to use" in reference to making models in the Google Drawings platform. However, Ms. Flynn was able to turn the conversation around and point out some of the pros of interacting with the technology to complete the science culminating activity. Students focused on the technology's ability to complete tasks faster because it was on a shared document, while Ms. Flynn added that being a scientist involves many elements of teamwork. One student said, "drawing on a piece of paper would (have been) harder...we worked at the same time on the computer." Ms. Flynn also narrowed in on how the act of taking pictures of their physical models of levers was a similar process to what scientists do when they are collecting evidence.

In this lesson, students used many technology tools including ChromeBooks, headphones, Google Drawings, Google Slides, cameras, and the Internet all at high levels and in line with the ideas presented in the PD. Ms. Flynn submitted this recorded video week two, after design challenges and Google Tools were reviewed with the participants as part of the PD. In each of the technology elements that she chose, Ms. Flynn demonstrated that she had been inspired by the tools introduced in the PD, and that even if the technology tool was difficult to navigate at first, it was worthwhile because it was being used in strategies similar to those of scientists. Her use of Google Drawings and taking pictures of models on the ChromeBook were aligned with the NGSS Science & Engineering Practices of "Developing & Using Models" and "Engaging in Argument from Evidence" as students used evidence from both models to explain the functionality of levers and pulleys. This moved her technology use into the "Modification" range on the SAMR scale because the technology transformed what could be done in her classroom.

Ms. Flynn also relayed to her students that using technology in these ways was important because it modeled skills scientists had to use such as teamwork, via collaborating on the document, and collecting accurate evidence, in the form of taking pictures for their SlideShows. Each of these elements drew from the week two and week three mini lessons in the PD. In these two weeks, the teachers were introduced to modeling tools, collaborative data collection, and making science have a real-world relevance. By the next week Ms. Flynn had internalized these concepts and created this cohesive lesson. In the lesson Ms. Flynn not only demonstrated a fearlessness in terms of the technology's performance, but also a commitment to using technology with her students to develop the skills scientists use today. Her ability to use a new technology tool when she may not have mastered it herself differs from the teachers in the first profile.

In contrast to this early lesson, one of the last lessons that Ms. Flynn submitted to the Google Classroom, was the one that used technology in the least innovative and least in line with NGSS and high levels of SAMR methods. In the lesson, technology was implemented as a tool for students to gather data on science topics instead of as a tool to engage students in a phenomenon. Similar to Ms. Jackson's lesson on Trash power, students interacted with a grouping of teacher-selected digital resources to look up information on renewable and non-renewable resources and then recorded their most important findings from the sources into a foldable graphic organizer. She began the lesson by asking students to post on Padlet, a digital Post-Its platform, all of the things they already knew about renewable and non-renewable resources. Afterward, she reviewed the responses as students commented on some of the posts. Pointing out that two student groups posted "there are two different kinds of natural resources" on the Padlet site, Ms. Flynn prompted the group to label their two foldable graphic organizers renewable and nonrenewable energy.

Next, motioning to the Google Classroom, she explained to the group of students that they would be watching a video on YouTube which gives an overall look into renewable and non-renewable resources. The students had 13 minutes to watch the video, pause, and rewind, as they recorded the names and facts about renewable and nonrenewable sources into their graphic organizer. While students were recording, she circled the room and aided students in need. The lesson closed with students logging off the computers and sharing out the data they gathered on the different types of resources, while Ms. Flynn copied down their findings into her own foldable, which was projected via a Document Camera.

In this example, the technology used was not particularly sophisticated in terms of NGSS and SAMR and did not align with how technology tools were presented in the PD. Like Ms. Jackson, Ms. Flynn's use of Google Classroom to post a video on scientific concepts to collect data instead of having them engage with the scientific concepts to make sense of phenomena sits low on the SAMR scale in the Substitution Augmentation range and only aligns with the NGSS Science and Engineering Practice of "Obtaining, Evaluating, and Communicating Information." This lesson ignored the engineering aspect of NGSS that was presented in week one of the PD; students simply read through sources to learn about trash power and then summarized what it said. There were no elements of inquiry or discovery. This lesson shows very little relation to high levels of SAMR, NGSS Science & Engineering Practices, or components of the PD, however, it was one of the only lessons submitted that demonstrated a low connection between technology and inquiry.

Finally, Ms. Flynn showed that she had confidence using technology for enhanced inquiry-based instruction in a lesson centered on Virtual Reality. In her final lesson submitted after the PD had concluded, she used Google Expeditions for students to come up with questions and create answers to those questions using evidence gathered from the virtual reality simulation. To begin the lesson, Ms. Flynn introduced a traditional "KWL" chart on Google Docs, where students posted what they know, what they want to know, and what they will learn about "what happens to my trash and recyclables." Students began by filling in what they know on the collaborative Google Doc via Google classroom. She put a spin on the "what I would like to know" column and had students not only come up with questions, but also statements on what kind of evidence they would need to collect in order to answer those questions. Finally, the students used the virtual reality application to collect evidence on the questions they had and made conclusions about what happens to trash and recyclables.

In this final lesson, Ms. Flynn used technology not only in ways that were high on the SAMR scale ranking in the Modification and Redefinition range because of her venture into Virtual Reality, but also in ways that aligned with the NGSS Science & Engineering Practices and the elements discussed in the PD. The use of Google Expeditions was a focal point for the week three mini-lesson in the PD and Ms. Flynn was able to use the tutorials posted in this online week to translate it into her classroom. She also used the VR as a means for students to collect their own data in line with the NGSS Science & Engineering Practice of "Arguing from Evidence." Technology in this lesson was able to enhance the inquiry-based nature to a level that could not have existed without it. Combining the high levels of SAMR, the Science & Engineering Practices, and the elements from the PD, Ms. Flynn demonstrated that she understands and is capable of implementing technology-enhanced inquiry-based instruction with her students.

Rachel Augustine. Ms. Augustine had many parallels with Ms. Flynn in terms of her technology use. In some of her lessons, tech implementation fell into low SAMR levels and ignored many of the NGSS Science & Engineering Practices, but in the majority of examples, she was able to incorporate both of these constructs as well as ideas discussed in the PD. The following will look into some of Ms. Augustine's lessons and how they placed her in the same teacher profile as Ms. Flynn. To begin, in her first video, which was recorded before the PD began, Ms. Augustine's lesson on deforestation used technology as a tool for students to gather data from. Similar to Ms. Flynn, Ms. Jackson, and Ms. McDonald's previous examples, the students scrolled through teacher selected resources to collect definitions of concepts and made sense of phenomena by summarizing the main ideas from what the source was relaying. In essence, in this lesson students learned from the technology instead of through doing science with the technology.

In this lesson, students worked in predetermined partner pairs and shared one computer. Ms. Augustine asked the students to log onto Google Classroom and pull up a Google SlideShow that contained information about deforestation techniques. As they worked through the slides, the students were prompted to answer discussion questions with their partner and record their answers on a worksheet. The slides contained information about deforestation and its effects, as well as things like prescribed burns. Although the students were asked to make predictions about what they thought would happen on the next slides, they did not collect any data or design experiments to answer those questions, and their predictions were readily resolved by clicking to the next slide. The students cycled through the slides with their partner for about the next 20 minutes of class until Ms. Augustine prompted them to complete a closure activity. In the activity, students had to answer a post on Google Classroom asking, "Do you think we should stop deforestation," and had to answer in a Claim, Evidence, and Reasoning format, giving at least two pieces of evidence to back up their claim.

Although this lesson asked students to do things like "Argue from Evidence" the technology used in the lesson only mildly enhanced what could be done on paper. Because the teacher was in charge of providing the resources and the students did not gather evidence through experimentation, virtual reality, or simulations, there was very little connection between this lesson and NGSS or transformation levels of SAMR. The use of Google Classroom and the Google Slideshow did not immerse students in doing science but instead asked them to read about science. This lesson sat most in alliance with the NGSS Science & Engineering Practice of “Obtaining, Evaluating, and Communicating Information” and the Substitution level of SAMR, but did show an understanding of NGSS, when Ms. Augustine asked her students to respond in a Claim, Evidence, and Reasoning format, however it could have been elevated if it had incorporated some ideas from the PD. Although her execution of technology could have been improved, she still demonstrated a greater understanding of the relationship between NGSS and technology than Ms. Jackson and Ms. McDonald because she asked students to do things like make a Claim, Evidence, and Reasoning while interacting with a technology tool.

In the next two examples, Ms. Augustine had students collect data using simulations to draw conclusions in the ways she wasn’t able to in the first example. In a lesson submitted week five of the PD, students used a Phet simulator to change out different materials to record the angle of incidence, angle of reflection, and the refracted angles of opaque, translucent, and transparent materials. In the simulation, there were virtual tools such as a protractor where students were able to accurately measure the angles they were viewing. Then they created three models of the angles based upon the various materials. The lesson closed with students comparing their models and using evidence from the simulation to make corrections to their models if there were any disagreements. In a similar lesson, Ms. Augustine used a Gizmos simulation for students to test out what materials were conductors and level of efficiency at conducting electricity. This lesson was her last recorded video and was submitted after the PD concluded. In the simulation, students set up three kinds of circuits, and then completed the circuit using different materials. Virtually, this simulation enabled students to see inside the wires of the circuit to get a glimpse of how electrons were being passed throughout it; something that could not happen if the experiment was completed in-person. The lesson closed with students creating their own definitions of conductors, as they had not learned this term before, and writing claim, evidence, and reasoning statements on what makes a good conductor. In each of these examples, students collaborated around a technology tool and used that tool to make evidence-based conclusions on the phenomena they were viewing. The technology was able to enhance or make possible things that could not be done in the classroom.

In week four of the PD, the focus was on using simulation tools for students to collect evidence on the workings of phenomena, and to use that evidence to draw conclusions to gain an understanding of the phenomena. In each example, Ms. Augustine's students did just that; in the first example, they were able to create evidence-based models of how different materials reflect light, and in the second, they were able to come up with their own definitions of the term conductor. In line with both the Modification level of SAMR, and the "Engaging in Argument From Evidence" and "Developing and Using Models" NGSS Science & Engineering Practices, these lessons drew heavily from concepts presented in the PD and showed an understanding of how technology and science could be merged together for inquiry. The focus of the lessons was dually on content acquisition alongside the development of science skills. Although Ms. Augustine's first lesson did not wholly align with the PD and NGSS, these last two lessons demonstrated that technology-enhanced inquiry-based instruction is something that was part of her repertoire.

The lessons described above from both Ms. Flynn and Ms. Augustine represent a large continuum of skills that the teachers command. Although some of the examples demonstrated lower-level SAMR skills and alliance to NGSS, they were more aligned than both Ms. Jackson and Ms. McDonald, and drew from more concepts in the PD. On the whole, their lessons focused more on skills than on gaining mastery through repeating content facts acquired from reading. In each example, the technology tools implemented in the lessons became more sophisticated and more in line with what was presented in the PD. By the PD's closure, these teachers were submitting lessons and presenting ideas congruent with an understanding of technology use for inquiry in both belief and practice. The following will look into these teachers' beliefs on the role of technology and how it can make a difference specifically in the science classroom.

Beliefs

As was demonstrated in the examples above, Ms. Flynn and Ms. Augustine had practices in their classroom that mostly aligned with NGSS and high levels of SAMR, and at other times their tech use fell short into the Substitution range. Their teaching strategies showed advanced levels of TPACK, and their beliefs matched their teaching strategies. The PD was able to impact their beliefs in the realms of how it can enhance practice and transform assessment. At the PD's conclusion, these teachers had strong beliefs that technology is a necessary component of science instruction, it's use can transform the design of assessment, and inquiry-based instruction can become possible through technology use in the classroom. The following will give a look into their beliefs and change in relation to the PD.

Throughout the PD, Ms. Flynn and Ms. Augustine were able to turn their beliefs into practice and implemented many forms of technology throughout their lessons. A belief that both teachers held in common which was developed from all the weeks of the PD was that technology is necessary for students to use in order to develop science skills in accordance with the NGSS Science & Engineering Practices. In her week six learning journal, Ms. Flynn discusses how technology must be used purposefully and that low Substitution levels do little to impact the learning of her students, " My biggest take-away from this hybrid PD in terms of using technology in the NGSS classroom is the importance of using technology meaningfully, not just as a substitution for something else." She follows up with noting that before the PD, she used technology as a tool for students to learn *from*, but now she sees it more as a tool students can use to learn *with*. In the focus group interview she elaborated, "For me beforehand it was more using it with center-based activities whether it be for video or a Google Doc that they're corresponding on. Or Google Slides for presentations. But, now it's really more of an instructional tool rather than just a tool."

With these two statements she demonstrated how her beliefs have changed as a result of the PD. She previously considered that any use of technology was good, but now realizes that for science learning to occur it must be purposefully crafted. In her second statement she put her beliefs in opposition to the practice of Ms. McDonald and Ms. Jackson and sees that having students learn from technology does little to enhance their acquisition of science skills. She now believes that through high levels of SAMR instruction and with the NGSS Science & Engineering Practices in mind, students can use technology in science class to learn in the likeness of scientists.

Ms. Augustine also describes how the rigor of the NGSS Standards must be kept in mind when using technology with her students. In her week two learning journal, she writes

> These standards are meant to prepare students for college and their careers. In today's world, every field you go into involves some sort of technology. Students benefit from using technology in school because they become familiar with using it and it better prepares them.

She followed up in the focus group interview with a similar idea describing "I have now tried to incorporate it in different ways. My views have changed from technology being useful to it being necessary because it can really change the way that students learn science." The PD was able to impact her beliefs to see that technology can bring a real-world relevance to science learning and that it is a lot more than a tool that is useful; it is a tool that is essential to prepare today's students for future careers and to develop skills in the likeness of scientists.

Different from the teachers in the first profile, these teachers were able to make the connection between using technology as a means to do science and acquire skills, whereas teachers in the first profile carried out lessons where technology was implemented as a means for students to learn from. In every week of the PD, a technology tool was introduced with the acquisition of skills in mind. These teachers were able to capitalize on this format of presentation, and their beliefs transformed to match what was described in the PD. Their beliefs were changed from relying on technology as a tool that can enhance instruction to a tool that is necessary for learning science in a meaningful and relevant way. Both teachers had previously thought it was okay to learn from technology but now see that science learning occurs best when students learn with technology. While this belief was well ingrained and represented a change in participants from start to finish, they did not always implement tech as a means to develop skills as Ms. Campbell had, and this is why they remain in the middle category.

In light of technology being a necessary tool to acquire skills, as a result of the PD, both teachers now believe that assessments need to change to also have a focus on skills. In week five of the PD, teachers watched a video that described how science assessments that focus on minute content details do little to capture the mastery of scientific knowledge that students have achieved. It seems both teachers were impacted by this video and feel as though their assessments will have to change as they integrate more technology into their instruction with their students. In her week five learning journal, Ms. Augustine wrote

> I believe that our assessments will have to change. Most of the assessments given only assess students on memorization skills instead of problem-solving skills. I think that assessments should pose a problem that is related to the unit of study and students will need to use what they've learned to solve that problem.

This description matches the way that technology was introduced to the participants in the context of design challenges or solutions-oriented learning. This statement shows an understanding that through technology-based instruction that is in line with the NGSS Practice of "Planning & Carrying Out Investigations" and "Constructing Explanations & Designing Solutions." These elements were described in week one, four, and five of the PD and were able to impact Ms. Augustine's beliefs.

Ms. Flynn was also impacted by the PD to believe that current assessments need to be changed to get a true representation of students' mastery. In her week five learning journal, she described

> The role of technology can change the way we assess our students in some ways. Using the SAMR model to incorporate technology into our daily lessons will allow our students the opportunity to research independently, teach others through technology, and self-assess. By utilizing technology in these ways, assessment of students on the part of the teacher will change.

As she uses technology more with her students in high SAMR levels, the way in which students are assessed will have to change to match the focus of the lessons. As students begin to learn content through technology and guided discovery, assessments should also measure mastery through a similar format. In these statements, both teachers recognize how implementing technology in new ways will impact the way in which their students are assessed. They were able to draw from the PD to come to this finding.

Finally, the most important change in terms of beliefs came in the form of the teachers seeing that technology can and should be used for guided discovery in their classrooms. Each week of the PD hinged on the idea that technology should be used in the science classroom for guided discovery. The teacher's beliefs reflected those presented in the PD at its conclusion and each saw the importance of technology's role in guided discovery in their classrooms. In the focus group interview, Ms. Flynn discussed how the role of the teacher changes when students are engaged in guided discovery.

> And with the drive being such as the kids are doing the learning for themselves, the teachers role has become so different over the years, where we're not standing up in front of the classroom teaching, we're telling them what to do and where to go and how to get it and they're learning it themselves.

Through guided discovery the students are able to take more ownership in their work and accomplish the development of skills in accordance with NGSS. In a second take, she elaborates how technology can enhance and accomplish guided discovery. In her week three learning journal, she writes, "I believe that providing students with the opportunities to use Google Tools or Science Journal will open them up to using these resources to explore topics they typically wouldn't and possibly create investigations of their own." In weeks one and two of the PD teachers were exposed to Google Science Journal and the other Google suite of tools. Through these activities, she is now able to believe that technology can make guided discovery possible for her students.

At the close of the PD, Ms. Augustine now also believes that technology can play an important role in guided discovery for her students, noting how technology can enhance the development of critical thinking skills. In her week six learning journal, she wrote "With technology, they can be involved in the learning rather than just learning about it. This helps with understanding. By researching and creating projects to problem solve, they are using their critical thinking skills." Through technology, students are able to design projects and create solutions that would otherwise not be possible without it. Components from the PD such as the week one design challenge or the week four simulations made an impact on Ms. Augustine's beliefs. As a result of the PD, both teacher's beliefs have been impacted to now see the importance of the role of technology for incorporating guided discovery into their classrooms.

Throughout the PD, these teachers were able to interact with elements that changed their beliefs on what technology was able to accomplish in their classrooms. They were able to come to realize that technology is an essential component for science teaching, and when paired with instruction in the highest levels of SAMR, it can transform what students learn. Drawing from themes presented in the week five mini lesson, Ms. Flynn and Ms. Augustine now see that as technology shifts instruction to be more skills oriented, assessment must also shift to properly measure students' learning. Finally, the PD was able to move these teachers' beliefs towards supporting the difference technology can make for guided discovery. They now know that technology use in science is an essential part of students designing, exploring, and learning on their own. Throughout the PD, their beliefs shifted to become more advanced and more confident in understanding how technology, NGSS, and high levels of SAMR can be merged together, and many of these ideas were reflected in their practice.

Technology for science. While these teachers held broad understandings of how technology benefits their students, they were also influenced by the PD to develop specific beliefs on how technology can be implemented to support science learning. There are many science specific ways that technology can help students learn, and both of these teachers were influenced by components of the PD to come to realize just how big of a difference technology can make in acquiring new science learning for their students. By the conclusion of the PD they were able to see that technology offers unique opportunities for students to collect and analyze data in the likeness of scientists, that simulations provide novel opportunities for the understanding of phenomena, and self-directed learning can become a reality with the aid of technology. These beliefs had been reflected in much of their practice in their submitted lessons. The following will look at how the PD was able to make changes in the teachers' science specific technology beliefs.

To begin, both teachers praised technology for its ability to enhance and organize data collection and analysis. Week two of the PD introduced the Google suite of tools to the participants including things like Google Sheets and Science Journal. Ms. Augustine and Ms. Flynn were able to relay their belief that these tools could help students collect and analyze data in the same way that scientists do. In her week three learning journal, Ms. Augustine described the fast pace and accuracy through which students can collect and analyze data using digital tools. She wrote "Students are able to collect data much easier so that they can spend more time on the important part, which is analyzing the data. These resources are a huge time saver." In the focus group interview, she elaborated "You can use class time more for data analysis rather than calculations." In these statements, Ms. Augustine felt that technology saves time so students can spend more time for things like data analysis and figuring out phenomena.

Technology tools save her time so that her students can do more projects such as those rooted in guided discovery. Ms. Flynn also noted the ease of data collection when students used digital tools. In her week two learning journal she explains,

> Technology can also be used as a way to document experiences, as well as, information and data collected during experimenting and investigating. Using video, voice recording, as well as, google sheets, tools, etc. students can include live evidence of the work they have done. Incorporating various tools within the classroom allows students to keep better records, evaluate others' work/data, and use time effective measures to collect and analyze their data."

Relating ease of time to the development of science skills such as collaboration and evaluation of evidence, Ms. Flynn has made a connection between technology and data collection. Both teachers are able to clearly describe a very specific use of technology for science in their classrooms, something they may not have thought about before the PD began.

Additionally, after viewing materials related to science simulations in week three, the teachers felt very strongly that simulations can develop science understanding for students in ways that physical labs may not and that their use enhances science instruction. In the Focus Group interview Ms. Flynn stated:

> For me it was that simulations with that whole website that allows the kids to experience real life situations in non-real time and opens up their science minds to different things that they normally wouldn't have been able to see first-hand that they can using that technology. So, that I really got a lot out of.

She believed simulations can physically and mentally take students places that they would not be able to do within the confines of the classroom. Later in the focus group interview, she was able to give a specific example of how she would like to use simulations for science learning with her students. She stated:

> I'm currently moving into the environmental and the life science so I'm definitely looking to find more use for incorporating technology with those. Especially with the life science with the seed planting and changing the variables of light and all that. Definitely gonna incorporate that too.

She saw the value in students being able to test their predictions by changing variables as a skill that is relevant to the NGSS Science & Engineering Practices.

Ms. Augustine also articulated the importance of implementing science simulations with her students. In her week three learning journal, she described

> The positive aspects of using simulations in the classroom are that students get to experience science instead of just talking about it. They are also very helpful in showing students how things work in the real world without worrying about things like time, size, or the price of certain items.

Here she was able to match her belief to align with the message of NGSS. Through engaging in simulations students are not only able to learn about science but they are also able to do science as was presented in the PD. By completing simulations and doing tasks like designing solutions, or changing variables, students are able to acquire skills deeply rooted in NGSS. Different from the teachers in the first profile, these teachers did more than just praise simulations, they also used simulation as a means for guided discovery with their students.

Finally, these two teachers feel that implementing technology in science can enable students to investigate on their own, and work through problems and phenomena in the same way that scientists do. It provides them the opportunity to use the same skills that scientists use in the field when they are researching and making discoveries. In her week five and six learning journals, Ms. Augustine describes how technology gives students the opportunity to develop skills in the likeness of scientists. She penned "There is a huge connection between tech and inquiry-based learning. Technology allows students to design and experience science in ways that would not be possible in the conventional classroom. They can be involved in the learning rather than just learning about it. This helps with understanding. By researching and creating projects to problem solve, they are using their critical thinking skills." When immersed in technology-based instruction in the classroom, students are doing much more than passively receiving information that they have to memorize and repeat, they are in control of their own learning and must rely on skills such as critical thinking to reach mastery.

Ms. Flynn also describes the importance of using technology for developing science specific skills in her students. In her week five and six learning journals she elaborates on the way technology can help students acquire skills,

> Offering students various technological tools allow them to engage in a different type of learning. Teachers can basically pose a question, an expectation, a goal, and students can utilize various tools to answer them with limited assistance, yet limitless possibilities. They can get the answer to a question at the touch of a button and see real life simulations of things through Virtual Reality, video or interactive media. Anything they want to see, hear, or learn is available."

Because technology makes interaction amongst students limitless, they can take ownership of their own learning and navigate problems and phenomena by sharpening their own science skills. Each of these teachers came to the realization throughout the PD that technology can enhance inquiry-based instruction and was able to use it for that purpose more than once before the PD was over.

As the PD moved forward, both teachers continued to grow in terms of their beliefs on science specific applications of technology. They were also able to act on these beliefs and turn their inner thinking into practice unlike the teachers in the first profile. Both Ms. Flynn and Ms. Augustine recognized how technology can be used for data collection and analysis, how crucial simulations can be in providing students the opportunity to engage with concepts that would otherwise not be possible in the classroom, and that technology gives students the time and space to research their own questions and obtain answers to those questions by developing science skills. Noting the relationship between technology and the development of science skills, and capitalizing on these beliefs in their practice, these teachers demonstrated that through exposure to technology tools in the PD, they were able to shift belief and practice to be more aligned to NGSS and high levels of SAMR.

Fears/ Resilience

While these teachers were able to move toward inquiry in implementation of technology and beliefs, their fears with using technology with their students centered on it not being used in alliance with the upper levels of SAMR. Instead of fearing that they would fail at using technology or how technology could merge with NGSS constructs as Ms. Jackson and Ms. McDonald had, these teachers' main fears hinged on overuse of technology as a means to replace hands on science labs, there not being enough time in the curriculum to use technology, and not using technology to its full potential.

A fear common to both of these participants was around the over-use of technology in the classroom as a means to replace hands on science activities. While these teachers clearly believe that technology is an important tool for science learning, they also see the value in learning through carrying out hands on activities. They fear that using technology just for the sake of adding a tech tool to a lesson without carefully thinking about its purpose, will take away from meaningful hands-on labs that can aid in the development of science skills. In addition, they fear that concepts may be lost on students if too many low-level approaches to technology are used, and if the tech is implemented in isolation from physical labs.

Ms. Augustine notes that students will not practice fine-motor skills associated with using scientific instruments such as a pipette in her week three learning journal if simulations are overused in the classroom. She wrote "I am not sure if there are any negative aspects of using simulations in the classroom. The only thing I can think of is that students do not practice the use of their fine motor skills like manipulating scientific instruments."

In a different take, Ms. Flynn also believes that over-use of technology can be detrimental and feels that it may reduce students' ability to communicate and collaborate effectively. In her week two learning journal she typed

> A non-benefit from using technology in the classroom, may be that communicating via technology may reduce the meaningful interactions that students could have with each other in conversation. Discussions, Q & A, etc. benefit from talking to others, not simply providing feedback on a document or other avenue.

Just as scientists have to use communication skills when collaborating or presenting their findings, she fears students who overuse technology in low-levels may not develop these necessary skills. Overall this fear centered on technology being overused and not in a purposeful matter at the expense of developing science skills that scientists actually need. Because these fears were focused on targeted technology use in high levels of SAMR to acquire science skills like those in the NGSS Science & Engineering Practices and did not demonstrate any lack of understanding of how technology can be used for inquiry, these teachers show a more advanced comprehension of how tech and inquiry can be merged together. They have demonstrated this in higher levels than the teachers in the previous profile as well as a willingness to pinpoint the technology tools that will help students to develop skills to be successful scientists.

While both teachers recognize that technology use must be targeted, Ms. Flynn also worries that even after selecting the most important technology tools there will not be enough time in the curriculum to integrate all of the applications, she feels are important to enhance her students' learning. In her week four learning journal, she penned “curriculum and time restraints do not always offer the opportunity for simulation” and “the negative aspect of using simulation in science would mainly be time.” She sees no other negative to using technology in science or applications like simulations other than the pressure she feels to finish the curriculum within the allotted days in the school year. Later, she discusses how she may be able to rearrange her units in the curriculum to accommodate more technology use, but then fears that her students may not be mature enough to use the technology appropriately in the beginning of the school year. Also, in her week four learning journal, she wrote “Rearranging my units would need to put these units in the early part of the year, and I fear that the level of understanding and maturity would prevent my students from fully understanding the concepts being taught.” In these statements, she is worried that the curriculum doesn’t allow time for technology-enhanced inquiry-based teaching, and if she rearranges the curriculum so that it does, she fears that it may not he developmentally appropriate for her students. Although she is doubting the abilities of her students, with these sayings, she still demonstrates that she is willing to rearrange her curriculum because she feels technology is a necessary tool for her students to use. On the whole, this fear shows a willingness to make amendments to the curriculum in favor of technology. It shows that she believes it is an integral part of science instruction.

Finally, Ms. Flynn has a breakthrough moment when she realized that her doubts in the students' ability to use technology effectively have been proven false as she engaged with using technology with her students. In the focus group interview, she remarked "...And the kids picked it up famously, and really the only thing holding me back was myself." With this statement she is voicing that all of her worries on student's maturity level have been for nothing, and also that she will not let this fear stop her from using technology with her students. Overall, both of these teachers had very few fears that centered on technology's inability to be used in alliance with NGSS and for development of science skills. The fears focused upon navigating the technology, which they felt was important due to logistical constraints of time and pacing as well as an unwillingness to have technology replace all physical investigations in the classroom. In their statements, these teachers alluded to a well-developed understanding of technology, SAMR, NGSS Science & Engineering Practices, and ideas presented in the PD. As the PD went on, they were able to overcome many of their fears and found meaningful opportunities to use technology in their classrooms with their students.

Summary

The teachers in this profile demonstrated beliefs and practice on technology that in a majority of instances was implemented for guided discovery, but at times was used in low Substitution levels. Throughout the PD, and in many of their later lessons, they showed a shift in beliefs and practice that technology should be used for science in alliance with inquiry-based learning. Interpreting many of the exposures to technology in the PD on their own, these teachers were able to capitalize on the technology tools demonstrated in the PD and translate them purposefully into their lessons. They represent a change in both beliefs and practice in relation to the elements of the PD, as well as a greater understanding of the relationship between technology and NGSS.

Ms. Flynn sums up the changes of the teachers in this second profile best in her responses to the Up & Down the Mountain Protocol and the post-PD participant survey. She elaborated

> I used to think that students had to give an oral presentation to show what they learned but now they can use different types of technology to get the same point across. I believe technology should be used for ...To be used as often as possible to promote independent discovery and investigation. It should not be used as a replacement for other types of learning, but as a tool to foster higher level thinking and independent, and collaborative work.

At the PD's closure she sees that having students learn from technology by doing things like reading about phenomena is not enough, and that students can and should be immersed in using technology for guided discovery. At the end of the PD both Ms. Flynn and Ms. Augustine held beliefs and demonstrated practice that aligned with technology being implemented for guided discovery with their students. They left the PD with the confidence to implement their beliefs into their practice with their students. Although the feelings and practice toward technology may not have been innate, these teachers built on the ideas presented in the PD to implement technology in line with both NGSS and high levels of SAMR.

Teacher Profile 3: Primarily Uses technology for Guided Discovery

Throughout the PD there was only one teacher who consistently used technology for enhanced inquiry-based instruction. Lori Campbell held beliefs and demonstrated practices that not only aligned with the upper levels of SAMR, but also coincided most often with the NGSS

Science and Engineering Practices. In nearly every opportunity, this teacher asked students to make predictions and test those predictions in alignment with the NGSS Practices of “Asking Questions & Defining Problems” and “Planning & Carrying Out Investigations,” while also breaking down the barriers of the classroom and truly transforming her approach to learning with virtual exploration. Instead of asking her students to look at documents and videos that explain phenomena such as different wavelengths of light, she took them to a virtual reality where they were able to see the different wavelengths and make their own sense of the phenomena by making predictions and using evidence to come up with a group consensus on the inner workings of it; and that is just one example of many where technology was used for guided discovery in the likeness of scientists.

Because this teacher demonstrated very few instances where technology was used in Substitution or Augmentation ways, and consistently used technology for transformation to Modify and Redefine what can be done in the classroom, she has been classified in this category. The following will chronicle and overall glimpse of Ms. Campbell and follow with a deeper look into how her beliefs and practices were those most aligned to the highest levels of SAMR and the NGSS Science & Engineering Practices out of the group.

The Teacher

Ms. Campbell has over seventeen years experience in teaching, five of which have been spent in Spring Grove Middle School where the study took place. Prior to her middle school teaching, Ms. Campbell taught in-patient youth at a Carrier Clinic for around 10 years. She has an undergraduate degree in teaching and a master’s degree in Special Education. All of the artifacts that she has worked on as a part of the PD were in reference to her Resource Science

Grade six classroom, where each day she instructs approximately six to twelve students with the aid of one-two paraprofessionals each day.

Nearly all of the artifacts that Ms. Campbell submitted and the ideas she alluded to, placed her as the teacher that exhibited beliefs and practice most aligned to high levels of SAMR and the NGSS Science & Engineering Practices before and after the PD. She remained the most consistent in her belief that technology should be used in ways that enhance inquiry-based instruction throughout her videos, learning journals, and lesson plans, and because this notion was so ingrained into her beliefs and practice the PD did not have a strong impact on her teaching. Averaging 78.5 on her pre/post TUSI scores, out of the entire group, Ms. Campbell had not only the highest score by eighteen points, but her before and after scores increased by only one point throughout the PD, showing she believed in technology before the PD and continued to act on those beliefs after the PD. She was also the only teacher whose score changed by less than ten points from before to after the PD. She had the lowest number of instances of technology use that aligned with the Substitution level, with a total count of five, and the highest number of Redefinition levels with a count of four. Standing alone as the only teacher to maximize the number of Redefinition examples of technology use, as many teachers did not even have one example of tech use that reached this level, she also had an unsurpassed number of technology instances that aligned with the Science & Engineering Practices. Leading the way with eight instances that aligned to the Practices of Asking Questions & Defining Problems, four with Planning & Carrying Out Investigations, seven on Analyzing & Interpreting Data, and nine on Engaging in Argument from Evidence, this teacher was able to capitalize on NGSS methods in her teaching. The following section will give an in-depth look into the specifics of how she was able to achieve these high counts of alignment for both SAMR and the

Science & Engineering Practices. Using technology for enhanced inquiry-based instruction is something that is clearly very highly ingrained in this teacher's repertoire. She may have been the least impacted by the PD because she was already using technology in alliance with, he

Examples of Tech Use

Throughout the PD, MS. Campbell used seventeen different technology applications, including many of the tools that were highlighted in the PD. She submitted two videos and three lesson plans, and in each of the artifacts, her lessons followed a similar format where students would be shown evidence of a particular phenomenon through Virtual Reality, a simulation, or another tool and then were asked to describe what they saw happening and why they believed it was happening. These predictions were shared with the class and then the students used evidence from the technology tool to reinforce or refute their claims, until the class came to a consensus on how a phenomenon took place. At this point, Ms. Campbell would introduce the vocabulary associated with the phenomena that matched the definitions students had generated as a part of their own understandings.

In her first video, which was submitted before the PD began, Ms. Campbell captured a lesson where technology was purposefully used for student discovery in the format described above. In the lesson, she challenged her students to explain the phenomena of commensalism, mutualism, and parasitism using the Google Expeditions App. Students used iPads to virtually experience three different organism pairings including a bird on a rhino's back, barnacles on a humpback whale, and a termite in a tree. The app provided an Augmented Reality view, whereby students were able to drop the organisms inside the classroom and use the iPad to move around the creatures and take a closer look at their conditions and relationships. In the beginning of class Ms. Campbell distributed a guide sheet, where students had to circle if they believed the organisms in the AR simulation were being benefited, harmed, or remained neutral by their coupling.

As the students spent time looking in each scene, they shared their predictions on what they thought using evidence they collected from the scene. For example, one student said, “I think the rhino is being helped by the bird because its eating bugs off its back and when bugs are on me it’s annoying.” Another student challenged the prediction and noted “...I think it’s (the rhino) being hurt by the bird ‘cause I can see cracks (on its back).” Students went on and the teacher followed up with more guiding questions until the group came to a consensus that both the bird and the rhino benefitted from the relationship.

This lesson aligned with M and R uses of technology because the students were taken virtually to a place where they could never go inside the classroom, and while they were visiting each of the scenarios, they were able to collect evidence that gave them the ability to make conclusions on the scientific concepts of mutualism, commensalism, and parasitism. This lesson drew heavily from the NGSS Practices of Asking Questions and Defining Problems, Developing and Using Models, Engaging in Argument from Evidence and Obtaining, Evaluating & Communicating Information. Drawing from both high levels on the SAMR model and Science & Engineering Practices, and because students created their own theories and then used evidence to verify their theories, this was one of the best examples of technology use throughout the PD.

Whereas other teachers used technology tools that explained the workings of a phenomena and then asked students to create a video elaborating on how that phenomena worked by essentially regurgitating what the sources the teacher had given said, Ms. Campbell had her students experience a phenomena through technology so that they could generate their own understanding. After students had drawn their own conclusions, she then used videos or sources explaining the phenomena to reinforce student-generated understandings. Instead of flat out telling students how an eye can decipher different wavelengths, she took students virtually inside an eye and asked them to explain what they saw happening. The technology itself then became a virtual lab, moreover a teaching tool. Technology enhanced inquiry teaching is about using technology for student discovery, and for that student discovery to generate evidence that can lead to scientific conclusions. This use of technology is more in line with NGSS because it follows the same process that scientists must undergo when they are making discoveries. They must first make predictions about what they see happening and then use evidence to back up those claims from evidence they generate, eventually leading to a scientific conclusion. While it is important to teach students about how to evaluate the validity of sources, it is more important to use technology for student discovery, which this teacher demonstrated mastery of in numerous instances throughout the PD.

She mirrored this process in a second example from a lesson plan posted on week six of the PD. She began the lesson by asking students to play a producers, consumers and decomposers simulation game on the computer. In the game, students took on the role of either a producer, consumer, or decomposer and the students were able to see how the various organisms interacted with each other in the setting. From there, students worked to define what the role of a producer or consumer was using evidence gathered from the simulation. Afterward, Ms. Campbell held a class discussion where students used claims, evidence, and reasoning to explain the phenomena they witnessed in the simulation. As each student made a claim on the role of a producer or a consumer, others in the class stated if they agreed or disagreed with stated definitions, until a class consensus was reached.

It was at this point, after the students had worked to define the concepts on their own, that the class then engaged in watching a video which thoroughly explained the roles of producers, consumers, and decomposers. Instead of having students use this video to define the terms in focus for the lesson, Ms. Campbell gave students an experience of the simulation, and had them define the terms on their own. The video then took on the purpose of a reinforcing tool as opposed to a data gathering tool, centering the main focus of the lesson on the evidence gathered from the simulation. Many other teachers in the PD used videos in quite the opposite format, as a way for students to be told how a phenomenon works instead of figuring it out for themselves. Because in this lesson, students engaged with the simulation technology tool to collect evidence, and used that evidence to make sense of the phenomena in focus, the technology use was elevated to higher Modification levels on the SAMR scale, while still aligning with the Science and Engineering Practices of Asking Questions & Defining Problems, Analyzing & Interpreting Data, and Engaging in Argument from Evidence. In this lesson plan, Ms. Campbell yet again demonstrated that technology can be used for inquiry-based guided discovery.

Finally, data collected from student surveys revealed that Ms. Campbell was using technology in high SAMR levels in alliance with NGSS before the PD began and continued to do so after the PD concluded. When asked if students agreed with the phrase “My teacher uses technology to help me learn science” Ms. Campbells students said they agreed for nearly the same exact reasons before and after the PD. One student said he agreed with the statement before the PD began because “My teacher miss C uses technology by using chrome books to help us learn by letting us play games we learned about to understand more about it and watch videos to research about what they are.” In this statement the student is elaborating that they play games in order to learn about a phenomenon and then use additional videos afterward to reinforce the workings of a phenomena. After the PD had ended, another student nearly mirrored what the first had said before the PD, agreeing that their teacher used technology to help learn science “Miss C allows us to have technology is answer questions to help us learn and have fun while answering questions.” In both responses there is a focus that the teacher is not just using technology to have students be told how phenomena works, but instead the main point is on using technology to explore a topic using student driven questioning, and to have fun during the exploration process. Similarly, when asked how technology helps the students learn science, one student replied “I think it does because it helps us understand more about it and how and where it came from our teacher Miss C told us to play these games that proves that if we know a lot about the meaning and how they were used.” Again, the students are stating that they have become accustomed to Ms. Campbell’s guided exploration format, where she uses a technology tool for students to explore and make sense of a topic and then uses additional technology to reinforce. Throughout many of the student’s answers, were responses focused on playing games and then using those exploratory experiences to make sense of a phenomena.

Overall, Ms. Campbell’s lessons had a narrow focus on guided inquiry and connection to the NGSS standards as evidenced by her videos, lesson plans, and statements made by her students. Even before the PD began, she had already mastered how to use technology to enhance the inquiry-based classroom. Her focus on using technology to give students experiences to collect data, and then use that data to make scientific claims on the inner workings of phenomena is what sets her apart from the other teachers in the group. The types of technology tools such as VR and AR and the ways in which she used it were far more advanced than other members of the group and centered in on student learning through guided discovery.

Beliefs

In conjunction with physically demonstrating lessons that used technology in ways that aligned with NGSS and the highest levels of SAMR, writings from Ms. Campbell's weekly learning journals captured beliefs that also revealed strong notions of using technology for enhanced inquiry-based teaching. She believed that students should be exposed to technology as much as possible, that technology will prepare students for the 21st century, and that technology and NGSS go together. Different from other teachers, her beliefs in her journals were consistent with what she was practicing in her classroom as evidenced by her videos and lesson plans. The following is a deeper look into her beliefs on the role of technology in general followed by a look into her beliefs on how technology can be used for science.

Broadly, Ms. Campbell feels as though it is important to expose students to technology in science as much as possible and that it is the teacher's job to do so. In her week five learning journal, she writes "I am on a constant quest to learn as much as I can about technology and how I can use it to both engage my students and as a scientific instrument in the classroom." She is a teacher who is constantly searching for novel ways to engage her students and make science more accessible through technology. She also feels that is a teacher's duty to continuously revamp their lessons through technology for the benefit of her students. In her week two learning journal she stated, "My hopes are that we as educators continue to introduce students to the newest technology that is available and relevant." Right from the start of the PD she has come out and described her own feelings on how important technology is in the classroom for the sake of the students. This shows that even before the PD she held strong beliefs on the role of technology, and that the PD was not able to make a large difference in either because she was already at elevated levels.

Building on the fact that technology is important, she also believes that technology is essential for this generation of students in order to be better prepared for the 21st century. In her last learning journal for week six she typed "I believe that technology can make a difference for our students because in an effort to help them become 21st century learners, it is our role and responsibility to make sure that they will have access to tools that will enhance their learning." Again, she is reiterating that it is up to teachers to expose students to technology and that without it, students will not be able to successfully navigate the demands of the 21st century. In the focus group interview she followed up with a similar notion saying, "I think it's important to pair technology with the NGSS standards in the science classroom in order to prepare students for the 21st century." She sees technology as a faction of life that will not be going away anytime soon, and therefore must be taught as part of science.

Finally, Ms. Campbell also believes that technology and NGSS go together, and that traditional ways of teaching cannot accurately increase learning in students or assess the science content they have mastered. She first describes this idea in her week five learning journal writing, ".... the 'traditional' way that science has been taught does not teach them to be the problem solvers that we need them to be." Simple read and regurgitate is a method of teaching that Ms. Campbell is strongly against. She does not believe that traditional methods will give our students the problem-solving skills they will need to be viable citizens in the future. She elaborates on this idea by discussing how assessments need to change in her week six learning journal.

> I do believe it is more important to assess the skills that are important rather than the skills that are easier to grade...it's my intention to create assessments that truly assess the skills

that students have learned and to encourage students to demonstrate those skills in the best way possible.

Even if creating skills-based assessments or giving students access to technology for guided discovery may have more challenges, she feels it is a necessary challenge in order to give students a chance at success in the future.

Overall, Ms. Campbell's beliefs reveal that she is a teacher who is committed to finding the most current technology for her students and using that technology in concert with the NGSS Science & Engineering Practices to design lessons that will best prepare our students for a 21st century future. She is not afraid of the challenges of inquiry-based teaching or performance-based assessment, instead, she feels it is all teachers' duties to find new technology tools that will enhance science teaching and better prepare our students for their futures. Many of these ideas came from who she already is as a teacher and not necessarily from the PD.

Technology for science. While Ms. Campbell clearly believes technology is worthwhile in the classroom, she also believes there are many ways technology can be used to enhance inquiry-based science teaching. She feels that technology can be used specifically in science for students to be able to create models and make hypotheses on phenomena, take students to places that were not previously possible without technology, and as a means for designing real-world solutions. These beliefs reveal someone that has thoroughly integrated technology into their pedagogy but done so in a way that enables students to get at science more effectively. The following will unpack her strong beliefs on how technology can be used to specifically enhance science teaching and learning.

One of the primary ways Ms. Campbell believes technology can be used to benefit students understanding of science is through its unique ability to help students create models and make scientific hypothesis. One of the eight NGSS Science and Engineering Practices, NGSS modeling asks students to use diagrams to make "...predictions of the form "if … then … therefore" ...in order to test hypothetical explanations (p. 50)." Throughout Ms. Campbell's lessons, students made models either using technology itself in the form of Google Drawings, or from using a technology tool like Virtual Reality or simulations. They also voiced aloud their predictions on the inner workings of phenomena and used evidence collected from technology to back-up or refute their claims. The evidence-based predictions and models she asked her students to make enabled them to generate their own understanding of topics. In her week four learning journal, she entered

> ...they (technology tools) allow students to experience models in the same way that scientists do and accomplish the same goals. Students using science simulation tools are also able to gain intuition, connect the dots, and make predictions that could otherwise not be done in the real world.

She is able to see that through technology or from technology students can make scientific predictions, a skill that will authentically carry over into their lives after school. Modeling and predicting are two science skills Ms. Campbell feels can be enhanced or made better through technology in the science classroom.

Additionally, Ms. Campbell believes an advantage of using technology for science is its ability to take students to places outside the classroom. In nearly every one of Ms. Campbell's lessons, her students traveled to different destinations and experienced a wide array of phenomena through AR, VR, and simulations. In Week one of the PD, her students interacted with producers and consumers using AR on iPad, in week six they virtually tested out materials to complete a circuit using an online simulation, and after the PD ended, her students travelled inside the human eye to discover how it was able to decipher different types of radiation. Throughout her learning journals, she also wrote about the importance of using simulations in the science classroom. Early on, in just week two, she writes " I believe technology can be used in the NGSS classroom to do anything from collecting data in Google Sheets and sharing it in real time to taking virtual field trips to the bottom of the Mariana trench using Google Expeditions." She sees the value of using technology to give students experiences they would otherwise not have and then adding on another layer of technology to do things like share data from the virtual experience. Beyond giving students the opportunity to virtual travel, she also sees the importance of simulations in making predictions and using tools in a similar way that scientists would. In her week four learning journal, she recorded "Science simulation tools can play the same roles in the NGSS classroom as they do in the real world." Stressing the ability of simulations for students to develop real-world skills that transfer beyond school in the likeness of scientists, in these statements, Ms. Campbells firm belief on the ability of virtual experiences to transform the classroom is highly evident. Throughout the PD, both her beliefs and practice revealed a teacher that was committed to using virtual exploration to enhance inquiry-based NGSS instruction.

Finally, Ms. Campbell believed and demonstrated that technology is important to use in the science classroom because it gives students the opportunity to make connections between science and real-world problems. By authentically exposing students to problems that science can have a hand in solving, she believes that students use of technology in science class can create students that know how to approach problems and use technology to solve them. As early as her week two learning journal, she writes "I believe students benefit from using technology in the NGSS classroom because they can gain a richer understanding of systems and scientific models. Students also gain an understanding of real-world applications of scientific processes using technology." Through technology, she believes students can gain an understanding of how science skills are relevant in real world problem solving.

She adds to this idea in a statement from her week five learning journal "Technology allows for so many more possibilities...that students can use to solve real world problems." In Ms. Campbell's beliefs, technology can do much more than enhance the science classroom; it can be used so that students may gain skills that can transfer to solving authentic problems they may encounter once they have completed school. The scientific process, and technology skills that students gain when using technology in NGSS ways will help students thrive in a way that would not be possible without having technology in the science classroom.

Fears/ Resilience

The fears that Ms. Campbell expressed amongst the PD sessions, learning journals, and in the submitted videos were in regard to her not being able to find new technology for her students or for the availability of the technology to not be enough to support the needs of her students. Throughout her lessons, she demonstrated an unmarked resilience and lack of fear in terms of navigating the technology tools themselves. There were several instances where some of the other teachers who were primarily using tech as a way for students to show what they know backed down from using the technology, or did not include it at all in their lessons because they were afraid that they were not knowledgeable enough at the tool or that it wasn't working how they expected. Ms. Campbell however, addressed each challenge with flexibility and iterated many times that if she was not challenging her students with more useful technology tools, that she was not challenging her students appropriately.

For example, in the recorded lesson she filmed prior to the PD beginning, Ms. Campbell encountered an issue with the Google Expeditions application. She met with another teacher to test out the app on a cell phone and noticed that the AR simulation was not working properly and was appearing on a white background instead of the classroom like it was intended. Instead of scrapping the lesson entirely, Ms. Campbell went to the media centered specialists and inquired about using the application on the iPads. Even though she had never tried the application with her students before, she was determined to make the lesson a reality. When she encountered an issue with the technology, she always stayed resilient and was able to problem solve a solution in order to keep the technology tool as a part of her lesson.

In another instance, during her post-PD recorded video, students were again using the Google Expedition Application, but this time in the VR format in the Virtual Reality Goggles. The students in her Resource level science course were noticeably excited by the Goggles and a little distracted from the new appearance of their surroundings in the Goggles. Students spent around 7 minutes playing around with the VR and getting their bearings, when the bell rang before Ms. Campbell was able to accomplish all of her objectives of her lesson. Whereas many other teachers may have canned the technology tool as being too distracting, Ms. Campbell expressed at the closing of her lesson "...even though you were distracted, hopefully it will get better with tomorrow." In this example, Ms. Campbell saw the value that technology can add to a lesson and does not back down even if there were a few bumps slowing her down from accomplishing all she had intended.

Finally, Ms. Campbell's one and only fear in regard to using technology in the science classroom is that technology evolves so quickly that she may miss out on an opportunity to provide it at a useful juncture for her students. In the focus group interview, after the PD, she stated, “my fears are that technology is changing so fast that it’s hard to keep up!” Ms. Campbell is clearly not a teacher who is afraid of using technology but is instead afraid that technology is outpacing her. She places a high value of using technology in the classroom, and she is not going to let anything stop her from using it to enhance her classroom. Constantly searching for new ways to use technology in the science classroom, Ms. Campbell is an innovator who has shown technology can be used for inquiry-based teaching and someone who will continue to use tech after the PD has ended.

Summary

Ms. Campbell demonstrated high levels of technology for science use before the PD and will continue to after the PD has closed. She was a master at using technology for NGSS instruction and can add some of the technology tools that the PD harped on into her wheelhouse. Other teachers in the PD group benefited from the questions she asked of their lesson plans and from the examples of her plans and teaching. Although she did not change much throughout the PD, she will continue to approach technology from an inquiry-based teaching standpoint. The small class sizes and population of students that she teaches has enabled her to be more fearless with how she approaches technology instruction. Her strong beliefs on the importance of technology in the classroom and for benefitting science teaching manifested themselves in her teaching. Ms. Campbell will continue to use technology in the highest levels of SAMR and in accordance with the NGSS Science & Engineering Practices.

Structure of the PD and its Impact on Change

As alluded to above, the PD followed a very similar format in its duration and each of the teachers’ changes can be attributed to its design. The participants were able to articulate that some aspects of the PD’s structure contributed to making changes, while other aspects did not foster growth. The impact that the PD had on beliefs and practices due to its structure varied by participant. Overall, the teachers felt that the PD was most helpful because it exposed them to more technology tools, the online format enabled them to log on and complete tasks at their convenience, the group dynamics fostered more effective conversations, and they also noted that the experiential nature of the program exposed them to instructional approaches that incorporated NGSS, technology, and inquiry. The following will describe the reflections the teachers had in relation to the structure of the PD, the level of impact that it made, and how the interactions amongst members related to their growth.

The PD exposed teachers to seven new technology applications that were rooted in inquiry-based instruction in alliance with NGSS. The teachers championed this aspect because it gave them many new applications to add to their personal repertoire. Ms. McDonald was able to capture this belief in a statement in her week six learning journal. She wrote "There are so many tools accessible for science teachers that I would have otherwise not been introduced to if it weren't for this hybrid PD. As a new teacher, I am grateful for learning about any different ways I can teach a topic!" Prior to the PD Ms. McDonald did not have exposure to or realize that there were many technology tools available for science instruction, however, while being a participant in the PD, she was able to learn about new applications that she could use in her classroom. Ms. Jackson expressed a similar feeling in reference to using Google Tools in her classroom. In her week three learning journal she replied "I've learned there are definitely more Google tools than I knew about. This PD definitely encouraged me to look into more of these tools as potential resources for the science classroom." She reiterated the fact that both of the teachers had not realized that many technology applications could be used for science and that the PD was able to make that connection obvious for them. Although neither of these teachers made great changes in terms of practice, they were still exposed to new tools.

Similarly, in her week five learning journal, Ms. Augustine reflected "The videos we've watched in this PD has helped build my knowledge of how to use technology in the classroom. It has also inspired me to use more technology with my students." The PD was able to expose her to new forms of technology and through videos, she was able to see practical applications of how the technology could be used in her classroom and how it could make a difference for her students. Ms. Flynn also realized how the introduction to new tech applications each week was able to inspire her to try new things and push her out of her comfort zone. In the focus group interview she shared "I think for me, it really opened my eyes to other things that were out there that I didn't know about or I wasn't comfortable using. And, its kind of forced me out of my comfort zone and pushed me to introduce things more. So, it really pushed me." Each week's minilessons inspired the teachers to try new things and pushed them to mesh technology and science into their lessons in ways they hadn't before.

Beyond exposing them to new technology tools, the PD was able to aid in the participants' individual growth because it was hosted on an online platform, which gave them the ability to log on and get things done at their own convenience. Ms. Flynn noted this factor of the online sessions making it possible for her to learn when she had the time to. In the focus group interview, she remarked, "This way you could do it when you needed to whether it be 6:00 in the morning on a Sunday or 11:00 at night on a Thursday. Whenever. You did it when you had the time and you made it work." She highlighted the convenience as a factor that made it easier for them to learn.

Ms. Campbell also described the freedom the online portion of the PD gave her in terms of completing tasks on her own time schedule. She stated:

> The hybrid format was beneficial because it gave me latitude to work at my own pace; something I would not be able to do if it was a traditional setting...I believe I was able to glean the same information that I would have if it were a traditionally formatted PD.

She described how she was still able to attain the same information that a traditional PD would offer but in a more beneficial format because she was able to work at her own pace. Time was another important factor in the hybrid PD for Ms. Jackson, who also remarked on how having the convenience to complete the week's tasks when she was up to the challenge kept her more engaged in the content of the PD.

> Yeah I think if I had to come after school I would've been like, I would've been so tired and when we have a meeting sometimes after school, all I wanna do is sit here and listen to someone talk for 40 minutes and that's not what you want to be doing with this content. You get to be trying it out or going on a website and practicing it and I wouldn't be my best learner I think if it was every week after school. (Focus Group)

Overall, the teachers felt like the hybrid format positively contributed to their learning because they were able to complete tasks whenever time was available, and when their minds were mentally ready to take in new information.

Additionally, the group dynamics that were established in the PD contributed to a positive experience and change for the participants. In the beginning of the PD, the group worked together to create norms for communication in the physical and online platforms. These norms helped to keep people accountable and ensured that comments were professional. Throughout the PD, the teachers also relied on protocol as the foundation to their conversations.

Ms. Augustine was able to capture how the establishment of norms and the uses of protocols contributed to positive interactions amongst the group. “We were able to meet and collaborate and reflect on our use of technology for the online portion and then share our views in person. We were still able to share ideas online through lesson plan feedback (focus group interview).” Because of the structure of the group dynamics, the collaboration that occurred online and in-person contributed to effective conversations and idea-sharing amongst the group.

Comments made on lesson plans through the use of protocols also enabled the group to have positive interactions. Each week, one teacher posted a lesson plan to the group to respond to using the Four A’s protocol. These interactions spurred thought provoking conversations that may have impacted the groups’ beliefs and practices. For example, Ms. Campbell often left comments on other people’s lesson plans using the “Four A’s” protocol that could have pushed them to make changes. On Ms. Jackson’s week 4 lesson plan, she commented asking if students could integrate more STEM components such as designing alternative energy sources or creating a model.

> Can a STEM component/station be added where students "design" a type of alternative energy and create a model? It can be anything, but it would be a way to get them thinking about problem-solving for alternative solutions (Week 4 Lesson Plan, Google Classroom).

This comment emerged because of the group dynamics that were established through the protocol. This kind of interaction, where Ms. Campbell asked Ms. Jackson if she could switch the lesson up to include more elements from the NGSS Science & Engineering Practices gave Ms. Jackson, as well as the other teachers in the group, an awareness of how changing the approach to lessons could deepen the science learning that occurs. Without the establishment of norms, or the reliance on protocols, interactions such as these may not have occurred, or they could have been stated in ill favor. Overall, the group interactions contributed to positive and meaningful conversations amongst the group.

Finally, the teachers felt the PD helped make more clear to them the connection that exists between technology, NGSS, and inquiry-based teaching. Because of the PD, they felt they now had a better understanding of the focus on skills that NGSS has and how technology can be used for their students to acquire and sharpen those skills. In the post-PD survey, Ms. McDonald describes how now because of the PD she can better grasp the narrow focus NGSS has on the acquisition of science skills instead of a gathering of science facts for her students. In the post-PD survey, she stated, “I have also gained greater insight into breaking down the NGSS skills.” This enhanced understanding of the NGSS standards will help Ms. McDonald to design better lessons in the future that use technology with inquiry in mind. While she wasn't able to carry out changes in terms of practice, the changes in her beliefs evident in this statement, are something she can build on in the future. Ms. Augustine also shared her feelings on viewing videos each week in her week six learning journal, “By viewing the videos you’ve posted, I could tell how those (SAMR) levels really made an impact in students’ learning.” She saw real-life examples of how technology and science can be merged together within the weeks of the PD and was able to come to the realization that teaching in accordance with the top level of SAMR is possible and important. Ms. Augustine also felt that she was positively impacted by the PD to try and teach in new ways. In her week five learning journal she wrote “The past tutorials have really opened my eyes to new and different ways to incorporate technology into my science classroom. I am excited to try out the various tools that we have been introduced to.” The teachers were positively impacted by the PD to attempt to take their teaching to new heights because of the exposure to different tech tools and practical applications.

While four of these teachers described above still had more room to grow in terms of using technology in high SAMR levels for inquiry-based NGSS teaching, there was one teacher who came into the PD holding a great understanding of these concepts in her beliefs and practices. Lori Campbell began the PD with beliefs that demonstrated she felt technology played an important role in the science classroom and she felt that the hybrid course was able to reinforce her beliefs and practice. Because she was already using technology primarily for inquiry-based teaching and learning, the PD was able to reaffirm her belief on the importance of tech in the science classroom and the NGSS methods by which it should be used. In the focus group interview, she stated "My beliefs about the role of technology in the NGSS classroom were that they are a necessary component that should be used as much as possible. The more students are exposed to it, the more comfortable they will be. This was my belief before the PD, and the PD confirmed this belief." This teacher was already well equipped with a developed TPACK for inquiry-based science and her artifacts shared with the group demonstrated a great depth of understanding of both concepts. While being an advanced participant, Ms. Campbell often submitted assignments late and felt that watching videos of other participants did not benefit her. In the focus group interview, she stated: "The least helpful part was watching the other teacher's video recording…" She may not have gained much from watching other teachers, however, her comments on other teacher's work often pointed out flaws in the designs of their lessons, or asked questions that could push the lessons to move toward more inquiry.

Because the PD was hosted in-person and online there was a unique opportunity for the teachers to experience, discuss, and reference the content the course covered. The structure of the PD and the sequence of events within it enabled some teachers to change in their beliefs, practices, or a combination of both. While most of the teachers felt that the design and assignments positively contributed to their knowledge-base of technology tools, one teacher felt like the interactions amongst her and the rest of the group did not make much of an impact on her learning.

Summary

Throughout this study, five teachers participated in a six-week hybrid PD on technology-enhanced-inquiry-based science teaching. The first and final sessions of the PD were hosted in person, and the middle four sessions were held on an online Google Classroom. Throughout the course of the PD, teachers were introduced to seven new technology tools and approaches to teaching science with technology in various mini-lessons online and through in-person labs. The PD was designed to be experiential in nature so that teachers engaged with technology in the same way that their students would in the future. The PD spanned from November 2018 to February 2019, with a three-week winter break. I worked alone as the facilitator and primary researcher to investigate the following research questions: (1) How do science teacher's beliefs on using technology for inquiry-based NGSS teaching change throughout the course of a hybrid six-week PD course? (2) How does technology use in teachers' science classrooms change after participating in a hybrid professional development? (3) What evidence of alignment between technology use, M and R levels of SAMR, and components of NGSS are observed before and after participation in a six-week hybrid PD?

To track their progress, teachers submitted three lesson plans, recorded two videos, participated in two surveys, collected two students' surveys, and completed six weekly learning journals. Feedback from the participants was used each week to inform the planning of subsequent sessions so that it could be relevant and meaningful for the group. All of this data was evaluated from a mixed methods perspective both quantitatively and qualitatively.

Following data analysis teachers were placed into three different orientation profiles characterized by the primary ways in which they used technology at the close of the PD as well as additional changes in beliefs and practice that occurred during the PD. Profile one consisted of two teachers who primarily used technology as a means for students to show what they know, and these teachers experienced the greatest change in terms of their beliefs but not in their practice. The two teachers in the second orientation profile typically used technology for guided discovery and at times used it as a tool for students to demonstrate their learning. These teachers experienced changes in both beliefs and practice throughout the PD. Finally, one teacher stood alone in the third orientation profile. This teacher was already using technology expertly merged with high levels of SAMR and NGSS constructs before the PD, and continued to do so after the PD.

To create the orientation profiles, first, teachers' videos were scored using the Technology Usage in Science Instruction Instrument (TUSI) and teachers within ten points of average score ranges were sorted into the same category i.e. (avg 40-50 is profile 1, avg 50-60 is profile 2). Next, data from the videos and lesson plans were coded according to the SAMR model and NGSS Science & Engineering Practices. This coding confirmed the original placement of the participants into their orientation profiles, as this sorting revealed participants also had similar outcomes in approach (i.e. profile one has most instances of S&A from SAMR and highest counts of Obtaining and Evaluating Information from the Science & Engineering Practices, while Profile three had the highest counts of M&R usages of Technology and instances that align with more Science & Engineering Practices). Finally, data from participants' learning journals was coded according to general beliefs, science beliefs, fears, and ways that the PD was of help to them. These codes were sorted chronologically to build a summary of each participant that visually displayed a timeline of when changes had occurred. This data also confirmed initial placement of participants into their orientation profiles, as statements and change were similar amongst participants in each profile.

The first profile consisted of two first-year fifth grade teachers. These teachers primarily used technology as an information transmission tool before the PD and this practice remained the same after the PD concluded. In a typical lesson, these teachers gave students a subset of digital media including online articles, books, and videos to review for a length of time. Then at the end of the lesson students would use a technology tool, such as a video recorder to report on the most important information they learned from the sources. This practice remained consistent before and after the PD.

Not remaining consistent, however were the beliefs of the teachers in this profile. In the beginning of the PD, these teachers felt that using technology in science was not developmentally appropriate for their students and did not offer any benefit to attaining science skills. At the end of the PD, their beliefs were on the opposite end of where they initially stood and the teachers were able to articulate exactly how specific technology applications could increase the mastery of science content and skills, and were even able to point out the flaws in their own instructional practices. Despite realizing that they had been using technology mainly for review, and that technology has specific merits for science, neither teacher in this profile was able to create a new lesson that used technology in ways demonstrated by the PD.

The second orientation profile consisted of one fifth grade teacher who has been teaching for 22 years and one sixth grade teacher who has been teaching for five years. Both of these teachers already had a fairly sophisticated understanding of technology and NGSS, and were able to replicate many ideas from the PD into new lessons submitted as a part of the PD. Their beliefs also became more developed as the weeks passed, and they left the PD believing that technology can be used to foster inquiry and being able to carry it out in high levels of SAMR in practice. The ideas from the PD resonated with the participants quickly and as early as week 2, as they had integrated many of the ideas into their own practice and belief system. They experienced change in terms of practice and belief.

The final orientation profile consisted of one teacher, whose beliefs were reinforced and made stronger by the PD. With 17 years of experience in teaching, including unique settings such as inpatient mental health and recovery students, and special education resource rooms, this teacher entered the PD with highly developed practices and beliefs. From day one she submitted lessons that nearly always used technology for guided discovery. She was the only teacher who was able to use technology in alliance with all eight of the Science & Engineering Practices and had the highest counts of technology use in the M and R range of SAMR. Her participation in the PD was minimal, although her comments on other teachers' lesson plans often asked thought provoking questions or suggestions as to how the lessons could be improved to foster more inquiry.

Overall, the PD was able to make an impact for the participants. Each orientation profile was characterized by a different amount of change in terms of beliefs, practices, or both. The length of years the participants had in teaching experience, as well as their placement in middle school or elementary school may have contributed to the change that the individual participants incurred as a result of the PD. The structure and content in the PD played a role the participants own growth.

Chapter 5: Discoveries

The hybrid PD contributed to differing amounts of change in either beliefs, practices or both related to technology-enhanced inquiry-based teaching for the individual participants. The following will describe how the participants changed throughout the PD including how the design of the course contributed to change and how characteristics of the participants may have hindered or helped evolution. First the discussion will dive into how the hybrid nature of the PD enabled teachers to change over time. This will give a look into how the experiences fostered growth, how the hybrid format was convenient, and how group dynamics brought on change. Next, the impact of the individual teachers' years of experience teaching will be analyzed in relation to how much change the PD was able to make. Afterward, the state of the elementary curriculum in relation to technology, science, and inquiry will be discussed. The paper will close with the implications of the study as well as a description of the limitations.

Hybrid PD Contributed to Ease of Time and Teachers' Learning at their Own Pace

Hybrid PD has been lauded for its ability to adhere to best practices for PD, lessen the cost of traditional in-person PD, and to capitalize on the ability of teachers to complete learning at their own pace and on their own time schedule (Owston, et al., 2008). However, much of the research on hybrid PD has come from teachers self-reporting on the knowledge they felt they gained in the form of surveys (Dede et al., 2009). This PD implemented best-practices for adult learning in professional development, and for acquiring knowledge on technology-enhanced inquiry-based teaching within the confines of a six-week duration. Data was obtained through self-reporting and the evaluation of artifacts. Structures for effective PD include that it should be job embedded, focus on collaborative/active learning, and should be sustained over a long time period. It should also include the facilitation of deeper knowledge of content, linkages across curriculum, assessments, and professional learning decisions in the context of teaching a specific content (Wei, et al., 2009). This study focused on each of these facets within the confines of six weeks. When teachers reflected on the elements of the hybrid format that helped them the most, they discussed how: the experiential nature helped them to gain knowledge on ways to integrate technology into their own classrooms, the structure of the online weeks gave them an opportunity to get things done on their own time and at their own pace, and the group dynamics contributed to a positive learning environment for the group.

The PD exposed participants to different technology tools as the weeks went by, and throughout each week, they were able to interact with the technology in the same way their students would in the future. Teacher's first immersed themselves in the technology wearing their "learner hats" and then reflected on how the tool could take shape in their classrooms using their "teacher hats." Immersing themselves in this format, the teachers experienced each of the steps in Kolb's learning cycle. Their ability to first have a concrete experience, and then move to reflect on this experience in a collaborative setting, pushed them to be more innovative. As they moved into the final phases of abstract conceptualization and active experimentation, they were able to draw from their experiences in the concrete experience phase in order to make the lessons more successful. Findings suggest that the teacher may play an even greater role in the students' technology-enhanced learning than the nature of the technology itself, and by moving through Kolb's learning cycle, the teachers were able to make changes in beliefs and practice that positively impacted their students (Tamin et al., 2011).

Throughout the PD, teachers often reflected on their experiential learning in comments in their learning journals. They summed up how experiencing the technology first-hand enabled them to make decisions on how to implement it with their students. For example, Ms. Jackson noted, "There's so many little pieces that go into it. Like how to plug into Google Classroom and what you do over here. So that I found was really useful and I kept going back to them when I was about to use it to make sure I was gonna do all the things I needed to do (focus group interview)." Because Ms. Jackson had experience using the technology, she felt comfortable with trying the tools later in her classroom on her own. Overall, the experiential nature of the PD enabled participants to better implement technology tools with their students.

Additionally, every participant commented in some way on how the online portions of the PD made it more convenient for them to complete the tasks each week. Many schools are now turning to hybrid PD because it is a solution to high-cost of in-person PD and because it is more convenient for working professionals (Blitz, 2003). It also can extend beyond time limits of traditional PD (Blitz, 2003). While this hybrid PD was able to extend the learning beyond what would have typically occurred as a one-day workshop, what all participants commented on as making a positive impact for them, was the convenience that an online format offers. Ms. Flynn summed up how the hybrid format contributed to the learning of the participants because it made it convenient for them to complete the tasks whenever they had free time. In the focus group interview, she described "this way you could do it when you needed to whether it be 6:00 in the morning on a Sunday or 11:00 at night on a Thursday. Whenever. You did it when you had the time and you made it work." For the participants, the group consensus was that the hybrid format of the PD made a difference in their learning because they could view the materials and complete the assignments whenever they physically had time and were mentally ready to do so. Other teachers also noted that they "were able to glean the same information as a traditionally formatted PD (Ms. Campbell, focus group interview)" and "I wouldn't be my best learner I think if it was every week after school (Ms. Jackson, focus group interview)." Combining online sessions with introductory and closing in-person sessions may have kept participants more engaged and enabled them to complete more thorough participation than a traditional PD.

Additionally, the set-up of the group dynamics in the hybrid PD impacted participants' ability to learn. During the in-person session, teachers established norms for the group. In later weeks, teachers used a protocol in accordance with these norms to comment on key aspects of each other's lesson plans and videos of their lesson. In a meta-analysis of studies involving PD on technology and inquiry-based science from 2005-2011, Gerard et al., (2011) identified community-based learning as one of the key factors to making teacher change as a result of PD a reality. Some members overtly commented on this element of the PD as making an impact. Others also noticed there were times when discussion amongst teachers in the online setting may have led to a change in belief or practice for the members.

In the focus group interview, Ms. Augustine reflected on the group dynamics both in-person and online, and was able to sum up the sentiment of the group on how working online contributed to her learning as a part of the PD. She responded, "We were able to meet and collaborate and reflect on our use of technology for the online portion and then share our views in person. We were still able to share ideas online through lesson plan feedback." Because of the steps that were taken to ensure group dynamics had a good foundation, and the reliance on protocols, Ms. Augustine articulated that both the online and in-person interactions amongst members of the group positively contributed to her learning as a part of the hybrid PD.

Additionally, each week teachers responded to each other's lesson plans using the Four A's protocol. The reliance on this protocol fostered positive, thought provoking conversations. Protocols have been effective at making changes in participants in short-term PDs on technology and science in past studies because they foster targeted conversation or reflection (Tan &

Towndrow, 2009; Trautmann et al., 2010; Yerrick et al., 2009). For example, on Ms. Jackson's week 4 lesson plan, Ms. Campbell commented, asking if students could integrate more STEM components such as designing alternative energy sources or creating a model:

> Can a STEM component/station be added where students "design" a type of alternative energy and create a model? It can be anything, but it would be a way to get them thinking about problem-solving for alternative solutions.

In statements like this one, the participants pushed the teacher who wrote the lesson plan to have an awareness of when more inquiry-based practices could be infused into a lesson. Overall, the hybrid format contributed most to the learning of the participants through experiential learning, the time convenience it offered them, and also through the group dynamics that were part of the PD's design.

Teacher Experience Can Impact Change

The teachers that participated in the PD ranged in length of years teaching from 1-22 years, and amongst the group, there were various levels of change that happened to the participants in terms of belief and practice. Two first year elementary school teachers experienced dramatic changes in terms of their beliefs but were not able to bring the change in beliefs into their practice. Different from the first two teachers, Ms. Flynn and Ms. Augustine with 22 and 4 years of experience respectively, experienced change in both beliefs and practices, and were able to integrate many of the ideas from the PD into their lessons. Last, Ms. Campbell, with 17 years of experience experienced little change, but was able to deepen her already advanced beliefs and skills on using technology in the science classroom. The teachers were able to make changes when they were primed to do so, depending on the years of experience they had, and the new teachers may have needed more support in terms of classroom management for inquiry before they were able to integrate changing beliefs into their practices.

Ms. Jackson and Ms. Augustine, the two first year teachers of the group experienced a major change in their beliefs in response to the PD, but had a difficult time integrating some of these ideas into their practice. Similarly, in a study of five elementary school teachers, Johnson & Dabney (2018) discovered that all first-year teachers in their study believed and were able to recite effective science instruction strategies but were unable to use these strategies in practice. Ms. Campbell and Ms. Jackson were also able to articulate the methods by which technology should be used in accordance with the NGSS Science & Engineering Practices, and high levels of SAMR, and could point out flaws in their own practices, but yet did not change much in terms of their approach in the lessons they submitted throughout the duration of the PD.

> For example, in the focus group interview Ms. Jackson summed up the problems with the first-year teachers' practices. She was critical of how she used technology for instruction with her students during the duration of the PD and was able to point out that her approaches were not for guided discovery or in alliance with NGSS. This demonstrated that her beliefs on the role of technology in the science classroom had gone from more traditional to more reform oriented. She stated: How I was using it before was mostly for, I would say, assessment or even just as a closure activity. So, a lot of it was letting them make a Flipgrid, showing what they learned and kind of more of an open-ended thing. I wasn't really using it for the bulk of the learning like where they would actually be receiving information.

In this statement, she pinpointed the flaws in using technology only for assessment or review and that she was missing out on the opportunity to use technology with her students as a learning tool. Similarly, Ms. Jackson also articulated the traditional flaws in her approach to using technology with her students, indicating her beliefs had to become more reform oriented. In the focus group interview she remarked that she had typically used technology for centers but did not use technology “as a teaching tool (focus group interview).” By the conclusion of the PD, both teachers had come to a realization that they previously missed the mark in terms of implementing technology for an instructional tool, showing a major change in their beliefs. The teachers were able to emphasize the various instructional approaches they took to using technology in science with their students that did not include guided discovery such as for assessment or review, which did not align with the ideas in the PD. However, they both noted that technology could and should be used as a teaching tool in science to immerse students in inquiry but were unable to carry these ideas into practice.

Additionally, researchers discovered that factors unrelated to first-year teachers’ preparation or self-efficacy negatively impacted their ability to teach according to their beliefs (Johnson & Dabney, 2018). First year respondents in their study reported needing to relearn science content facts for their grade level and/or experiencing challenges with classroom management when using a student-centered, hands-on approaches as the two biggest limiting factors from translating their beliefs into practice (Johnson & Dabney, 2018). Ms. McDonald captured this sentiment with the struggles that come with being a first-year elementary science teacher in her focus group interview. She remarked,

> I think as a first-year teacher, me and Ms. Jackson are both first year teachers, I feel like I have so much to learn. I know every teacher feels that way and it's a constant thing of always learning more but...I was nervous to teach science. And fifth grade science, it's not easy, it's stuff I had to teach myself first.

First year teachers have much to learn and in terms of PD impacting practices with technology use in alliance with NGSS. It seems there may be a need for these teachers to learn the basics of content and classroom management alongside technology-enhanced-inquiry-based practices in order for effective instruction to take place. First year teachers may need overt instruction on classroom management for inquiry and technology use with their students for it to become a reality in their classrooms. There are less obstacles to changing beliefs for first year teachers, than there are to changing practice.

However, changing practices from being more traditional to more reform oriented in teachers with more experience is something that has been demonstrated in previous studies. In Campbell et al.'s 2014 study, after a one-year intervention, seven out of eight participants' beliefs and practices had moved from being more traditional to more reform oriented. In a follow-up study in 2015, again after a one-year intervention, four out of four participants in the study produced lessons that were more aligned to NGSS, used technology in more sophisticated ways, and had a better grasp of content knowledge (Campbell et al., 2014; Campbell et al., 2015). Interestingly enough, the participants in this study were secondary teachers, and also had experience with teaching for longer than a year. In these studies, they also used teachers' beliefs to approximate teacher practice because they found that what was said in learning journals, matched what was going on in the classroom (Campbell et al., 2014; Campbell et al., 2015). In my study, however, what the first-year elementary school teachers said about what should be done in practice, was not what they carried out in practice in their classrooms.

Other than the first-year teachers in the first orientation profile, the remaining participants were impacted by the PD and made changes to both their practice and beliefs congruent with what was found in the Campbell studies. One elementary school teacher, Ms. Flynn who had 22 years of experience was able to put some of her changing beliefs into practice. In the beginning survey when asked about the role of technology in the science classroom, Ms. Flynn responded "I believe the role of technology in the science classroom is to enhance lessons and offer an additional tool to communicate, learn, etc." While on the closing PD survey, she responded to the same question

> I believe the role of technology in the science classroom is to be used as often as possible to promote independent discovery and investigation. It should not be used as a replacement for other types of learning, but as a tool to foster higher level thinking and independent, and collaborative work.

Throughout the PD, her belief on the role of technology evolved from it being a tool that can support learning to a tool that promotes guided discovery and higher-level thinking. She had made the transition in beliefs from technology being a means for something that students can learn from, to its being a tool that students can learn with. She exemplified this learning in a recorded video that was submitted week two of the PD. In this lesson, she had students create models of levers and pulleys using Google Classroom to make predictions about what would happen if you moved the load and the fulcrum closer and farther away from each other. In this instance students weren't reading about levers and pulleys but were creating models using technology to draw conclusions about how they worked, and therefore turning her new beliefs into practice.

Ms. Augustine, with four years of experience, had a similar change to Ms. Flynn and the participants in the Campbell (2013, 2014, 2015) studies. In the beginning of the PD, she submitted a lesson where students clicked through PowerPoint slides on a computer in order to learn more about deforestation, a lesson that ranked low on the SAMR scale. Before the PD began, she felt that this was a great example of how students could integrate science and technology. However, due to her experience, by the end of the PD, her practices and beliefs had changed. In one of her final lessons, students learned about conductors through a simulation, a practice that sat in opposition to those carried out in her first lesson, and a skill that was demonstrated in week four of the PD. As students navigated through the simulation, they were able to come up with their own definitions for conductors. At the close of the PD, she was able to comment on how she now believed technology should be used as a tool for students to learn with. Unlike Ms. Jackson or Ms. McDonald, Ms. Augustine was able to quickly change her beliefs of the role of technology in her classroom and implement those beliefs into practice because she already had four years of experience. These years of experience may have given her more exposure to basic classroom management skills that enabled her to make a swift change.

Finally, Ms. Campbell was already an advanced technology user when she began the PD, and the PD was able to reinforce and deepen her beliefs, however she did not experience much change. With 17 years of experience in more nontraditional settings, this teacher was more willing than any of the others to take risks and be creative with classroom management. In some of her first lessons, she was already using technology in high levels of SAMR, and at the close she continued to do in ways that aligned with all eight of the Science & Engineering Practices. I believe her unique experiences outside K-12 education as well as her 17 years in K-12 education, may have primed her to be more fearless when it came to integrating technology and translating beliefs into practice to be less of an obstacle.

These examples have shown that it is possible for a hybrid PD on technology-enhanced-inquiry-based teaching to make an impact on participants beliefs and practice. However, the amount of change that participants incur may be dependent on the amount of experience teachers have. Also, there may be special exceptions for first-year teachers. First-year teachers may need more support in the areas of classroom management during inquiry-based investigations and the re-learning of science content alongside technology for science PD. Linking back to Kolb's idea of the experiential learner, as this PD was designed from an experiential perspective, first year teachers may need more support to enter the "Active Experimentation" phase to act on ideas presented in the PD. Veteran teachers with more experience may have an easier time translating ideas gained from a hybrid PD into practice. This also calls into question Induction programs for first year teachers and pre-service training. These programs designed for beginning teachers may need to give teachers actual experience with classroom management and curricular expectations of content knowledge so they can be ready to integrate ideas presented in a PD into their repertoire of practiced skills.

Elementary Science Teaching Still Needs Reform

Three out of the five participants in this study were elementary school teachers, and after data analysis, two of them were classified into the first orientation profile. Although the elementary teachers experienced different amounts of change as a result of the PD, something that was common amongst all of the elementary teachers participating in the study was a feeling of needing to revise the science curriculum in order to merge the constructs presented in the PD into their own science teaching. Elementary school teachers have typically had a difficult time teaching science, citing self-efficacy issues, time pressure from state testing mandates, and lack of access to supplies as some of the main reasons (Avery &Meyer, 2012; Bursal, 2012; Gunning & Mensah, 2011; Kind, 2016; Mansfield & Woods-McConney, 2012; Riegle-Crumb et al., 2015). Studies have also found that a lack of content knowledge hinders elementary science classroom instruction (Appleton, 2008; Hanuscin et al., 2011; Stein, Larabee & Barman, 2008).

Additionally, in a survey of over six hundred elementary school principals, Winn (2016) found that many have limited science background and experience with science teaching, which may negatively impact teachers' ability to allocate proper time to science and have the supports in curriculum and PD for it to be taught effectively. Clearly, there are many factors hindering science instruction from reaching optimal levels, and there needs to be reform in curriculum and scheduling in order for NGSS instruction with technology to be performed in the likeness of the ways presented in the PD.

Throughout the PD, many of these limiting factors were echoed by the participants as each of them expressed needing a reform in the way the science curriculum is designed, implemented, and supported. Ms. Flynn pointed out how time and curricular constraints were obstacles to integrating technology in science. In her week four learning journal she responded, "The negative aspects of using technology in science would mainly be time...while curriculum and time restraints do not always offer the opportunity for simulation." Throughout the PD, she championed the use of simulations with her students for its opportunities to take students places they could never go physically, and for its ability to teach concepts through guided discovery. However, she still felt that she could not effectively use simulations with her students because of limiting factors out of her control, like the timing dedicated to science from the Master Schedule, and the way in which the curriculum was written. Ms. Jackson also felt that the elementary curriculum needed reform but for other reasons. In the focus group interview, she described

> Yeah, looking at the standards too, our elementary curriculum doesn't really align with the Next Generation Science Standards so at first I was like, well it's kind of hard to find things online that are on grade level that connect with what we're teaching with our

> curriculum And they give you what they should fill out and it's a lot of graphs and math to do. So, it's a little bit harder.

In her opinion, the curriculum is not aligned to what the NGSS standards are trying to get at, which is the acquisition of skills over content. She also felt that a lot of what is expected for teachers to cover in the science curriculum is actually a lot of math, meaning that this school may be prioritizing time for tested subject areas over science.

It is no surprise that elementary schools have a troubled history with science teaching, especially in the wake of reform like NGSS. Many factors contribute to elementary teacher's inability to teach science up to the standards of NGSS, such as allocated time, curricular design, and reinforcement in terms of appropriate PD. A systematic approach to looking at where and why science teaching is falling short is needed in order to diagnose and rectify the problem. While the PD did make an impact in all of the elementary school teacher's beliefs, and some of their practices, a small PD with a limited number of teachers like this one will not be able to undo many of the issues that currently exist with elementary school science teaching. Science in the elementary school needs reform, and this is something the participants also voiced.

Implications

In designing a hybrid PD on technology-enhanced- inquiry-based teaching, there are four elements that are most important to include. Length of time, experience of participants, group dynamics, and time management are important aspects to consider. First, the most important idea to consider is length of time. This PD was successful in changing beliefs; however, it was difficult to change the practices of less experienced teachers. In addition, even studies on longer length PDs have found that teachers may abandon new technological techniques due to difficulties with the functions of the tool or technical difficulties without support (Gerard et al., 2011; Kopcha 2009). Ideally, to address both issues professional development on science and technology should span the length of a year, if possible. And, if the PD is going to be short in duration, there should be some element of technical support available to participants at least within the first year. Six weeks was a long enough span of time for the participants in my study who had more experience to make changes to beliefs and practices, however, longer term PD may cause participants to make a more deep-rooted change.

Second, the design of the PD should be experiential in nature and include tutorials for a reasonable number of technological tools. Barriers to technology implementation in the classroom include teacher beliefs, planning time, and training that lacks connection to practice or that focuses solely on the functions of technology instead of how it can be used during a science lesson (Kopcha, 2016). Giving teachers the opportunity to experience technology first-hand in the role of students made the PD more connected to their practice and helped them to anticipate areas where they may have to troubleshoot with their students. In this study, teachers experienced seven new technology tools in the span of six weeks. Participants may have had an easier time absorbing information from the PD if I had focused on a smaller number of tools within the short time span. Although each of the teachers did make a change in terms of either their beliefs, practice, or both, either expanding the length of time the PD ran for with the same number of tools or lessening the number of technology tools could have contributed to more growth.

Third, the establishment of group dynamics through the use of norms and protocols can also contribute to positive outcomes in the design of a hybrid PD. Because there was an expectation of how to interact through the norms, and how to comment on plans through the use of the protocol, collaboration and conversation amongst the participants, even in the online setting were fruitful. The online setting actually contributed to a more even playing field in terms of discussion amongst the participants. No one teacher dominated discussion, or spoke unfairly to their group mates, and the comments made were targeted toward making progress. Communities of practice, like the community in the small-group PD have been shown to unite members in a shared community of change (Merriam & Bierema, 2013). Through the foundations established in the design of the PD, teachers were motivated to work together to make a change. Teachers also worked together as they moved through the stages in Kolb's learning cycle and received support from each other when they were in the final stage, active experimentation.

Along with group dynamics, it is important to consider the grade taught, years of experience, and familiarity with technology when creating a cohesive group. As evidenced by the two first year participants, there are certain supports that are necessary to include in the design of the PD for beginning teachers that may not be necessary for participants with more experience. In this study, the two first year teachers were able to experience change in beliefs but not in practice. In order to support these teachers to turn their new beliefs into practice, there needs to be explicit instruction in the PD on classroom management for science inquiry, for technology use, and for when the two are merged together. Video of other teachers carrying out technology-enhanced inquiry-based lessons, or modeling and coaching could be possible supports embedded in the PD to help these teachers. More advanced teachers found watching videos of less advanced teachers to be a non-effective component of their learning. It cannot be assumed that first year teachers go into teaching knowing how to manage a class that is immersed in using technology for inquiry-based science.

For more advanced technology and inquiry-based teachers, it is important to give them more of a leadership role in a PD group that consists of teachers from all levels. The advanced teacher in this group often submitted assignments late and did not feel that the interactions with other teachers in assignments such as videos helped her to move forward. If she had more of a leadership role, such as if the structure had given the opportunity to teach others for one of the weeks, she could have moved forward more. If she had the space within the PD to lead, she could have used that opportunity as a chance to grow in terms of possible finding new content to explore or reflecting on her own process of teaching to deepen her learning. The structure of the PD within the mixed group of individuals, did not give her the chance to expand her knowledge and skill set to a level beyond what had already existed when the PD began. Additionally, if she was part of a group of more homogenous advanced users, there may have been more opportunity for her to grow.

Finally, when hosting a hybrid PD, it is very important to allocate the appropriate amount of time to assignments, and to set clear deadlines and expectations. Especially in the online weeks, teachers needed a rigid schedule to follow, as well as to be aware of deadlines. In this PD, I assigned around two hours' worth of work on the PD per week. This work included reviewing tutorials, trying out the technology tools, commenting on a lesson plan, and reflecting on learning in a learning journal. Ms. Flynn commented on the ease of learning because she felt the amount of work was reasonable and expectations were transparent. In the focus group interview she stated. Participants felt the PD kept them accountable, while not being overbearing in terms of the workload. Overall, it is important to set manageable and clear expectations for students that are appropriate when taking into account that the participants are full time professionals. These reasonable timeliness and appropriate workload enabled participants to make a change in both beliefs, practices, and both.

To summarize, the four most important things to include on a PD on technology-enhanced-inquiry-based teaching in order to impact beliefs or practice include a long duration in PD or support, establishing an experiential approach to learning, fostering embedded effective group dynamics, and assigning an appropriate workload.

Recommendations for Administrators/ Supervisors

Along with the recommendations described above, administrators and supervisors may need to take into account the experience and knowledge individuals have when designing a PD or establishing groups. In the PD I designed, the ideas presented, and pace of the course may have been too much for first year teachers to absorb into practice. When working with first year teachers on this topic of technology-enhanced inquiry-based teaching, it is important to not only focus on the topic in the PD, but also on skills for classroom management in the inquiry-based classroom. Additionally, when selecting a group to participate in the PD, it is important to carefully select the participants in it based on experience or give those with higher levels of experience with technology more of a leadership role. In this PD, the group was very mixed in terms of their experience with technology, NGSS, and both. While four members gleaned much from the PD, the teacher that came into the PD with the most knowledge and practical skills actually did the bare minimum to participate and often submitted items late. If administrators or supervisors play a role in selecting a group to participate in a hybrid PD, they should either select a group with around the same skill level, or ensure that there are opportunities for those who already have a lot of knowledge to partake in activities that give them a chance to share that knowledge with the group or expand further. Additionally, administrators and supervisors need to reevaluate the elementary curriculum. In this study, every elementary school participant noted that the elementary curriculum needs to be revised in order to make time for science learning through technology-enhanced inquiry-based science teaching. Revisions need to come in the form of allocating the proper time for science in the Master schedule, changing units to reflect the acquisition of skills over the memorization of facts as reflected in NGSS, and learning through inquiry.

Administration also recommended that this hybrid PD take place as way to remedy the drop in marking period grades that was occurring for students who had moved from 5th science grade to 6th grade science. This study was not able to evaluate the impact that it had in the areas of student achievement. Administration may need to look at pinpointing the variables that are affecting science marking period grades for 6th grade students. If or when the sources are identified administration, a targeted approach that may or may not involve a hybrid PD will be appropriate.

Recommendations for Future Research

Finally, future research can build upon the findings in this study and should consider the long-term impact of a hybrid PD. In this study, results were measured before and after a six-week intervention, but there was not an opportunity to see if the PD made a long-term change. Future studies could again look at data such as lesson plans and video recordings of lessons to see if techniques presented in the PD were still evident in the participants later in the school year. Other studies could also look at the impact hybrid PD makes on elementary school teaching specifically. Because elementary school science teaching has traditionally lagged, it is worth looking at if hybrid learning opportunities, such as this one, make an impact on the quality of elementary science education. Last, a future study may want to change the length of the PD and then evaluate the impact it has made. The PD in this study was fairly short in nature, and research on technology and inquiry-based teaching professional development was typically more successful when longer in duration, usually spanning the length of one year or greater (Campbell et al., 2013; Campbell et al., 2014; Campbell et al., 2013). There is very little research on hybrid PDs on science and technology lasting for one year, so this may present a unique opportunity for exploration.

Additionally, there has not been much research on how the SAMR model can make a difference for science teaching with technology. Future studies may want to look at how this model can impact teachers' beliefs and understanding of technology enhanced inquiry-based teaching. Research in the future can build on the rich examples of technology enhanced inquiry-based teaching at the different levels of SAMR. For example, Ms. Jackson's approach to technology where students looked at a subset of digital resources to learn about science clearly characterizes a level "S" on the SAMR scale. Whereas Ms. Campbell's lesson where students learned about commensalism and mutualism via Google Expeditions is an example of a level "R" on the scale. Creating ways to look at how teachers develop their beliefs, understandings and changes in practice associated with technology and science teaching, future empirical research can look into the unique scenarios when teachers are able to move up or down the SAMR scale in terms of practices.

Limitations

Every possible caution was taken to try and lessen the number of limitations in the study. However, this study may have been impacted by the fact that I am a member of the seventh-grade team and have worked with the two seventh grade teachers for two years. I also introduced only technology products that were compatible with my districts. There may be other technology tools that are more appropriate to use for inquiry-based instruction, but I was limited to sharing only those products that could be used within the confines of the district. I also was limited in the time length of the PD. Nearly every study on technology-enhanced inquiry-based-instruction in the literature occurred for a year or longer, however my PD was limited to six weeks. A goal of the PD was to make more cohesive the learning that occurred in 5th and 6th grade science. Because this PD only ran for six weeks, I did not have access to data that would conclude the impact the PD had for students. Administration wanted to target 5th and 6th grade science teachers because they had noticed a downward trend in marking period grades from 5th to 6th grade science. Actual data and statistics on the marking period grades was not made available to me and did not impact the design of my study. Many variables may have impacted the apparent downward trend, and this study was not able to address all of those variables. A six-week hybrid PD format already existed in my district, so I was limited to having my PD run for six weeks. I also believe the number of tools that I introduced during the time-span of the PD may have overwhelmed the participants and learning may have been more effective if I had introduced fewer technology tools during the allotted time. Finally, I may have individual biases on how I believe technology tools should be implemented in accordance with NGSS. I tried to minimize this bias by basing my opinions on those of research articles, but I may have a bias or more familiarity with certain technology tools.

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Appendix A. Curriculum of the Hybrid Professional Development

6 Week Hybrid PD on Technology- Enhanced Inquiry-Based Science Teaching

Before the Intervention
• Journal Prompt Questions piloted during Science Department Meetings with teachers not involved in the study and revised if necessary • All fifth and sixth grade science teachers invited to participate in the PD by the director of PD via an email • All participants filmed themselves on a Swivl Camera (unmanned) and I scored the lesson using the TUSI instrument • Participating Teachers Teachers administered a survey to students on their teacher's technology use

Data Collection Methods
• Video Observations scored by the TUSI instrument (pre/post) (quant) (*T-Test*) • Student Survey (pre/post) (quant) • Lesson plans (qualitative) • Dialogue on online community (qualitative) • Teacher Weekly Journals (qualitative) • Focus group or interviews (qualitative)

Weekly Asynchronous Meetings (Week 2 - 5) Agenda and Activities by Day	
Sunday	• Mini-lesson video posted
Monday	• Teachers may view mini lesson
Tuesday	• 1-2 teachers post lesson plan that uses technology • Rest of the group comments on the lesson plan using the "Four A's" protocol
Wednesday	• Additional day for teachers to comment on the lesson plan
Thursday	• Additional day for teachers to comment on the lesson plan • Reflective journal prompt posted-

	teachers may begin to respond to prompt
Friday	• Last day to for teachers to comment on lesson plan • Additional day for teachers to comment on reflective journal prompt
Saturday	• Last Day for teachers to respond to reflective journal prompt

Week 1 (In- Person meeting)	
Activities	Journal prompt
• Teachers sign up for Google Classroom when they walk in • Teachers receive a syllabus of activities for the course of the hybrid PD • Teachers participate in the "Balloon Race Car Google science journal activity" as if they were students • Teachers respond to a post on the Google classroom about the Google science journal activity "What role did technology play in learning science content? Is this something you have done or something similar in your classroom before? Why or why not? • Complete "Hopes and Fears" protocol	• How often do you use technology in your classroom? What ways do you use technology in your classroom. How do you make your decisions about when and how to use technology in your classroom. What is your approach to using technology and NGSS together?

Week 2 (Online meeting)	
Activities	Journal prompt
• Group posting of norms • Watch a mini lesson on Google Science Journal (the app they used in the first session) • 1 teacher shares a lesson plan and the	• How do you believe technology can be used in the NGSS classroom? How do you think students either benefit/ not benefit from using technology in the NGSS classroom? What are your

group critiques by writing at least two comments on the plan • Watch a video: https://www.youtube.com/watch?v=OdPJ0jHihSg Gary Johnston - Teacher in a Chinese international school used technology to completely change his approach to a unit on water conservation • Teachers write down all of the technology applications they see and rank them on the SAMR scale • 1 teacher shares a lesson plan and the group critiques by writing at least two comments on the plan	hopes and fears for technology use in the NGSS classroom. • Has this video changed the way you see technology and science teaching going together? Why or why not? Have you ever done a lesson similar to this teacher? Why or why not? Would you ever like to use technology in similar ways with your students? Why or why not?

Week 3 (Online meeting)	
Activities	Journal prompt
• Mini lesson on Google tools, slides, docs, and forms/ Google glass - how they can be used in science • 1 teacher shares a lesson plan and the group critiques by writing at least two comments on the plan	• Do you think google tools can be used to benefit your students in an inquiry-based science class? If yes/no how so? Do you think you will use Google Tools in your class? Why or why not? What questions do you still have about Google Tools? What are your beliefs on using Google Tools in the science classroom?

Week 4 (Online meeting)	
Activities	Journal prompt
• Mini lesson on Gizmos science simulation • 1 teacher shares a lesson plan and the group critiques by writing at least two comments on the plan	• What role do you think science simulation tools can play in the NGSS science classroom? What are the negative/positive aspects of using simulations in science? Do you believe you will use simulation in your classroom? Why or why not?

Week 5 (Online meeting)	
Activities	Journal prompt
• Mini Lesson on a technology of the group's choice related to assessment • Teachers watch each others recorded videos in predetermined pairs • Teachers also watch a video on assessment • 1 teacher shares a lesson plan and the group critiques by writing at least two comments on the plan	• How can the role of technology change how we assess our students. Do NGSS and M&R uses of technology mean that our assessment will have to change? If yes, why/how do you think so, if no, why/how not? • How have the past tutorials helped/ hindered your thoughts on using technology in the science classroom. Do you see a connection between technology and inquiry-based teaching? Why or why not?

Week 6 (In- Person meeting)	
Activities	Journal prompt
• Teachers watch a video where different levels of Tech are used • Teachers rank the activities on the SAMR scale • Close with a "Up and Down the Mountain" Protocol	• What was your biggest take-away in terms of using technology in the NGSS classroom from this hybrid PD? What are some tech skills you feel you are going to use/ not use in your classroom right away? Why? Now, how do you believe technology can make a difference for our students?

After the Intervention
• All teachers that participated will film themselves on a Swivl Camera (unmanned) and I will score the lesson using the TUSI instrument • Teachers will administer the same survey to students on their teacher's technology use

Appendix B. TUSI Instrument Reproduced from Campbell et al., 2014

Construct	0 Never observed	1	2	3	4 Very Descriptive
A. Technology should be introduced in the context of science content					
1. Features of technology are introduced & illustrated in the context of meaningful & relevant science					
2. Students use technology in the context of meaningful & relevant science					
3. Students use a variety of technologies such as word processors, presentation software, spreadsheets, and internet in the context of learning meaningful and relevant science					
4. Technology related activities support the development of skills such as locating relevant information or discriminating between useful & non useful information in meaningful and relevant science					
5. Students are learning to use technologies as tools in the context of meaningful and relevant science					
B. Technology should address worthwhile science with appropriate pedagogy					
6. Teacher uses technology to promote student-centered, inquiry-based pedagogy					
7. Students engage in technology and use it for observing and data collecting					
8. Students use technology to facilitate conceptual development, understanding of scientific process skills, and their overall scientific literacy					
9. Students use technology to display data in a way that helps them formulate conclusions					
10. Technology is used to enhance the learning of worthwhile science concepts and process skills while reflecting the nature of science					
11. Technology is used to help students collaborate in building their knowledge of science and scientific inquiry					
C. Technology in instruction in science should take advantage of the unique features of technology					
12. Technology is used in a way that takes advantage of the capabilities of technology and extends instruction beyond or significantly enhances what can be done without technology					
13. Technology is used as a means of helping students explore topics in more depth and in more interactive ways					
14. Technology is used to enhance the presentation of complex or abstract content					
15. Teacher employs technology to enhance the teacher's role, not to replace it					
16. Technologies and hands-on lab experiences play a complementary role, so that the actual event under study can be perceived as a concrete event then analyzed by appropriate simulations					
17. Technology leveraged to enhance science teaching in ways that would not be possible without technology					

D. Technology should make scientific views more accessible					
18. Technology uses in the laboratory makes scientific concepts more accessible through visualization, modeling, and multiple representations					
19. Teacher uses technology such as simulation to provide representation of concepts that are difficult to represent in everyday life					
20. Technology use in laboratories helps students to pose questions					
21. Students understand that stimulation or computer software isn't actual phenomenon					
22. Students are given the explicit opportunity to reflect on the nature of scientific models and the role they play in the construction of scientific knowledge					
E. Technology instruction should develop students' understanding of the relationship between technology and science					
23. Technology is presented as knowledge (not necessarily scientific knowledge) applied to manipulate the natural world and emphasize the interactions between science and technology					
24. Technologies are used in learning science to provide opportunities for demonstrating the reciprocal relationship between science and technology					
25. The teacher facilitates students reflection on the technological applications used in the science laboratories					
26. As students use technology in science laboratories their reflection on how technologies produce trade-offs is facilitated by the teacher to assist students in developing a deeper understanding about the relationship between technology and science					

Appendix C. Pre/Post Student Survey

Student Survey of Technology Use (Pre/ Post Intervention)

Please fill out the form to the best of your knowledge. Remember the form is anonymous

1. 1) Grade

Mark only one oval.

5

6

2. 2) Teacher

Mark only one oval.

A

B

C

D

E

F

3. 3) On average I use technology ________________________ times in science class per

week Mark only one oval.

1 time

2 times

3 times

4 times

5 times

4. 4) I believe my teacher uses technology to help me learn science

Mark only one oval.

strongly disagree

disagree

neutral

agree

strongly agree

5. 5) My teachers ask me to use technology to (check all that apply)

Type my answers (S)

Research questions (S/A)

Create PowerPoints (S/A)

Record Videos of my Explanations (M)

Create Scientific Models (M)

Work with students in other classes (R)

Collect Data (M/R)

Complete Simulations (M/R)

6. 6) Provide a reason for your response to number 4 in 2 sentences or more:

7. 7) How do you think technology helps you learn science? Provide a response in 3 sentences or more:

8. 8) How do you wish my teachers would use technology in science class? Provide a response in 2 sentences or more

Appendix D. Semi-Structured Focus Group Interview Protocol

1) How do you feel the PD impacted your view of technology use in the NGSS classroom? Why do you think so?
2) Can you describe what your beliefs on the role technology in the NGSS classroom were before the PD, and what they were like after? Do you think they changed or stayed the same? Why do you think so?
3) What was the most/ least helpful part of the PD? Why do you think so?
4) How do you plan on using technology with your students in the future? Can you give an example?
5) What else do you wish the PD was able to accomplish?

Appendix E. Participant Survey

Technology & Science Hybrid PD Participant Survey

A) Last Name:
B) First Name:
C) East Brunswick email address:
D) Number of years teaching science:

1) I would consider myself a (select one)_________________ when it comes to technology use for instruction with my students

a) Beginner
b) Intermediate
c) Advanced
d) Expert

2) I would consider myself a (select one)_________________ when it comes to NGSS instruction with my students

e) Beginner
f) Intermediate
g) Advanced
h) Expert

3) What did you gain/ learn throughout this PD? (please respond in 2 sentences or more)

4) What continues to be your biggest fear/ concern on using technology for science instruction with your students (please respond in 2 sentences or more.

5) I believe technology's place in the science classroom is ___________________ (respond in 1 or more sentences)

6) I feel most comfortable using technology to (check all that apply)

a) have students type answers
b) have students research questions
c) have students create slideshows
d) have students record video
e) engage my students with students from other classes
f) have my students collect data
g) have my students complete simulations

7) Which mode of information transfer helped you to learn best throughout the course of the PD? (select all that apply)

a) Videos made by me
b) Videos from You Tube
c) Examples of how I use the technology
d) Articles
e) Reflection Questions

f) Step by step tutorials
g) Learning Journals
h) Commenting on lesson plan

Appendix F. Protocol from Tan & Towndrow (2009)

Science Practical Skills
Name _________________________ ( ) **Date** _________________
Class Secondary 1 ( )

Objectives
This task aims to help you:
1. Develop a critical eye for details during science practical work.
2. Develop your ability to identify good science practical skills and habits in the laboratory and be able to comment on why they are good.
3. Develop your ability to identify poor science practical skills and habits in the laboratory and be able to comment on why they are good.

Procedure
1. Get your worksheet, your computer and the digital video clip ready.
2. Play the video clip and look for good or bad science practical skills.
3. Pause the clip when you come across a relevant segment.
4. Note the time the episode occurs in the clip and then comment on it (Refer to pg 2)
5. Start the clip again.
6. Continue until you have completed the clip.
7. You should pick out at least 5 episodes to comment on.

Your Reflections
Fill in this portion at the end of the activity

The good points about this activity were:
1.
2.

The bad points about this activity were:
1.
2.

Data
Complete the table as you watch the digital video clip.
Title of Clip: ______________________________

Episode	Time	Description of Skills	What should have been done (if bad practice only)