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A Holistic Approach to Science Education: Disciplinary, Affective, and Equitable

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In this article, we argue that science education is more than the high stakes, rigorous practices and methodology that students often find dull and uninspiring. We present that aesthetic and humanistic motivations, such as wonder, curiosity, and social justice, are also inherent reasons for doing science. In the MSUrbanSTEM program, we designed an approach that built on these aesthetic and humanistic aspects of science. We share three case studies to present everyday pedagogical approaches to science education used by three Chicago Public School (CPS) teachers during a school year. These classroom practices used wonder, curiosity, and social justice as motivations for engaging in science and provided a disciplinary lens to look at the world that students found to be fundamentally interesting and inspiring.

***Keywords*:** science education, aesthetics, wonder, social justice

INTRODUCTION

Throughout ages, science has held a position of importance in society for different reasons. These reasons could be of world leadership and prosperity (as often claimed by politicians; e.g., USA-USSR space race), instrumental (getting an economically stable job; e.g., engineering in different forms as opposed to liberal arts (Robinson & Sexton, 1994; DeBoer, 2000), social justice (learning to solve the problems of the world while reducing inequality and bringing justice; e.g., gender and racial equality in STEM (Barton, 2002, 2003)), and aesthetic (doing science for the sheer curiosity; e.g., as written by Richard Feynman (Mehta & Keenan, 2016)). However, high stakes standardized testing in schools often deposes these motivations as a fundamental reason for students to study science, often shaping teachers' pedagogical approach to teaching science (McNeil, 2002; Stage, Asturias, Cheuk, Daro, & Hampton, 2013; Olsen & Sexton, 2009). This often ends up in low engagement among students to continue to pursue science as a career and even understand science as an interest, which can have several personal (e.g., anti-vaccination campaign in the US), political (e.g., reduced funding in science, Griffith & Scharmann, 2008), and environmental repercussions (e.g., climate change).

Dealing with Low Engagement

Students often label science as hard, dull, or uninteresting (Basu & Barton, 2007; Bennett & Hogarth, 2009). This perception can be seen as responsible for low student engagement and motivation to study science, let alone understand its practical implications (Pintrich, 2003). A lack of interest in science in school can also lead to decrease in number of students opting for science, engineering, or technology majors in college (Chen, 2013). Similar arguments can be made for mathematics. Therefore, we need to first understand the reasons behind this perception that causes low engagement with science. In this article we focus on three such reasons: a faulty, rigorous perception of science, lack of affective motivations, and social inequity.

The first reason behind low student engagement stems from a rigid curricular structure that tries to mimic a common perception of scientific rigor and methodology that is considered as driving scientists and other science-related professionals (Bennett, Lubben, Hogarth, & Campbell, 2005). The problem with creating such a pure fact-based, methodological approach is twofold. First, students tend to miss the relevancy behind learning the core content (Van Berkel, DeVos, Verdonk, & Pilot, 2000). In other words, teachers have trouble convincing students why it is important to study, for instance, the atomic structure of carbon when they do not fathom any real-world applications. Instead, students—under pressure to excel in standardized tests designed to measure retention of facts—often rely on memorizing facts. This results in students losing interest in science as a discipline. Second, this rigorous, methodological, and fact-driven perspective of science is that of an outsider. A rigid representation of science misses the affective/sentimental, wonder and curiosity-driven aspects that are considered as the essence of science by many scientists and professionals (Feynman, 2005; Chandrasekhar, 2004; Girod, 2007; Dawkins, 2000; Root-Bernstein, 1996).

This leads to the second reason behind lack of motivation: lack of affective motivation. Scientific method is not the only factor that drives scientific research and motivates professionals. Several scientists and researchers (Chandrasekhar, 2004; Feynman, 2005; Girod, 2007; Sagan, 1995; Girod & Wong, 2002) have spoken of the value of beauty and aesthetic as their motivation for science. We can say the same about mathematics, as often mathematicians speak of inherent beauty in math (Orrell, 2012; Henriksen & Mehta, 2016). By aesthetic and beauty in science, we speak of ways of looking at science that inspire an emotional response. Scientists have often narrated the sheer joy of such experiences and wonder in doing science. They associate a sense of curiosity and wonderment with their passion and love for science as their profession. Unfortunately, pedagogies around science often fail to address these affective aspects that have inspired scientists throughout centuries (Pugh & Girod, 2007). In other words, the significance of affect has been overlooked as if it did not belong in science and could only exist in arts.

This thinking aligns with the one-dimensional mindset that shapes the science curricula today, and which can also be considered as causing a third reason for lack of motivation to pursue science: social inequity. Roth and Barton (2004) have attributed general public's lack of proclivity to science to a feeling of apprehension towards the harm that science is capable of doing (or has done) to people (for example: atomic bomb, drugs, weapons, etc.) and a rigid, highly technical indoctrination that supports a white, middle-class, and male standpoint, which marginalizes women and minorities. They claim that reform in science education should focus, therefore, on social justice, where people can see value in doing science, and are taught concepts that they can use in real world situations.

However, this faction of researchers often opposes an emphasis on understanding fundamental or critical concepts in science, such as atomic structure of carbon, star and planet formation, and so on, dismissing them on the ground of being "knowledge about the world that is simply inaccessible to our experience" (Roth & Barton, 2004, pp. 4-5). As the National Academy of Sciences (NAS) highlighted, doing science for the sake of doing science is only one of the reasons why science is important. Supporting the push for social justice and equity, NAS (2012) called promoting scientific literacy as a "democratic ideal" (p. 277). They recommend a science for equity to create a future where the field of science has a representation of all communities to solve problems without biases.

We see this as one of the motivators for students to do science. We argue that a disciplinary understanding of science that comes for learning science for the sake of science out of wonder and curiosity is equally important. Therefore, a more holistic and balanced approach is necessary. An understanding of these motivators combined with the instrumental reasons often promoted through political and familial discourses can be seen as important elements that should ideally make up an engaging approach to science education.

RETHINKING SCIENCE EDUCATION

There are several approaches we, as educators and researchers, can take to address a combination of these issues in our classrooms. First, to address the concern about concentrated and rigid treatment of the scientific method, there needs to be an epistemological shift in teaching that explains that the scientific method is just a tool to assume critical thinking, so students can learn how to scientifically frame questions that lead to systematic search for answers that explain natural phenomenon. It needs to be clear that the scientific method is an approach and should not overshadow the scientific curriculum in forms of sheer list of facts and figures. It is through the scientific method that students should learn to explore and find answers that either support or challenge the existing facts and theories or replace them with better explanations. In other words, the scientific method is a lens to doing science. It should not, however, dominate the pedagogical approach, but only inform the dialog of doing science. This can come from understanding science as a discipline, and not just as a rigorous methodology full of rigid facts.

Second, to address the lack of an aesthetic appeal—to which scientists have often attributed their passions—pedagogies around science education need to address the emotional component (Zembylas, 2005). Emotional elements need to be a part of every classroom experience; and, in a science classroom, these can be supported through the language used to address experiences of scientists, when creating a classroom experience for students, when witnessing a scientific experience either in a laboratory or a natural setting, or when retelling a story attached to a discovery or invention. The way we frame the rhetoric around science can be charged emotionally to inspiring aesthetic experiences similar to those felt by professionals.

Some common aesthetically-charged terms that scientists have often identified when describing their experience in doing science are wonder, awe, and beauty (Dawkins, 2000; Girod, Rau, & Schepige, 2003; Hadzigeorgiou, 2012). Creating experiences for students that stick with them are more likely to inspire them to ask questions and be curious. Girod (2007) also found that aesthetically framed language inspires students to look at mundane, everyday objects with a sense of wonder and curiosity. In his work, he found that a teacher who created metaphorical and aesthetically appealing settings for learning and doing science was more likely to inspire wonder and curiosity than a teacher who takes a more instrumental approach to learning science.

Third, when addressing the elements of social and gender inequity, NAS (2012) highlighted that the reasons for these differences were complex and researchers had a variety of explanations for it. Honoring the dynamics of students' personal backgrounds and a range of knowledge they bring in, NAS recommended pedagogies that understand students' personal motivation for doing science. A sense of wonder and natural curiosity may not be enough of a motivation for all students at all times. Sometimes a will to solve a problem in their local community may act as a stronger reason to inspire students. NAS also cited studies that showed:

> …all individuals, with a small number of notable exceptions, can engage in and learn complex subject matter—especially if it connects to areas of personal interest and consequence—when supportive conditions and feedback mechanisms are in place and the learner makes a sustained effort. (p. 280)

Therefore, further elaborating on the need for teaching science with social justice in mind, NAS (2012) echoed what Roth and Barton (2004) had stated, and made a case for teaching problem-solving in a way that reflects students' common expectations. However, NAS differed from Roth and Barton's position slightly and emphasized the value of knowing the core ideas and practices in sciences and engineering.

The MSUrbanSTEM Perspective

To incorporate aforementioned motivations in classroom, Michigan State University's WIPRO STEM & Leadership Teaching Fellowship program (MSUrbanSTEM), funded by Wipro Ltd., took an approach based on a combination of John Dewey's philosophy of experience-based learning and the TPACK framework (Mishra & Koehler, 2006). While teachers have restricted freedom to experiment with the content due to curricular and standards-based expectations at school, district, state, and often national-level, they can still choose to experiment with pedagogical and technological applications in classroom to increase student engagement.

MSUrbanSTEM instructional team worked with Chicago Public School teachers for a year bringing in a creativity and wonder-driven perspective to teaching and learning science (and other STEM disciplines). One of the key purposes of this program was to help STEM teachers design their own pedagogical moves to engage their students in science content by using and repurposing technology available and accessible to them; using Mishra & Koehler's (2006) TPACK framework. Through this program, these teachers (and their students) learned to *explore* the world around them from a disciplinary lens of science, *create* lessons and assessments that provide students connections to relevant real-world experiences of science, and *share* their work and practice publicly through social media as a part of their service. In this article, we share the work, methods, and experiences of three science teachers who took leadership to explore, create, and share engaging learning experiences for their students. We use these three cases to discuss a holistic approach to science education. In the next section, we will shift to discussing how this approach looked when three science teachers implemented it in their classrooms using their individual and independent projects called *DreamIT*.

METHOD: THREE CASE STUDIES OF SCIENCE TEACHERS

In this article, we share our case studies of three MSUrbanSTEM fellows who teach science in CPS. In these case studies, we looked at their personal accounts and reflections, documented throughout the year, to understand the direct impact of our approach to science education on their teaching and learning. We will focus specifically on their DreamIT project reflections and Summer Reflection, which was made at the end of summer semester (see Horton, Shack, & Mehta of this special issue).

When looking at these reflections, we started with a lens of the three aforementioned major components that we consider important to engagement in science education. These are: (a) practices that help learners understand *science as a discipline*, (b) a setting that encourages *affective experiences* like wonder and curiosity, and (c) science as a tool to *solve societal problems and promote equality*. In addition, we also looked at the elements of *explore, create, share,* that we see as integral to STEM education and teacher professional development overall. The pedagogies that we care for in science education, when combined with these components of effective teacher training, created the *science* in MSUrbanSTEM .

In the next few sections, we will begin by presenting a brief introduction of each fellow's work and commitment to providing quality education. We will then describe the projects (DreamIT) that each fellow undertook as a part of their MSUrbanSTEM coursework and activities, their approach toward implementing these ideas in their classrooms, and how effective they were in executing their plans. In describing their work, we will provide a brief summary of what the activities and projects they engaged in were aimed at with respect to the MSUrbanSTEM coursework.

As you will read in other articles in this special issue, these case studies were also driven by a common question:

> In what observable ways have teachers demonstrated an exploration of science-based, technological, and pedagogical practices in planning and implementing their DreamIT projects?

THE THREE SCIENCE FELLOWS

As representative of the larger set of science teachers among the 25 fellows, we randomly selected three science fellows. In this article, specifically, we review their DreamIT teaching projects from their year of being active MSUrbanSTEM fellows by highlighting their project aims and providing examples of what they did in order to reach their goals. The next section will cover the DreamIT projects of MSUrbanSTEM fellows: *Pamela, Andrew,* and *Doris*—all K-12 science teachers in the Chicago public school system. But, before we introduce the three fellows and their work, let us throw some light on the DreamIT project.

What is DreamIT? Each of the MSUrbanSTEM fellows completed a DreamIT project, which was the primary teaching project they did throughout their one-year fellowship tenure; starting in the summer of 2014 and culminating at the end of the following school year (summer 2015). The MSUrbanSTEM instructors asked the fellows to develop a DreamIT project proposal and implementation plan in the summer prior to the school year. Each DreamIT project was expected to be rooted in the basic teaching and learning philosophies endorsed by the MSUrbanSTEM program, such as repurposing everyday technology (e.g., cell phone camera) into teacher pedagogical practices, accepting failure in the teaching process, and learning by doing, to name a few, with necessary flexibility for practical adaptation and implementation.

The DreamIT projects required fellows to go beyond developing and implementing an everyday teaching plan. When creating and prior to implementation of their DreamIT projects, fellows had to share their project ideas with a student focus group and a teacher (colleague) focus group in their schools, and then use their feedback to improve their project. Fellows were then required to provide continuous reports on their progress, successes, and failures concerning their DreamIT projects to the instructors. At the end of the fellowship year, a small team of researchers downloaded every detail of these projects from the fellows' websites. These reports were qualitatively analyzed for emerging themes and patterns that underscore the scientific pedagogies of these fellows. Let us now look at each of these fellows in detail.

Andrew. Andrew is both a high school and college level chemistry teacher. Andrew's DreamIT project was centered on increasing disciplinary understanding and engagement. As a chemistry teacher, he understood that his biggest challenge was capturing the abstract nature of his discipline and making it relevant for his students so they could find creative ways of solving problems in the world. He defined the goal his DreamIT project as "for all students to be able to interpret and synthesize visual models of chemical phenomena, utilizing multiple tools and methods." The ability to interpret and understand modeling was the key idea that Andrew subscribed to for his DreamIT project. Being able to accept models as representations of different chemical phenomena, in various forms is a major step toward becoming a better scientist, according to Andrew. Additionally, he stated that this ability to interpret modeling would help his students to develop creative expression and communication skills.

Andrew wanted his students to become familiar with inquiry methods and expected them to apply their inquiry methods to everyday questions in testable forms such as, "Why do we add salt to roads when it snows in the winter?" Such an inquiry was used to interpret models to explain and support scientific claims. But, soon Andrew realized that students struggled with creating models that displayed chemical phenomena on the atomic level. He referenced several readings from his summer face-to-face session with MSUrbanSTEM and found student misconceptions to be the biggest challenge he and his students face. He decided to implement an iterative attempt at understanding student understanding, where he would try to check what and how well his students know the concepts of chemistry. He provided his students with "multiple opportunities to display acceptable evidence of understanding throughout each unit of study."

We started to identify a pattern in what Andrew cared about. While his interest revolved around creating a strong disciplinary understanding of chemistry, he was aware that it was more complicated than what could be defined under one overarching theme. Early on in summer itself, Andrew used Lee Shulman's ideas and identified that he was dealing with learning pathologies of amnesia, inertia and fantasia, which helped him break down what he had been calling "misconceptions." In his summer reflection he noted:

> I feel that both amnesia and inertia are products of the modern educational system that tells students to memorize facts and move on and can both be treated with more emphasis on applied science techniques and student reflection. Fantasia, where student misconceptions persist even after learning and reflecting on new information, seems to be the most serious and terrifying pedopathology. I will have to be careful to immunize as many of my students as possible from this terrible disease.

One the one hand, Andrew used Shulman's learning pathologies to tackle the discipline-related problems in his classroom. He started to design multiple ways for his students to "get from point A to B" in their understanding of the concepts. On the other hand, he also identified that it was important for these concepts to "stick" with his students. In his own words, he figured out a way to make his lessons stick:

> If I have learned anything in my first six years of teaching high-school chemistry, it is that tapping into student emotion is key to successful teaching. I have worked hard to make students aware that I am there as a support for them, that I demonstrate respect and equity to all and I can balance work and play. What I need to do now is make the actual content, pedagogical and technological knowledge I want them to gain somehow tap into their emotions. I need my lessons to stop being lessons and become stories.

This helped Andrew solve the problem of relevance and answer the one question, he believes, all teachers struggle with the most is: "when are we ever going to need this?" We could highlight that although Andrew's focus was on teaching his students the core disciplines of science, he found that affective motivation was critical for long-term engagement. Like Doris and Pamela, who we will talk about next, Andrew had also used TPACK as a lens throughout his teaching, repurposing technology to find the "sweet spot" between technology, pedagogy, and content. We will learn more about this aspect through the experiences of our other two fellows.

Doris. Doris is a former geologist but is currently a middle school mathematics teacher. Her former career and exerptise influenced her science oriented DreamIT project. During her year with MSUrbanSTEM, Doris had been involved in developing Engineering a Healthier Lifestyle, a module for grades 5-8 that focuses on using personal and public health issues to engage students in inquiry-based and project-based learning with the motive to enhance student ability to make informed decisions and increase their curiosity towards the world. In order to achieve this goal, she embraced the TPACK framework and integrated it in her approach to teaching and learning. Through her DreamIT big idea, Doris helped her students realize that each individual is an intricate part of the myriad interdependent relationships that exist in dynamic complexity around us. She titled her big idea, "Web of interdependent relationships," and explicated that identifying this aspect about the ecosystem we live in would make students cognizant of their "decisions and actions" as having a ripple effect on things or people.

She posited that, to teach students effectively, teachers need to reflect on their own learning and experience so as to capitalize on students existing knowledge and help them create their own meaning. This idea is pertinent in the accounts of her work where she articulated, "…if I truly want my students to learn, I need to build on what they already know so I can take them to what I think they need to know or be able to do." However, Doris added that, in the past years, when she changed her focus from math to science, she had been facing the challenge of assessing the varying range of students' prior knowledge in her classroom. She felt the need to bridge the gap between what students know and was being taught to them through the classroom discourse. This line of thought, according to her, originated from Shulman's (1999) notion of learners making meaning of "new ideas" that they are presented with by connecting them to their existing knowledge or conception. According to Doris, Shulman's ideas resonates with that of Ausubel's position on, learners' prior knowledge being a key factor impacting their learning. These ideas were also discussed during the MSUrbanSTEM summer reading discussions.

Like Andrew, Doris also integrated Shulman's conception of "fantasia" where learners are under the wrong impression of understanding concepts and their "misconceptions" are prominently embedded in their mind. This propelled her to use a phenomenon familiar to her 6th grade students, who—even after learning how seasons occur—still held onto their fantasia (misconceptions) that the seasons are caused by the distance between the sun and the earth. While dealing with her students' misconceptions, Doris posed an important question, "how does a science teacher go about teaching the competencies for disciplinary thinking hoping that student learning does not turn into amnesia, inertia, and most definitely not fantasia?" This question followed an array of questions from her containing *ifs* and *hows* on teaching students the skill of managing transdisciplinary skills as they sift through the large amount of digitized information available to them and still be able to "synthesize" that information meaningfully. Like Kevin, Doris was also struggling with making her content relevant to her students, and he was starting to find her solution under a transdisciplinary approach.

As Doris' challenges got more real to her, during the implementation phase, Doris had to modify her DreamIT plan to accommodate for the changes recommended by her colleagues and students. Similar to what Andrew had experienced in his class, she realized it was important for him to move from a "traditional pedagogy for teaching science" and first uncover student misconceptions for them to learn concepts profoundly. Hence, it then became important for her to expose students to enriching academic content, teach them to work collaboratively, and "engage in academic discourse." According to her, unless this is done, students will have a difficult time perceiving the transdisciplinary application of knowledge acquired and, therefore, its relevance.

Having identified with the problem of misconceptions, engagement, and relevance, Doris adapted a threefold solution. She used the C-Success (Create Simple yet Unexpected Concrete Credible Emotional Stories Stick) framework to introduce her big idea of "web of interdependent relationships and systems" in her classroom. She helped her students conceptualize themselves as being a part of an interdependent world by showing them Sir Martin Rees' Ted Talk (where he urged humanist action to prevent dark consequences from scientific and technological development). Further, she introduced "World of Wonder (WoW) mini-projects" as an initiative to build on student *interests, curiosity, and a natural sense of wonder* towards the world, and strengthen their research skills. For this mini project, each student identified a question that s/he was curious about and presented her/his research process that comprised of the elements Doris had designed and introduced. Finally, to tie her project to the everyday practical expectations, she used the Next Generation Science Standards/Common Core State Standards to design rubrics for easy assessment for her students. The rubrics were articulated clearly and contained student responses depicting their different levels of understanding. She also used "surveys, interactive science notebooks, exit slips" and summative assessments as evidence of students learning and ongoing understanding.

As we can see, like all teaching, Doris' experience with her DreamIT implementation was messy and riddled with challenges. Despite those challenges, shed use these as examples of what problem solving looks like in the real world and she built on it to continually better her pedagogies. We learned from Doris that, like Andrew, her problems were centered on misconceptions and she too found her solutions for engagement and relevance through affective motivations. But, we also learned that Doris found transdisciplinary skills and knowledge to be integral to making content relevant for her students. In our third fellow, Pamela's, story, we will see that how, in science, disciplinary understanding and affective motivation also need a third element—social justice.

Pamela. Pamela is a middle school science and English language arts teacher. At first, a STEM fellow teaching two disciplines that are often perceived as segregated subjects may seem unusual. But, the ability to integrate two seemingly contrary subjects within the classroom speaks directly to her open mindset when approaching education and creating pedagogy. Pamela's DreamIT project also reflects her vision of transdisciplinary integration in the classroom by merging language arts and science. But, the content of her project was not limited to those two subjects, and also included topics like social justice, debate, politics, and technology, illustrating the creative and open mindset that echoed her own personality. Pamela's DreamIT project goals were:

> For students to obtain, evaluate, and communicate environmental issues affecting our community while developing skills of an activist and a global citizen. The big idea is for students to recognize is the fact that they are change agents in the community and their activism will support future generations.

Pamela wanted her students to feel empowered in being change agents to help clean, protect, and save the planet. What makes this project interesting is that she identified two primary approaches to reach her goal. She implemented a *social justice* student development element coupled with *an understanding of scientific discipline* to learn about the environment, pollution, and the ecosystem. Using this, she required her students to investigate how politics, economics, identity, and culture each influence an individual's actions and choices in efforts to develop their own communities. This gave her students background information concerning how and why their communities look and behave in the ways they do, and helped them better understand what they are capable of doing in order to change or impact their communities.

To address one of the most important factors, when Pamela created her DreamIT project, she had her students do their DreamIT projects on their home community of South Deering in south Chicago, so they could directly relate to and have a real understanding of the environment that they were *exploring*. Pamela followed John Dewey's teaching philosophy of meeting the students' where they are by appealing to the background knowledge of what the students are bringing to the classroom. But, she noticed that this project was not as easy as she had expected it to be. The students had not been previously primed to think about their community outside of the neighborhood's physical traits. Her students first responses when prompted to discuss their communities were, "There are crack heads and gangs" in their neighborhood, and "Trumball park is in our community." This showed that despite Pamela's attempt to create a project that the students could relate to, they still lacked the necessary critical lens to complete the project. Pamela, however, dealt with that issue by inspiring critique with methods learned from the MSUrbanSTEM program. Pamela used this as an opportunity to facilitate further inquiry and made her students *create* videos (called Explain IT) to explain the problem at hand. The purpose of this was to activate her students' prior knowledge and generate new questions; which she could do by easily finding an accessible balance between her content, pedagogy, and technology available to her students. This led the students to think of questions like, "Did closing the steel mills help pollution go down?" or "Is petroleum coke put in other environments? If not, why is it put in ours?"

Building off her breakthrough, despite early hiccups, Pamela required her students to form groups, collaborate, and create action plans to address societal improvement, while using science as their support and validation. Using the understanding of science for the purpose of social justice, not only did this project empower her students, but also endorsed the power of teamwork while allowing them to learn about their communities. Students gained an understanding of science as a discipline to write about and campaign for the importance of fixing their communities. During the process of this yearlong project, knowledge of environmental science gave the students the tools to understand why their communities were potentially threatened. However, writing and *sharing* were equally important parts of the DreamIT project because this built student writing, debating, and communication skills that were the language arts portion of the project. Pamela's DreamIT project gave students a goal in both her subjects: science and language arts, blurring the boundaries between the two disciplines. The student felt purpose to protect and save their communities using science and writing, as opposed to just doing science and writing for school sake.

In review of the entire project, the first quarter of Pamela's school year was spent discussing power and activism through readings about Malala Yousafzai. Next, students researched the community to build knowledge and learn about its assets. They then generated a list of topics that they wanted to explore with small groups including, history of industrialization in the southeast side of Chicago, petroleum coke, and ecological concerns, to name a few. As the year progressed, students began to work with groups several times a week in order to do more thorough research to answer their burning questions. Pamela reported her students as being "extremely engaged, motivated, and extended their learning beyond the classroom." The students even requested that they report their progress to the community by building a website. After a class vote, they created a website and Twitter profile to do just that.

The students' desire to create the website and Twitter profile speaks powerfully to the investment that the students had in their work, yet it is also important to note that those two items were not the only way that technology was used in Pamela's class. Throughout the DreamIT project, Pamela was purposeful in using technology and developing her students so that they could effectively be activists for this cause. She stated that,

> Some instructional strategies to develop communication skills include: think-pair-share, conversation roundtable, debates, cooperative learning, and community service. To foster access to Internet and iPad apps such as, EduCreations, iMovie, iMotion HD, Twitter, and KidBlog will be suited for solving our problem.

There are some common themes that we can identify as emerging from the three cases we have discussed. We can see that, like Andrew and Doris, Pamela also found discipline to be important. But, she gave preference to using science as a tool to solve real world problems over understanding science for science's sake. In other words, she approached the problem of relevance and engagement through a more Deweyan method, by allowing her students to learn by doing. Let us look at these common themes in more detail now.

Cross-cutting Themes

Science as a discipline. The role of understanding the scientific discipline is apparent in all the three cases. We can see that our three teachers felt it critical for their students to know and understand science as a discipline and use that as a lens to solve problems in the world. While Andrew and Doris were more concerned with this aspect, they focused on solving student misconceptions in parallel with addressing its relevancy to them. Pamela, as we saw, approached it from somewhat opposite direction. She focused on making science relevant to her students by giving them real world problems to solve. Her students soon realized that they needed to understand science to be able to solve these problems in the real world. If they know science better, they will be able to solve problems better. Pamela gave them a reason to learn science that was tangible to them.

Making science relevant. Pamela stated in her final reflection that, "fostering a creative mindset, integrating disciplinary thinking, tackling misconceptions, and repurposing technology for education are critical ways to encourage student engagement and achievement in schools." This was similar to Andrew and Doris' approach to creating an engaging setting for their students to learn science that was relevant to them. Pamela was creative in endorsing a science project that had a direct connecting purpose, which the students could relate to because it affected their community. She integrated several disciplines in order to execute her DreamIT project, including science, language arts, and social justice. Pamela encouraged her students to tackle their misconception that their communities were environmentally safe and helped them raise awareness. Andrew, on the other hand, tackled the misconception problem first. He found it to be at the root of all other problems. We can argue that Andrew felt it would be harder for his students to solve problems if they did not know the concepts. But, he too took a hands-on approach to help his students learn the abstract concepts in chemistry. He used modeling as a transdisciplinary habit of mind to learn by doing, similar to what Pamela was doing, only in the real world.

Doris, somewhat in tandem with Pamela and Andrew, had identified the importance of a transdisciplinary approach and used that to create problem-solving opportunities within her classroom to tackle with misconceptions. Using the cases of these three, we have three different approaches of balancing between relevance and disciplinary understanding to engage students in a science classroom.

Emotional engagement. We found in all three cases that fellows emphasized the role of emotions to engage students. Andrew underscored the importance of making lessons more like stories that his students remember and are engaged with for a longer period. Doris found that providing students with an opportunity to explore their curiosity engaged them with her content. Pamela found that students were more engaged when they cared about what they were doing. In all three cases, our fellows remind us that emotional involvement with content helped student engagement.

Technology for assistance. It is apparent from the use of various technologies and pedagogies that the three fellows were intent on using technologies as a pathway for student learning, in combination with appropriate pedagogies for given content; and this balance of technological, pedagogical, content knowledge (TPACK) is a major theme from the MSUrbanSTEM program. Students were provided with opportunities to explore, create, and share their experiences of doing science through social media, their local student communities, or web. Though it is important to highlight that students shared their research and their conclusions of their environment through social media outlets, it is even more important to underscore that they did so with the intent to make change in their communities.

DISCUSSION

The work and pedagogies of the three science educator fellows that we shared in this article have several things in common that generally aligned with the MSUrbanSTEM pedagogies mentioned in the introduction section. These three fellows had different specific goals but had similar ideas concerning their broader pedagogy, and desire to offer their students an innovative way to become more effective learners of science and the world around them.

We found some components of our three-part holistic pedagogical approach transfer on to our fellows more than the others. As a reminder, the three components that we emphasized in our pedagogy are (a) practices that embrace the scientific discipline as a lens of looking at the world, (b) a learning setting that encourages aesthetic experiences like wonder and curiosity, and (c) science as a tool to solve societal problems and promote equality. We found that our fellows were able to create a reimagined version of our pedagogy. In other words, our fellows appeared to have prepared new, customized recipes based on the ingredients that we offered. While in some cases fellows used more of the social justice element, and in others, fellows combined these approaches in unique ways. However, in all cases, we found that the new pedagogical stances were informed heavily by their individual contexts. For instance, where Pamela's class needed a more social motivation to study science, Doris drove her students by curiosity.

In sum, the MSUrbanSTEM pedagogical approaches to science education can be treated as a recommendation to science teaching that teachers can modify based on their needs and context. This suggests that how we should be looking at scientific literacy is very dynamic and deictic. Although the rules of the trade still need to be defined by the agreed-upon scientific methodology, the motivation to do science may vary depending on students' personal background, knowledge, and communities. Every student can have a reason to love and pursue science. Every student has a potential to do science. It is only a matter of the right motivations.

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