Summer 2022

Cultivating Student Agency Through the Use of Authentic Science Practices

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CULTIVATING STUDENT AGENCY THROUGH THE USE OF

AUTHENTIC SCIENCE PRACTICES

by

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A capstone submitted in partial fulfillment for the degree of Master of Arts in Education:
Natural Science and Environmental Education

Hamline University

Saint Paul, Minnesota

August 2022

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CHAPTER ONE

Introduction

In the spring of 1995, the Agassiz Environmental Learning Center director invited me to attend an informational meeting about our school joining a pilot River Watch program. The learning center director had written a grant proposal allowing four schools running the length of the Sand Hill River in northwestern Minnesota to be trained, mentored, and supported to run a citizen-based water-quality program within each of our schools. It was my first experience having students participate in authentic science, and it changed my view on the type of opportunities students need to be successful. During their time in the program, students learned real science and, more importantly, how to communicate their knowledge to a variety of audiences. In addition, most of the twenty-five students who participated in the program went on to study science post-secondary. I would call that a success by all standards (including state and national).

I left that school wondering how to recreate the experience with my next group of students. Was the critical piece to the program's success that it was authentic? That it was citizen-based? That it was hands-on science? Or was there something I was still missing? In the course of my career, I have concluded that the success of an authentic science experience is the ability of the student to communicate their knowledge to an audience. This realization leads me to the research question: *How can we use authentic science experiences to improve student agency?*

Chapter One will cover the different occasions I have had the chance to develop authentic science experiences for students and discuss the successes and learning moments I have experienced along the way. I will show the rationale of how authentic science can be incorporated in any setting and still align with the state, national, or international standards and the context of why it is essential in our present-day conversations about science education.

Background

It took twenty years of teaching in three very different settings before I understood how to use authentic science well in the classroom. I leaned into authentic science experiences early because student engagement increased when they worked on things that actual scientists do. Engagement isn't agency, however. It took a long time before I connected the power of students personally communicating their knowledge of the science with their understanding of the science.

River Watch: My first experience teaching authentic science

From the fall of 1996 to the spring of 2000, I was the adult supervisor for the local River Watch program at a small rural high school in northwestern Minnesota. During the four years I worked with students in the program, I witnessed all the natural offshoots of their learning. Primarily they were trained by, and reported to, science professionals from the Minnesota Pollution Control Agency (MPCA). Lab equipment was shared between the four partnering schools and scheduled for use once a month during the testing windows. Students and I spent testing days off-schedule collecting water samples from five different bridge decks along our stretch of the river and running nine water parameter tests. Each month we sent our data to the MPCA.

It was left up to each site how we chose our students and ran the program. The three other schools involved ran it as an extension of an existing elective course such as chemistry or advanced biology. I chose to run it as an enrichment program because I wanted continuity in students running the tests. I thought having a range of kids in grades 10-12 would allow the majority to return, as mentors, for the next group of applicants. Not having the program attached to a course permitted any student in the building to apply. I wasn't thinking about it at the time but have since learned that making a program sustainable is one of the most critical parts of its design. We avoided the pitfalls of other schools that had wavering enthusiasm and a learning curve for incoming students each fall. They based their rationale on attaching grades to the work, thinking that would motivate students to do well. I was convinced that students would want to do their best if it were fun and real. I was partly right. Doing real science made it fun for us, but our best work came when students had opportunities to share their knowledge with different audiences. The freedom of not having it attached to a class allowed us to work through the summer; students wanted to maintain a monthly database for state use and came in during summer break to make it happen.

I thought learning the technical skills to run the tests was the critical part of the learning because my training as a science teacher was traditional. I was taught that students learn what you teach them directly. It would take me years to reflect on why the program was so successful. I came to understand that the success was due to the students communicating their results to others. The director of the Agassiz Environmental Learning Center, who wrote the original grant, had the insight and experience to know that community support and involvement would help the students be more invested in their work. He arranged for a regional forum where students from all four schools could share their successes. This format was based on the same one used at the state forum, which students would also attend. The conference audience included local newspapers, community leaders, regional conservation professionals, school administration, and peers from other sites. Preparing for their presentations made it clear how much they were learning. I mistook the running of the tests for where the learning happened. I would understand in my next school that wasn't the only piece, or even the most important one. The students hadn't missed what I had; summarizing their work and successes to a broad audience put the onus on them to prove that they knew what they were doing.

Field Science: Developing authentic science curriculum

My first attempt to design authentic learning was developing an elective course at a suburban high school in southeastern Minnesota. State standards were shifting, and the administration wanted a science course developed for the general students not as interested in science now required to take an additional elective in science. It would need to have an environmental aspect and cover both earth science and lab practices. The school was adjacent to a small river separated by a narrow strip of woods. I decided the curriculum would center around the kids learning as much as possible about the woods and river. Over the next few years, I learned as much as possible about Minnesota trees and wildlife and developed lessons using real-world data. This experience also led me to Hamline's Master of Natural Science and Environmental Education program.

Students would learn how to use a compass and a surveyor's chain during the school year to map the woods. We'd learn the different species of trees, calculate the board feet of standing trees, and write up a sustainable management plan for the property during the winter months. With the thaw of the river in spring, I'd take what I could from the River Watch Program, and we'd test some water parameters: dissolved oxygen, total nitrates and nitrites, turbidity, and pH. Once May arrived, we'd also use benthic macroinvertebrate sampling for an overall snapshot of the river's health. Students liked the course, and it grew from one section to three. The science was authentic, but something was missing that made it complete. I thought it might be the partnership of sharing the data with professionals. It turns out the missing piece was the onus of sharing the knowledge they had gained.

United Nations School of Hanoi: Connecting the knowledge to practice

In 2011 I moved with my family to Vietnam to be the Environmental Studies teacher at the United Nations International School of Hanoi (UNIS). A D-12 International Baccalaureate (IB) school serving students from over 62 different countries in the heart of a city of more than six million people. I had much to learn with the IB and a lot to let go of my American view of education.

The current Next Generation Science Standards (NGSS) are very much in line with the IB philosophy of what a student should know and be able to do. The criteria emphasize students using their scientific knowledge to synthesize new information and justify their arguments using evidence. A natural extension of that is to communicate your understanding to others. The IB promotes communicating results — always. This way of teaching was new for me; I would use tests to inform me of students' progression of content knowledge, but assessments were primarily communicative pieces processed by students at the end of their learning. We also had the freedom of working across subject matter as we saw fit.

In the spring of 2013, we gathered our grade 8 teaching staff to discuss a two-day off-schedule project of our choice. Two humanities teachers proposed having students develop eight new community service programs in line with the United Nations eight

Millennium Development Goals (MDGs). I suggested using decision-making protocols created by Alan AtKisson, an American leader in sustainable thinking. So there we had it. In one month, we would lead the grade 8 students by developing eight actual proposals that would either be accepted or denied by the school's board of directors. Proposals dealt with reducing child mortality, improving maternal health, and achieving universal primary education, just to name a few. How's that for authentic science?

We set two days aside, assigning students into one of eight groups, each given an MDG. One day and a half to develop a real solution, another half day for the groups to present their proposals. The following 48 hours were magic. My room was charged with MDG 4: Reduce child mortality. Kids quickly moved through their required steps using AtKisson's pyramid protocol, designed to narrow the idea. What's happening? The number one killer of children in Vietnam is motorcycle accidents. We already had a program on campus trying to get proper helmets on children, so they moved on to number two — drownings.

Northern Vietnam has as many lakes and rivers as Minnesota, but children are often not taught how to swim. Narrowing the question isn't the real issue; it's engaging in a discussion through four lenses of thought. The pyramid is four-sided and divided like a compass: north, east, south, and west. Each group is to argue for a solution based on their side. North is the voice of nature; what's best for the environment? East for the economy; what's this going to cost? South is society; how does this fit with the culture? West is for the individual's well-being; put yourself in the shoes of one person who can't live with this solution (AtKisson, 2011). Together the four groups reach a single capstone proposal.

Students used all their resources. Of course, they researched online but gained ground on their ideas when they interviewed adults on the campus. They got the input of nurses, swimming instructors, and community leaders on what would be a sustainable solution. Their proposal: To develop a community service program to teach local children in Hanoi how to stay afloat if they fall into the water. The staff of UNIS was willing to donate their time to train local physical education instructors on what they needed to pass on to their students. UNIS would provide bus transportation and substitute teacher costs. Each trimester, UNIS staff would train a new group of instructors from a district in the city on how to teach survival skills to their students. The board of directors accepted the proposal unchanged, and it was in operation until recently, when students once again updated service programs. In less than two days, grade 8 students had developed a real-world solution to save lives and communicated it clearly to the board of directors. The students were ecstatic, and it was clear to all of us their depth of knowledge and mastery of skills. A total of three proposals were accepted, but the experience was the same for all eight groups. Like my first experience with River Watch, students owned their knowledge and proved their skills by communicating clearly to an audience.

Research Question

How can we use authentic science experiences to improve student agency? I've come to understand that the most challenging part of the question is measuring the meaningfulness of student work. I feel it is easier to gauge students' mastery when they communicate their experiences. Through communication, students can give voice and choice, which is key to building agency (Mameli et al., 2020). These three stories represent the significant progression of my thinking and show the variability of authentic science. Authentic science can be done within the classroom, as an extension of the school day, as an ongoing project, or even as a one-off activity.

Rationale

As the state of Minnesota transitions to its new science standards, it will be essential to go beyond the routine inquiry-based projects of the past. This type of curriculum writing only gets us through five of the eight standards: asking questions, developing models, planning investigations, analyzing data, and using mathematics and computational thinking. The remaining three standards of constructing explanations, engaging in argument from evidence, and communicating information are better suited for authentic science. These three standards also align well with the fourth criteria of the IB: Reflecting on the impacts of science in the world.

As classroom teachers, we must change our thinking that conclusions are not just an answer to a problem but an agreement between different groups of people who see the world through different lenses. To better prepare our students for a world where we expect them to be critical thinkers, we need to practice authentic science.

Conclusion

Chapter One focuses on my personal experiences of using and developing authentic science projects with students and the need for communication of knowledge to be part of that experience. The IB and NGSS standards both put weight into students communicating what they know about science to an audience (International Baccalaureate Organization, 2015; National Research Council, 2012). Minnesota standards are transitioning to add this component by the 2024-25 school year (Minnesota Department of Education, 2019)

Chapter Two will focus on the academic literature on authentic science experiences and how using the NGSS as a framework fits the growing trend of student-centered education and socioscientific issues-based instruction. Also discussed in Chapter Two will be ways to develop student agency with a look at the need first to develop teacher agency. In Chapter Three, I will outline the details of my capstone project, which will center around building teacher agency through an introductory professional development session followed by a semester-long professional learning community. The professional development session will introduce teachers to pairing the NGSS standards with authentic science practices using examples from successful programs. The professional learning community will be a support network for teachers to use while developing and modifying their authentic science experiences.

CHAPTER TWO

Literature Review

Introduction

Authentic science practices are those that model what real scientists do to explore the world and probe for answers. Beyond traditional inquiry, authentic practices allow students to understand the nature of science more comprehensively and how it operates in different contexts of their lives. In this chapter, we will explore what authentic practices are and how they are used to change the approach to teaching and learning to allow us to answer the research question: *How can we use authentic science experiences to improve student agency?*

After defining authentic science, we will look over the eight practices developed within the Next Generation Science Standards (NGSS) by the National Research Council in 2012. The NGSS have been adopted outright by twenty states and used as a framework by twenty-four others who have used them to develop their own state standards (National Science Teaching Association, 2014). This list includes Minnesota, which will fully implement the new standards by the beginning of the 2024-25 school year (Minnesota Department of Education, 2019). The change in standards and practices is a perfect time to refocus our attention on all aspects of knowing science using authentic experiences.

We will discuss the benefits of using the NGSS practices to align with authentic experiences in the classroom and the advantage of structuring classrooms to be more student-centered. Finally, we'll lead to how this all lends itself to cultivating student agency and focusing on developing relevant issues to engage students. Specifically, we will discuss the benefit of using socioscientific issues as a way to connect with students and allow them to demonstrate their agency through classroom discussions within the community of the classroom.

Authentic Science Practices

When considering science education, the word inquiry comes to the front rather quickly. While most people know that inquiry involves some level of exploration, Crawford (2012) states it well:

> ...teaching science as inquiry, at its most basic level, involves helping children to find answers to questions using logic and evidence. Inquiry involves going beyond the simple asking of questions, to trying to figure out how to make sense of data to answer a scientifically based question. (p. 26)

Crawford goes on to point out that although inquiry is a cornerstone of science educational practice, there is still disagreement as to what constitutes inquiry. Many teachers refer to anything hands-on or lab-based as an example of inquiry; if the student is recording data, then that is enough (Crawford, 2012). One can argue that inquiry alone is not enough to teach students how science works. Science fairs, a common practice among schools, are undoubtedly inquiry-based. However, many projects are still not authentic because, too often, the investigation has already been performed with known results (Rivera Maulucci, 2014). The teacher cannot simply replicate other scientific findings and place them in the classroom to lead students through inquiry. According to Crawford (2012), a better method than this is for the teacher to modify the work to meet the needs of the students. Crawford continues by stating that it is crucial during the modification process to replicate the practices of real scientists in the field. This is what makes it authentic. Inquiry alone is not enough to be relevant for students and promote agency; instructors need to explicitly teach the practices used by scientists. According to Schwortz and Burrows (2021), students need to experience how scientists approach knowing with realistic examples of what real scientists do. These experiences ensure the learning is relevant and motivate students by knowing that what they are learning is authentic.

Just as inquiry can take on different understandings in different classrooms, so can the term authentic science. Glackin (2016) discovered in a study of outdoor education that teachers defined authentic learning in different ways. Some thought the act of doing an outdoor experience made it authentic because the students were able to measure things from the real world. Others thought students having autonomy over their study made it authentic, while another group thought students' construction of explanations from real data made it authentic. In many ways, they’re all right. According to Crawford (2012), authentic science does not mean it’s a novel or an important study to science, but that it’s a meaningful problem to the student that can be investigated and answered using science practices. One goal of science education should be to produce students who reflect on the world around them and have the skills to learn about it. Crawford (2012) goes on to state that authentic science experiences allow students to develop investigations that are meaningful to them.

The Nature of Science

In science education, knowing what you know and how you know it is called the nature of science. According to the National Research Council (NRC) (2012), teaching science only through inquiry leads to confusion. Often, students and some teachers think conclusions can only be achieved through the traditional scientific method. Teaching that the inquiry method is used exclusively across all sciences puts too much emphasis on experimentation and prevents students from knowing the other ways in which science investigates problems. Being clear about all the ways in which students can explore science is why the NRC developed the Next Generation Science Standards (NGSS) a decade ago. Instead of focusing on inquiry alone, the NRC chose to identify eight practices associated with scientific investigation and knowing. This way of thinking aligns with earlier work that supports how students can explore science in a decontextualized format while still understanding how it fits into the more extensive nature of science (Clough, 2006). Clough extends this idea that it is essential to explain that decontextualized practices are still part of a broader process to avoid students dismissing the practice and activity as not critical to the nature of science.

Common Science Practices

The Minnesota Department of Education (MDE) has chosen to adopt the NGSS, which the NRC developed. Even though the Minnesota standards are currently in draft form, they have already found their way into most science classrooms, with full implementation set for the 2024-25 school year (MDE, 2019). The NGSS and subsequent MDE science standards have three dimensions:

scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. This project will focus only on the first dimension, scientific and engineering practices, as it offers the best framework to develop and assess authentic science practices.

While standards (disciplinary core ideas in the NGSS) are usually the main focus of what is being taught in classrooms, practices offer an opportunity to focus on any study's core ideas and tenets. By using a limited set of standards, teachers can revisit students' skills often, allowing students to gain mastery over time. It also helps the students to understand that these overarching concepts cover all aspects of science regardless of the specific topic (NRC, 2012). The eight practices of NGSS (listed on the next page) span three spheres of activity:

- Investigating
- Evaluating
- Developing Explanations and Solutions (NRC, 2012, p. 45)

Within these three spheres, it is easy to see how the traditional scientific method fits in, but it also supports other practices employed by scientists and engineers. It represents a progression of thought emphasizing the last two practices: engaging in argument from evidence and obtaining, evaluating, and communicating information as the most critical and challenging practices for students to master (NRC, 2012). The NRC sums up its reasoning by stating, “A focus on practices (in the plural) avoids the mistaken impression that there is one distinctive approach common to all science — a single scientific method” (p. 48).

The eight science and engineering practices developed by the NRC (2012) are:

- Practice 1: Asking questions (for science) and defining problems (for engineering)
- Practice 2: Developing and using models
- Practice 3: Planning and carrying out investigations
- Practice 4: Analyzing and interpreting data
- Practice 5: Using mathematics and computational thinking
- Practice 6: Constructing explanations (for science) and designing solutions(for engineering)
- Practice 7: Engaging in argument from evidence
- Practice 8: Obtaining, evaluating, and communicating information (p. 42)

These practices parallel the four science criteria of the International Baccalaureate Organization (IBO): Middle Years Programme (MYP). The MYP assesses science students on: knowing and understanding, inquiring and designing, processing and evaluating, and reflecting on the impacts of science (IBO, 2015). This shift is good news for Minnesota science students to be taught and assessed on concepts that are becoming nationally and internationally agreed-upon practices. Practice-based approaches to science education allow students to engage in the process of science entirely rather than simply show they can memorize the steps, and it gives students real opportunities to develop scientific skills (Berland et al., 2015).

A Constructivist Approach

A focus on practices requires a shift in thinking and teaching practices. Glackin (2016) pointed out that constructivist methods need time and repetition for students to develop their skills well enough before they can work independently. The author warns that even teachers who are self-proclaimed constructivists frequently use teacher-centered activities even though they fully believe students learn best by building on prior knowledge. Interestingly, when it comes to student learning, Glackin found that whether or not the teacher taught the unit constructively was more important than the teacher's area of expertise. Even during the outdoor science study, it was less critical if you taught biology and more essential if you designed the unit to allow the students to independently build on what they knew. Teachers of chemistry and physics successfully taught outdoors using constructivist methods (Glackin, 2016).

In line with the NGSS practices, Kruse et al. (2021) found that students who understand the different parts that collectively make up the nature of science are more likely to trust science, comprehend socioscientific concepts, and take action on environmental issues. They also had fewer misconceptions about how science works and had better communication skills regarding scientific matters. The disappointing finding of the study showed that teachers often thought they were bridging the gap between different aspects of the nature of science. However, unless they taught it explicitly, students didn’t benefit as much as in classrooms where the various practices within the nature of science were clearly laid out (Kruse et al., 2021). This realization reinforces the need to cover the different science practices and constantly reinforce how they fit together as a more extensive nature of science. Eastwood et al. (2012) support this concept, using an integrated approach to teaching the nature of science that explicitly demonstrates when and where specific practices fit within science rather than a stand-alone approach that shows the inquiry process only.

Summary of Authentic Science Education

Authentic science experiences allow students to understand and explore scientific practices in different ways. An authentic experience could be a full science inquiry involving traditional experimentation, but it could also be a smaller practice focusing on a single facet of the nature of science. Authentic science practices aim to make the experiences relevant to students' lives and transferable to later studies. Because the practices are smaller and designed to show different aspects of the nature of science, it will be necessary to use a constructivist approach that builds student knowledge over time and allows them to revisit practices to attain mastery. This science education method aligns with the NGSS practices and the IBO criteria.

Approaches to Teaching and Learning

In approaching the mindset for teaching and learning science that promotes student self-efficacy, Crawford (2012) states that:

> When our teachers are given opportunity to participate in authentic science, they demonstrate greater confidence in enacting inquiry-based instruction in their classrooms; their enthusiasm, in turn, increases, and we see evidence of motivated and engaged students in their classrooms. (p. 38)

Give teachers the autonomy to develop authentic science, and they will gain confidence that will, in turn, transfer to agentic change in their students. This is the first step in supplying teachers with the resources and training to be confident and capable of designing and implementing authentic science experiences, increasing the teacher's content knowledge (Greene et al., 2012).

Teacher Training and Professional Development

According to Greene et al. (2012), it is important in teacher training to realize that one training session does not fit all. The more an individual teacher connects with the science and/or the scientific practices of a particular training, the more likely they will bring it into the classroom and pass that experience on to their students. Many schools have passionate teachers willing to take a deep dive with their students during a particular unit of study. In a world of standards needing to be covered, taking too much time on one topic is frowned upon by others. In a world of practices, it is encouraged to slow down for the needs of the students. Reinforcing the concepts for students and allowing time for them to master their skills is all that should matter. There is value in revisiting the practices and reinforcing the skills. Greene et al. (2012) go on to show that growth in content knowledge is critical to keep up with the advancements in the field if schools expect teachers to develop curriculum experiences that match the needs of their students.

In one study, Greene et al. (2012) ran a two-week-long professional development program where teachers worked on authentic science projects with research scientists. They found that teachers grew in their content knowledge and how they connected that knowledge to other concepts in science and other subjects. It deepened not only their scientific understanding but also their cross-disciplinary knowledge. They also showed that how teachers structured their knowledge was affected too, allowing them to gain the confidence needed to implement authentic science with their students when they went back into the classroom. When teachers receive authentic training they connect with, it gives them the skills to self-initiate programs that benefit their students. This growth in teachers' self-efficacy is vital for developing and supporting students through their own experiences. Glackin (2016) reminds us that growth in teachers' ability to implement and manage authentic science experiences with students has a real effect on their approaches to teaching and student learning.

Alignment of Teaching and Learning with the NGSS Practices

The argument can be made that aligning curriculum to the NGSS practices is a much simpler task than either developing large inquiry projects or alignment to dozens of standards. In addition, it allows students to explore science questions from different ways of knowing, which makes it more straightforward for them to explore something relevant and meaningful. Schwortz and Burrows (2021) point out that the NGSS structure supports authentic science experiences and can easily be adapted for informal education programs such as after-school sessions, environmental learning centers, or summer camps. In an informal setting, science practices will often be taught in a decontextualized manner, but this can still be beneficial for teaching students the nature of science. Kruse et al. (2021) inform us that using a constructivist approach allows students to understand the nature of science by building on decontextualized practices. In one study, they led sixth-grade students through activities of different levels of contextualization: decontextualized, moderately contextualized, and highly contextualized. Kruse et al. were surprised by the findings when students stated that decontextualized and moderately contextualized activities felt more like real science than highly contextualized activities. It shows that what students consider authentic experiences doesn't always match ours and should reinforce the idea of approaching the nature of science from more than a single lens. Schwortz and Burrows (2021) support this idea by stating that it is the very process of combining the knowledge of acquired skills and practices that allows students to come to know the nature of science, not by following a prescriptive methodology. However, this does not mean we abandon the inquiry method but rather change our approach. Instead of teaching a six-step sequence that we practice step by step, we allow students to master different practices that authentically mirror what is done by scientists and use our expertise and training to help them construct the larger picture of how science works and operates (Crawford, 2012).

Changing our approach to teaching science has to be done purposefully. As Crawford (2012) points out, it is critical to train teachers who may not know how to develop authentic science practices for their students. The need for teacher training is echoed by Glackin (2016), who discovered that teachers who approached authentic science practices using traditional methods were less effective, regardless of their knowledge base and subject background. Students engaged more when allowed to practice in a more student-centered environment that allowed them to collaborate and discuss their findings with one another. One key benefit of focusing on just eight practices is the ability for students to revisit these practices throughout the school year. Revisiting skills allows students to master these practices over time using different units of study. According to the NRC (2012), revisiting practices for mastery is one critical pathway for getting students to enjoy what they are learning and proving to themselves that they can do the work of real science.

The Value of Student-Centered Learning

Shifting teachers' mindset from focusing on dozens of standards to eight practices must be accompanied by another shift in how classrooms are structured. According to Mameli et al. (2020), this starts with training teachers about the value and importance of student responsibility and ownership. If students are going to be active learners and participate in authentic practices, teachers need to bring them into the decision-making process. This doesn't mean all decisions are up to students to make on their own, but it does mean, using the criteria of the practices, that students have choices and options in what they do. Compared to student responses, teachers tend to overestimate how often they allow student choice. This means teachers must be proactive in creating an environment that allows for a consistent student voice to be heard, promoting student accountability (Mameli, 2020). Berland et al. (2015) point out that teachers need to transform classroom structure and practices if they want to engage students in meaningful learning.

Creating a space for student voice and student choice is the beginning of creating engagement from students. Anderson et al. (2019) found in a study looking at students making the transition from middle to high school that as students age, they value involvement more, and as their perception of losing control of choice increases, their engagement decreases. One would think that a drop in engagement would negatively affect assessment grades, but that wasn't wholly the case. The study further showed that student performance rose with increases in student agency more than engagement. This discovery falls in line with Mameli et al. (2020), who learned in their study that students who perceived a greater ratio of student-centered assessments promoted greater student agency. Students saw themselves as active participants in their learning and capable of deciding what and how they investigate scientific questions. Ultimately, Mameli et al. show that teachers and students who work cooperatively together allow for authentic experiences that are more effective.

Summary of Approaches to Teaching and Learning

If teachers are interested in cultivating agency in their students, they need to be serious about changing their approaches to teaching and learning in the classroom. The change in practices and standards promoted through NGSS and being adopted by MDE is a perfect opportunity for self-reflection on the current teaching practices. The new practices present a challenge for science teachers who, although strong in the knowledge of their subject matter, are sometimes less comfortable or inexperienced in designing and implementing authentic science inquiries. Schools can support teachers through training and professional development, but it needs to match the teachers' interests and the students' needs.

Using the NGSS practices as a template for planning is an excellent way to develop authentic science experiences. The focus on practices offers the chance to shift towards student-centered practices, allowing more student choice and voice. This shift also allows students time to revisit practices several times throughout the year, promoting true mastery of the practices.

Developing Student Agency

Developing student agency is more than simply getting students to buy into what is happening in front of them. To develop agency is to put the onus of learning onto the students, or as described by Massey and Wall (2020), agency is to take action; it is not something you know but rather something you do. Mameli et al. (2020) write that agency, responsibility, and equity are diminished when activities are teacher-centered. Unfortunately, this is the most commonly found model, not only in American classrooms but in the world. The learning experience is enhanced when teachers see the students as social agents in the learning process, and agentic practices are employed to reach a common goal set by teacher and student. When teachers unilaterally set goals (or the curriculum sets them), students fall short of the desired target because they are passive participants. Mameli et al. (2020) continue by pointing out that true student agency is for students to have the ability to affect change in how they learn, set goals, and transform the learning process. This result will occur the closer a room aligns to being student-centered with teacher and students sharing the same vision for learning. With the teacher taking on the role of guide and facilitator in the process, students will be able to practice the skills that are agreed upon to develop student agency.

According to Robertson et al. (2020), it is important to view students as truly creative thinkers in the process of learning, not just mere consumers of knowledge. With this mindset, it is possible to truly cultivate student agency if teachers keep students and student learning at the focus of the curriculum plan. Massey and Wall (2020) clarify that effective teachers develop curriculum for the needs of their students, with Robertson et al. (2020) adding that when the curriculum is student-centered, with students acting as agents in their learning, student agency will be a natural outgrowth of that process. Ultimately engaging students in research leads to an agentic mindset (Massey & Wall, 2020), and one way to achieve this is by allowing students to be actively involved in agentic practices (Mameli et al., 2020).

Developing Teacher Agency

Before student agency is developed, it is necessary to develop teacher agency. This idea should make sense; you will not be able to develop students who think for themselves if it isn't modeled in the classroom. As previously discussed, student-centered classrooms need healthy interactions between teachers and students to find common solutions. It would be impossible to develop student agency if teacher agency wasn't considered by either themselves or their administrators. Robertson et al. (2020) propose that giving teachers an agentic approach to their curriculum allows them to act with intent and purpose and, in turn, promote student learning in the same way. To achieve this, administrators need to support suitable types of professional development for science teachers. According to Wright et al. (2021), teacher agency based on solid ideals will allow teachers to draw on both intrinsic and extrinsic values, bridging the gap between where the teacher's passion lies and the standards that need to be met. Although it is widely agreed that developing teacher agency will lead to cultivating student agency (Massey and Wall, 2020; Robertson et al., 2020; Wright et al., 2021), it is pointed out specifically by Massey and Wall (2020) that teachers need to feel supported to be successful. Massey and Wall (2020) go on to state that if the risk of failure of a curriculum project outweighs the reward, teachers will abandon their agency for the short-term benefit of meeting curriculum standards. This is a clear reminder that teachers need to be supported less in curriculum delivery and more in developing professional knowledge (Robertson et al., 2020).

One of the more critical aspects of the need for teacher training came from a study by Mameli et al. (2020). They found that teachers had an exaggerated view of their ability to cultivate student agency and responsibility, whether the activity was teacher-centered or student-centered. Although the study was inconclusive in quantifying the cultivation of improving student agency, it supported that students had a perception shift of their beneficial role in student-centered learning when teachers continually placed them within the decision-making process. This shift reduced teacher-student disagreement and increased student responsibility and equity perceptions in both teacher and student measurements. The study concludes that although it is difficult to measure student agency directly, it should not deter the idea of training teachers to be agents of change within their classrooms. When teachers worked with students to reach a common curricular goal, it positively impacted teacher and student perspectives and reduced teacher-student disagreement. This result aligns with the views of Massey and Wall (2020) that agency is a verb and needs to be promoted by both teacher and student. Wright et al. (2021) further support the point that even experienced teachers need help aligning curriculum to develop authentic student-centered activities and grow both student and teacher agency when done well. Mameli et al. (2020) support this conclusion with their study showing that implementing student-centered activities improves the agentic practices needed to cultivate student agency.

Teaching What is Relevant

There has been a long-standing goal to learn science by doing rather than by studying. To be successful with active learning, teachers need to engage students in the process of science (Berland et al., 2015). According to Habig and Gupta (2021), relevancy can be accomplished first by engaging students with science practices and secondly with relevant experiences in their lives. Habig and Gupta continue with their findings showing that students who engaged in science that was personally meaningful to them were more likely to re-engage more frequently, with greater depth of understanding, voluntarily and independently. Habig and Gupta's study was part of an informal science education program run through a museum, where students worked alongside researchers. Although many schools may not be able to recreate this exact partnership, it nonetheless supports the idea that studies relevant to students' lives have measurable effects of growth on their engagement and agency.

According to Berland et al. (2015), the intention of using relevant topics for students is that it explicitly teaches students the nature of science by engaging them in meaningful matters. By coupling this idea with the practices, students can understand how the epistemological practice of science affects their view of the world; in other words, students can learn how they know what they know. This result differs from traditional inquiry, where a student picks a topic to investigate, plans and runs experiments, analyzes results, draws conclusions, and then writes a report for assessment. By asking students to enter the arena of engaging in the argument with evidence, we are giving them license to use their interdisciplinary skills and knowledge that are needed to do science well (NRC, 2012). The alignment of scientific practices with classroom practices is critical, according to Berland et al. (2015). Teachers must explicitly show students how they use science practices in the classroom beyond simply engaging in meaningful topics. The point is to give students tools that allow them to develop workable solutions to real problems. Berland et al. expand on this by showing that students have increased motivation when they see how knowing science supports their goals. Like anyone, they are motivated when they find the work meaningful.

Using Socioscientific Issues for Relevance. Socioscientific issues lend themselves to using the students' knowledge of the nature of science to engage in dialogue and discussion (Zeidler and Nichols, 2009). Because they are controversial in nature, they lend themselves to students to balance moral and ethical concerns while remaining in the practices of science (Leung, 2020). According to Zeidler and Nichols, this connection further deepens students' understanding of how science operates in their lives. Using their science knowledge to support conclusions with evidence is not an easy task but is critical for developing a sense of using what you know to take action (Peffer and Ramezani, 2019).

Traditionally, science has been taught by students being rewarded for relying on disciplinary knowledge, which, although important, is not the only practice they need to master. Socioscientific issues engage students better by being personal. Once engaged, students need to understand how they know something scientifically to communicate it as an argument (Leung, 2020). Berland et al. (2015) warn us not to fall into the trap of allowing students to write an argumentative essay in place of open community discussion. When students are permitted to pen their answers, we let them engage in what they call pseudoargumentation because the student is focused on meeting the rubric and creates an argument of criteria. When students argue and discuss in a community, they need to use the knowledge of science and society, making it an authentic experience. The characteristics of a good socioscientific issue for classroom use, identified by Sadler et al. (2006), can be summarized as follows,

- Connected to the course subject
- Data-supported
- Real, rather than fabricated
- Have contemporary relevance
- Controversial
- Illustrate the nature and process of science

Leung (2020) clarifies that teachers need to explicitly teach science practices and how they fit into the nature of science before engaging students in socioscientific issues. You cannot assume learners can navigate these issues without the structure of the practices and epistemological grounding. Teachers should also not assume students will come to a clear conclusion during this process and must inform them that it is all right not to have a clear answer at the end of the process. According to Leung, it is the exercise of practicing the nature of science that matters most. Counter to that, Eastwood et al.(2012) clearly state that socioscientific issues engage students better than other topics and promote high expectations for students to use all of their scientific knowledge and practices because of the personal and controversial nature of the subjects. Eastwood et al. demonstrate that students engaged in quality socioeconomic issues exercises show growth in their understanding of the nature of science and content knowledge.

Summary of Developing Student Agency

The development of student agency is a difficult thing to measure. If we look at scientific agency as an action, we can at least measure it indirectly based on knowledge and understanding. To truly cultivate student agency, it is necessary to view students as creative thinkers capable of developing their own conclusions based on the practices of science we have taught them. Before focusing on student agency, we must start with teacher agency. Even teachers with a solid knowledge base in their subject area can lack experience in developing authentic practices. This reality means that teachers may often need training to build teacher agency.

If teachers expect students to use all of their science skills and knowledge, they will be motivated and show more growth if the topics are relevant. Teachers should give care in allowing students to have a voice and choice in how and what they explore in their authentic study. Socioscientific issues are especially beneficial in engaging students due to their controversial and personal nature.

Conclusion

The adoption of the NGSS standards by the Minnesota Department of Education is an opportune time to assess how we are teaching our science students. I conclude that we need to focus heavily on the eight overarching practices of the NGSS and embed authentic science practices as much as possible. This action will change the approach to teaching and learning most of us do and, in many cases, will require teacher training to facilitate the change. In addition to necessary training and support, teachers must be encouraged to independently explore options for authentic science that meets the needs of their students.

Using socioscientific issues as a culmination to demonstrate students' knowledge of their science skills and their understanding of the nature of science is a more authentic measure than inquiry experimentation alone. Because of the personal and controversial nature of socioscientific issues, students are more engaged and motivated to solve questions that the classroom community develops. By discussing and communicating their answers with supported reason, students can demonstrate their complete understanding of the science practices in an authentic setting. To meet this challenge, it will be necessary to address a current gap in the way science is taught and to help teachers develop their skills to lead authentic science practices.

Going beyond inquiry-based experimentation and allowing students to self-direct their own learning can be challenging for even veteran teachers who are confident in their content knowledge (Habig and Gupta, 2021; see also Eastwood et al., 2012; Leung, 2020). To address this gap in teacher training, it's important to support teachers with experienced mentorships, partnering them with experts in fields they want to explore with their students all while building peer support between teachers doing the work (Habig and Gupta, 2021).

In Chapter Three, I will share my project of designing a semester-long professional development training to address the gap in science teaching practices. Through an initial workshop, I will introduce and identify the idea of authentic science experiences to district science teachers. This professional development training aims to support the critical first steps in cultivating student agency by offering teacher training and an ongoing professional learning community to develop and implement authentic science experiences with students in their base schools.

CHAPTER THREE

Project Description

Introduction

Increasing opportunities for students to participate in authentic science must begin with teacher training. If we are going to create an environment that cultivates student agency, we must first create the support for teachers to improve and demonstrate their agency in science by allowing them the opportunity to explore the parts of science they know best. The capstone project is to offer an initial two-hour professional development (PD) session followed by a three-month-long professional learning community (PLC) to district science teachers in grades 5-12. By allowing teachers the opportunity and support to develop their own authentic science experiences, we can answer, *How can we use authentic science experiences to improve student agency?*

I based the PD sessions and subsequent PLC on the four practices of cultivating teachers who support student agency laid out by Massey and Wall (2020), which are summarized below,

- Support and develop a professional identity.
- Identify a clarifying vision and long-term goals.
- Focus on the students.
- Research one's practice.

Following these four practices makes it possible to give teachers the freedom and support to develop authentic science experiences that will cultivate student agency in the natural sciences.

Project Overview

The project is an initial PD session that will occur in November 2022, followed by a virtual PLC from December 2022 to February 2023, followed by an in-person gathering in March 2023 to share participants' results, successes, and challenges. In the initial PD training, teachers will be introduced to authentic science, what it looks like, and how to choose, develop, and implement authentic science opportunities for their students. Following the initial PD training, I will facilitate support for teachers through a PLC, which will meet twice a month, where teachers will be able to work with one another to align curriculum with the standards, determine formative and summative assessments, and offer a place to seek trusted advice on their developing experiences. The final meeting in March will be an informal PD to share celebrations, results, and challenges.

Project Rationale

To cultivate student agency, teachers must first identify their own agency. One of the most critical pieces to developing agentic actions in teachers is to offer intentional, ongoing support within their content area (Robertson et al., 2020). This project aims to allow teachers to develop authentic science projects and experiences for their students with autonomy while offering support when and where teachers feel they need it. They will cultivate student agency by supporting and encouraging teachers to lean into their interests (Massey and Wall, 2020). Massey and Wall refer to agency as a verb; it is something you do, not just something you have. To develop student agency, we must start with what we teach and our interests as teachers. This research matches my own lived experiences as a teacher. The most impactful units I've been part of weren't just authentic but matched my interests and skillsets as a scientist. For example, if allowed to work from an ecological angle, I am more comfortable taking on a larger, more open-ended project, knowing I have the skills to guide students when they face challenges.

Scientific inquiry has always been the cornerstone of science education, but according to Feldman and Pirog (2011), scientific inquiry is not enough to develop a student's knowledge of science. They should learn how scientists gain knowledge and practice these tasks to know how science operates. In the classroom, although programs offering opportunities like sustained, place-based education or community partnerships are good and genuinely authentic, students don't need to be involved with the entirety of the process to gain an advantage from experience. Kruse et al. (2021) found that you can take the science practices out of the context of a study, and students still feel as though they were acting like real scientists. This project intends to support the small-scale occasional authentic science experience and the large-scale ideas that come to fruition.

Project Description

This project is an initial two-hour fall workshop that will introduce teachers to examples of authentic science, alignment to the new science standards, and ways they can oversee authentic science projects at their sites. A three-month-long virtual PLC will follow during the winter to help teachers implement and refine their authentic science ideas. Formal accountability of the PLCs will happen through sharing goals and results during a spring PD session.

Fall PD Session

During the middle of the second quarter, the district sets aside time for teachers to collaborate, learn new classroom strategies, and discuss curriculum changes for the year.

Disciplines schedule these PD sessions, so those in attendance will be full-time science teachers. This PD intends to encourage participants to design and develop their own authentic science experiences.

The initial PD training will identify authentic science happening in classrooms and how to build on that in alignment with the standards. The reason for starting here is because, in my own experience, science teachers are pushed to think of inquiry as the only form of authentic science; that authentic science only happens when students run research projects in their entirety. Academic research supports that authentic science can be deconstructed and still beneficial. Using this knowledge, we can better identify where teachers embedded it in their curriculum, even when a single practice is a goal. I will also share examples of authentic science done in other settings, and facilitate others to share, so teachers can see what may fit best with their background and unique school setting.

While taking on an authentic science project may be large-scale, like partnering with a community group or starting a citizen-science program, it can also be a stand-alone unit or even a set of skills aligned to the standards. One of the main goals of the initial PD training is to tap into the science teachers' expertise in the room and generate a set of examples where they see a pathway for quickly implementing authentic science practices in their classrooms. As Knowles (1992) pointed out, it is essential to build on the background knowledge and interests of the adults in the room and not present the information as an expert on what others should be doing. In line with Wright et al. (2021), teachers are more likely to implement place-based education practices in their classrooms when it aligns with their expertise and the curriculum standards.

Because of the ongoing nature of developing distinct, authentic science experiences for each of their sites, it will be essential to create a PLC of participating teachers to continue accessing support and resources as they continue developing and refining their projects.

Authentic Science PLC

Following the initial PD session, a virtual PLC for participating teachers will take place biweekly during the winter. The PLC portion of this training intends to allow teachers a resource they can turn to if they choose. In developing their own authentic science experiences, I am asking teachers to take a giant leap into whatever they decide to develop, whether a single unit, an ongoing student-initiated project, or a community partnership. Whatever the choice, teachers will need support, and a PLC seems like the best thing to offer. The PLC will operate in the true sense; teacher-initiated goals based on the needs of their students, set by the group. In my experience, PLCs are too often in name only, with agendas and goals set by others. DuFour (2007) noted that PLCs offer the best real-time benefit for schools to have sustained and substantive improvements that teachers in the building drive. A colleague set up the only PLC I’ve truly enjoyed. We met voluntarily to talk about improving assessments and were accountable only to one another. I intend to create a space for teachers to meet as a PLC and will resist all urges to set agendas and goals.

Participating in the PLC is not a requirement, and I expect not all teachers in the initial workshop will, or should, be part of the ongoing PLC. As highlighted by O’Keeffe, *In Praise of Isolation* (2012), not all team members work better together; some teachers will dive into the research and required work much better on their own and should be allowed the space and opportunity to do that. So the ongoing virtual PLC will be set up along two strands. The first will be a committed core group of teachers who volunteer to meet regularly to work as a PLC, setting goals and working collaboratively to meet those goals. Secondly, the opportunity for drop-in questions by teachers who choose to work independently but still feel the need to check in with others in their field when they want.

Spring PD Session

Unlike a traditional PD session, the spring meeting will allow participating teachers to come together and share the results of their authentic science experiences. Of course, this acts as an accountability measure, a critical step in designing teacher-led PLCs (Easton, 2016), but it also serves as a chance to celebrate endeavors with our peers. The origin of my research question, *How can we use authentic science experiences to improve student agency?,* began with observing student onus being on display when they communicated their results. It seems fitting that the project ends with similar modeling of shared experiences.

Setting and Audience

The initial PD training will take place in the fall, mid-way through the second quarter. The intended audience is middle and high school educators teaching dedicated science courses in grades 5-12. The district this project is designed for is large, with four separate middle school sites, three separate high school sites, and two alternative learning sites for both the middle and high school populations. It is a diverse school district, with BIPOC students making up 44 to 54% of the students in any given building, but BIPOC teachers only represent 4% of the instructional staff (Shearer, 2022). In addition, about 14% of the community was born outside of the United States (United States Census

Bureau, 2021). These demographics demand a shift in our approach to traditional classroom experiences and offer an opportunity for transformative changes in developing authentic science relevant to the students coming through our doors. In the past five years, the district has provided many PD opportunities for staff to respond to the changing needs of our students, including culturally and linguistically responsive teaching methods. Developing authentic science experiences that allow student choice and voice would enable embedding culturally and linguistically responsive principles into the curriculum, extending it beyond a superficial classroom management level and incorporating it into how students learn.

Researcher Positionality

As a teacher, I want to give my students opportunities that allow them to take ownership of their learning by participating in authentic science experiences. I strive to develop curriculum that will enable them to recognize their talent that best supports scientific practices. My goal is the same for both adolescent students in the classroom and adult learners in professional development. My personal experience in school was always positive. I am the son of a high school science teacher, which gave me access to scientific inquiry and discussion whenever I wanted. My dad’s friends were my teachers, advisors, and coaches. My personal community and my school community were one and the same. I need to be aware that every student in the classroom brings a very different background and point of view. I lack the understanding of a student who doesn’t see the point of education, doesn’t feel supported by the school system, and doesn’t feel valued by a system that doesn’t look and feel like their community. As a cisgender white heterosexual male, I represent the traditional establishment whether I like it or not. I need to understand this to design adult professional development opportunities and curriculum for students that invites full participation from everyone present.

Timeline

- Summer 2022: I designed the initial PD session, PLC topics, and wrap-up PD celebration.
- Fall 2022: I will offer an initial two-hour PD session in November to introduce the topic of authentic science to teachers and lead them in recognizing authentic science practices already being used in their classrooms. Participants will also be introduced to more extensive authentic science experiences and walk away with practical, authentic science formative assessments.
- Winter 2022-23: I will facilitate a virtual PLC twice a month from December through February, with six meetings total. The PLC will allow participants time to align their practices with state standards, determine student goals and assessments, and act as a resource for ongoing support while implementing authentic science practices.
- Spring 2023: I will facilitate a wrap-up PD session to celebrate the work done by teachers and students, allowing the opportunity for participants to share their findings and results.

Assessment

I will give participants the same pre and post-attitude surveys during the fall and spring PD sessions. This purpose is to know how teacher attitudes shift during the experience. I'm most interested in learning about teacher perceptions of their ability to affect change in student agency. By giving the same pre and post-attitude survey to participating teachers I hope to understand if there is a connection between teacher confidence when using authentic science practices and student agency. Students will not be participating in the attitude surveys, but teachers will be able to observe and rate student agency through action.

In addition to the attitude surveys I will ask participants to take, each teacher in the PLC will share the results of their chosen goals during the wrap-up PD session. Attaching a PLC to the initial PD training fosters teacher agency, allowing teachers to practice with purpose and accountability they choose for themselves.

Summary

This capstone project consists of training teachers who want to implement authentic science experiences into their classrooms, followed by a virtual PLC to support their ongoing development and refinement of those ideas. The project will conclude with another PD session for participants to share results and findings. During the initial PD session, I will show teachers examples, both large and small, of authentic science experiences that can be implemented in the classroom and are in alignment with the NGSS practices. Teachers can join a virtual PLC following the PD session to continue refining and implementing their ideas. Teachers who choose not to participate in the PLC will still have access to the group on a drop-in basis if and when they need to connect with peers.

Chapter Four will cover lessons learned while developing this project and detail the most critical connections between the literature review and the capstone project. Also covered will be the limitations and implications of the project in its current format and ideas for future projects that teachers could implement. Finally, I'll discuss how this project benefits the profession of science teaching.

CHAPTER FOUR

Conclusion

Introduction

In this chapter, I will discuss the major learnings I encountered during my research of the question, *How can we use authentic science experiences to improve student agency?* Most importantly, I will highlight the literature reviews that influenced my capstone project idea. I will also discuss the project implications on how science teaching is currently approached, including the limitations of working within the current academic structure. Recommendations for future use will also be described, including extensions to this study and ideas to overcome the limitations of the project. Lastly, I will describe the project's direct benefit to science education.

Major Learnings

Throughout my time as an educator, I've wondered about teachers' effect on students choosing a career in science. I was drawn towards authentic science practices because I’ve learned through experience that using them positively affects engagement. I wondered if higher engagement and understanding lead to student career choices in the sciences. When I began my capstone project, that was my burning question. The most memorable units I’ve done with students centered on authentic science practices, so I made a straight-line connection between them and student engagement and knowledge. I had also learned through experience that students demonstrate depth of understanding when they communicate what they have learned to others.

The research supported a different order of steps and connections. Clear communication can result from a deep understanding, but more often, prepared communications for an audience deepen understanding of the topic (Berland et al., 2015; Leung, 2020; Peffer and Ramezani, 2019). In addition, the research supports that students will put more work into communicating when they care about the topic and have a choice of how they approach the solution (Sadler et al., 2006). I can now see that these pieces were all in play during those impactful units.

More critical than engagement, I learned from the research that student agency is a more significant factor in increasing student willingness to learn a topic deeply (Leung, 2020; Peffer and Ramezani, 2019; Zeidler and Nichols, 2009). From there, my research question developed into its current form, *How can we use authentic science experiences to improve student agency?* What I had witnessed in those memorable moments wasn't as simple as students understanding complex scientific relationships because they had used authentic science practices. It was a combination of using authentic practices on topics the students cared about doubled with giving them a choice in how they explored the topic.

Project Ties to Literature

Authentic science practices are any classroom activities that model what real scientists do. While most will recognize inquiry and data analysis as authentic practices, the list also includes modeling, developing explanations, and arguing from evidence. Collectively there are eight practices identified by the National Research Council (NRC) and developed into the Next Generation Science Standards (NGSS) which the Minnesota Department of Education (MDE) adopted for implementation starting in the 2024-25 school year. (MDE, 2019; NRC, 2012).

Using authentic science practices makes the work more relevant and meaningful for students, allowing students to better understand the nature of science (Crawford, 2012; Glacken, 2016; Schwortz and Burrows, 2021). The research of Glacken, Schwortz and Burrows, and especially Crawford, reinforced what I had experienced in the classroom. It was encouraging to have my idea backed by the findings from experts in the field, and it gave me the confidence to dive into the other research questions I had. I spent a lot of time trying to find research that linked the engagement of authentic practices to success in science, but the connection that kept popping up in the writings was student agency.

Agency is more challenging to measure than engagement. Massey and Wall (2020) advocate that agency can be equated to action, making it more easily observed and measured. They also advocate, along with Mameli et al. (2020) and Robertson et al. (2020), that students need to be involved in curriculum choices if we want them to develop true agency. It was this block of research that changed my original project idea of creating authentic science units for teachers to use. I was still of the mindset that authentic science was the key, but I was learning that you encourage student agency when students get real choices in what they study. It's also the point I was feeling overwhelmed because how could I create a project of something so open-ended?

Developing agency in students will happen more quickly if teachers are allowed to develop their own agency first (Massey and Wall, 2020; Robertson et al., 2020; Wright et al., 2021). In order to achieve this, teachers must feel supported and given the opportunity and time to explore their passions in their respective fields of study (Massey and Wall, 2020). This connecting of research points is what brought me to my capstone project. The way to affect student agency was to offer teachers an opportunity to cultivate their own agency. So I decided to offer professional development (PD) for teachers to identify authentic science already in their curriculum and use the NGSS standards to expand authentic practices that are missing. Robertson et al. (2020) proposed that teachers need time and support to develop their ideas for true agentic change. A second PD session didn't seem sufficient to support teachers, so I decided a PLC would give teachers what they needed to develop new authentic experiences. Finally, as accountability for my project and the PLC, there will be a face-to-face sharing of results to celebrate the work. I based the idea and importance of a face-to-face meeting on my best experiences with students. The energy of being together in the same room when you communicate your findings simply cannot be replicated online. My justification for taking PD time to share results is to honor the work and ideas of the teachers.

Project Implications and Limitations

The most obvious implication of the research is the value of allowing teachers to develop their own agency. I will offer a district-wide opportunity allowing teachers the time and space to work curriculum more towards their interests in science. On a larger scale, this conflicts with a common trend of creating units and assessments that are the same between teachers and sites. The main reason for aligning authentic science ideas with the eight practices of the NGSS is to find a common way for teachers to agree on assessments. This approach is a shift towards standards-based teaching and learning. If teachers and administrators can agree on how students display mastery concerning each of the eight standard practices, then it is less critical that everyone is teaching the same topic in the same way.

The district I work in is a good example of an approach for assessing student learning that matches my research. We adopted the NGSS practices before the state of Minnesota, aiming to standardize how teachers measure student achievement. In addition, the district has moved to a grading for learning model that allows students multiple opportunities to show mastery of a single practice. In order to give teachers the autonomy to explore their interests so, in turn, it can lead to an increase in student agency, there must be a committed effort to focus on fewer practices when assessing students. This approach would be a big policy shift for many districts. The past trend of aligning curriculum between teachers and testing students on the same facts runs counter to allowing student choice to foster agency.

There are key limitations in allowing teachers the opportunity to develop their agency, most notably time. My project is a one-off PD training. To truly affect change, there needs to be a sustainable plan for training new teachers in the buildings and fostering the continued growth of teachers who participated in the past. With all the demands of re-licensure hours and new initiatives, PD time is a precious commodity, and it would be unrealistic to think my project in its current form would be the lasting solution. Another limitation is the structure of the grading calendar. Once again, the district I work in is a good example of the constraints put on implementing something that needs time to come to fruition. The NGSS practices emphasize explaining results and arguing from evidence. Allowing students multiple attempts on topics of their choice takes time to develop. The school calendar is still often based on a nine-week turnaround. At a minimum, this means districts need to move to a semester grading window, which would significantly shift how teachers communicate student progress with parents and guardians.

Summary of Major Learnings

When I started researching how authentic science practices can benefit student learning, I focused on a short path from practice to student knowledge. What I learned is a much lengthier pathway starting with the need to develop teacher agency prior to student agency. Authentic science practices, in turn, allow students to understand the nature of science as they explore answers that are meaningful to them. The implications of this research are the importance of allowing teachers the time and resources to foster their own agency and the time and resources needed to allow students to develop agency. The lack of workday time and the nine-week grading period limit the scope of implementing an ongoing culture of developing teacher agency.

Recommendations for Future Use

One of the limitations of my project, making a sustainable support system for teachers, has me thinking about a future PD session. I often use Alan AtKisson's decision-making models with students when there is a need for a sustainable solution. These models necessitate a group working together to find a balanced solution. Science teachers who have gone through the PD and PLC of my project would be good candidates for improving the efficiency and effectiveness of maintaining a culture of agentic change.

The focus of my research materialized as the need for students to be able to choose topics in order to foster agency. I chose to align this to the NGSS practices for practical reasons for implementation in the classroom. I did not directly explore how this would affect scientific or environmental literacy, and I think this would be a natural line to explore. I would also recommend the need to research whether the grading calendar timeline impacts the ability to foster real agency. Although I think experienced teachers could engineer a way around a short grading period, another reason I am thinking about following this PD project with another.

My district is currently reviewing how we approach our teaching and learning. I fully intend to communicate my new learnings at the department site level, and to the district committees I sit on. Most notably, I am part of the committee on standards-based practices and think the connection of developing teacher agency prior to student agency will prove critical to our decisions on how to support teachers to improve the delivery of science instruction.

Benefits to Science Education

The most significant benefit I see of my research is the connection of student success by supporting teachers in developing agency. As teachers, we are constantly in a cycle of improving units, collaborating on approaches to teaching, seeking outside resources, and assessing student work. This research highlights the need to allow teachers time to increase their expertise and knowledge in specific areas they desire. By using the umbrella standards as the assessment criteria, teachers would still be able to collaborate effectively even though they are taking different approaches with their students.

Summary

Using authentic science practices in the classroom can motivate students to see themselves as doing real science. If the intent is for students to take ownership of their learning, we should be striving to foster student agency. Prior to affecting student agency, it is essential to allow teachers the opportunity to improve their agency. Time and support are critical in allowing teachers the chance to grow their agency in the topics they teach. By using the combination of PD training and a PLC for support, this project aims to allow teachers to foster their agency. The final intent is that teachers with greater agency will increase their students' agency through authentic science practices.

The implications of this study are the need for more time and resources to accomplish the task of fostering teacher and student agency. Changes to how we offer PD to teachers and grade period structure may need to be modified to assure success. Currently, these are both limitations to the study. This study represents a narrow focus on improving teaching and learning and lends itself to being extended to other areas. The connection between using authentic science practices to affect teacher and student agency is clear, and the need to offer PD training and support for teachers through PLC work directly benefits science education.

In conclusion, the need to offer PD training for identifying authentic science practices in the classroom leads to an important step in answering my research question, *How can we use authentic science experiences to improve student agency?* The how in my question has been answered — by first improving teacher agency. It is critical to support teachers as they take the time needed to create authentic science experiences, and a PLC is a natural fit for this purpose. The research supports that student agency will improve by first improving teacher agency by focusing on authentic science practices.

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