Handbook of Research on Teacher Education and Professional Development

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Chapter 32
A New Understanding of our Confusion:
Insights from a Year-Long STEM Fellowship Program

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ABSTRACT

This chapter discusses the philosophies and practices that drive the MSUrbanSTEM Leadership & Teaching Fellowship Program. This multi-year project offers a professional development program to a selected cohort of K-12 STEM educators from Chicago Public Schools, one of the largest urban districts in the U.S. This chapter provides a holistic view of the program, shares the fellow selection process, and focuses on the strategically developed curriculum and the theoretical bases for the chosen pedagogy. This allows the authors to explore the psychological and philosophical principles, based on the idea of accepting confusion, and embracing failure in beliefs about pedagogy and STEM instruction, which are used to expand the skills and abilities of these selected urban school teachers. Finally, we provide some initial findings about the teachers' growth and development both in their efficacy and leadership abilities.

πόλλ' οἶδ' ἀλώπηξ, ἀλλ' ἐχῖνος ἓν μέγα
(A fox knows many things, but a hedgehog one important thing)
— Archilochus

He is in a new confusion of his understanding;
I am in a new understanding of my confusion
— Robert Graves, "In broken Images"

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'UNDERSTANDING' THE PROGRAM

How one frames a complex issue or problem has a significant influence on how they seek to understand or resolve it. Framing helps people interpret the world around them and helps them communicate these interpretations and understandings to others. It helps individuals to organize complex phenomena in somewhat coherent, understandable categories, helping persons to separate relevant aspects of a given phenomenon from irrelevant. Framing helps provide meaning.

The importance of framing becomes even more significant when looking at teacher education and teacher professional development. One approach to teacher professional development (PD) (which can be called the hedgehog approach) emphasizes the value of clarity and order; seeking to organize activities and plans. This approach emphasizes that teachers in training should know what teacher educators value. This hedgehog approach is clear in idea and is driven by theory, which becomes a lens for interpreting facts, and is ready for application. For instance, in the case of PD for science educators, the hedgehog approach may offer a singular focus on removing student misconceptions, or on modeling as being a critical component of learning science.

A contrasting frame towards teacher PD (which can be called the approach of the fox) assumes messiness, focuses on multiple theoretical perspectives, is tentative in application, comes with a belief in deconstructing and questioning what one thinks is fact, and is driven more by bottom-up notions of the richness of practice and the world within which it functions. This chapter is an attempt to describe a project that utilizes such a frame.

These contrasting frames (that of the fox or the hedgehog) can lead to different forms of PD with different goals and expectations, that vary from traditional formats of PD and hence different outcomes. The authors attempt to capture these contrasts within the title of this piece, an excerpt from Robert Graves' poem "In Broken Images," as well as with the quote from Archilochus with which the authors begin the article. The authors deliberately adopt the culminating lines of Robert Graves' poem as the title of the chapter, since this poem became representative of what the researchers were engaged in as a part of a year-long professional development program designed to help teachers grow their pedagogical and leadership skills to facilitate innovative STEM (Science, Technology, Engineering & Mathematics) instruction. To be clear, this idea (of getting a better understanding of our confusion) was not something that was imposed on the teachers who were part of the program, but, rather, was an emergent idea that grew organically as the participating teachers and program instructors worked together over a year.

Emphasizing the inherent messiness in teaching and professional development is not to suggest that the designers of the program were not deliberate or thoughtful in their approach, but rather, that in their planning they were sensitive to the disturbances and disruptions that could open up spaces for conversation and learning. In some ways, the poem argues that the ultimate goal that educators can aspire to, over time, when engaged with the wicked problems of teaching and learning, is "a new understanding of our confusion." This is not a pessimistic goal but rather a realistic one, respecting both the complexity of the task that this program is facing, and respectful of the ongoing effort to understand the complexity.

The program, described in great detail below, aimed to embrace an attitude of questioning and wonder, where failure and confusion were not only accepted, but expected; and where technology was not perceived as a solution, but rather as a context and tool for inquiry. In brief, the goal of this PD program was not to lead fellow teachers into a single solution, (in Robert Grave's words, to be "quick and dull" in "clear images,"), but rather to embrace ambiguity as well as the inherent messiness of the process and through that, accept the contingent and temporary nature of any understanding that is reached at

any given moment. It was about becoming "sharp, mistrusting our broken images." This chapter is an attempt to capture some of the richness and messiness of the one year of this three-year program.

Structure of the Chapter

More concretely, this chapter describes the Michigan State University Wipro UrbanSTEM & Leadership Teaching Fellowship (LTF) program (the MSUrbanSTEM project) as an innovative teacher PD program that uses iterative and design-based thinking along with the integration of technology into pedagogy and classroom practices. This program seeks to support a selected cohort of teachers, to develop strong STEM disciplinary and teaching skills; in developing their capacity to design transformative and innovative, multimodal instructional experiences; through enacting an active learning community of practice, all as means of enhancing the quality of instruction in the STEM disciplines. While describing the detailed pedagogy and curriculum that this program uses, the authors are purposeful in continuously framing it within a broader Deweyan approach of designing an experience that respects the knowledge of practice that the teachers came in with. This MSUrbanSTEM program also continuously considers the theme of wonder in its curriculum, asking that the fellows think beyond what is placed before them, even while respecting the deep knowledge of practice that the fellows bring to the program.

In order to provide a holistic view of this program, the authors will briefly describe the background and foundation of the program highlighting the fellow selection process, with a specific focus on the theoretical bases for the pedagogy used. Then the authors present the program's instructional approach, including the format and structure of the program, the pedagogical practices followed. Finally, the authors conclude by providing some initial findings about the teachers' perceptions of growth and development in various areas, and by sharing reflections that could be of interest in implementing a similar program.

THE CONTEXT OF THE MSURBANSTEM PROJECT

The MSUrbanSTEM program was created as a partnership between a private IT company - Wipro, a public university - Michigan State University (MSU), and the third largest public school district in the country - Chicago Public Schools (CPS), with some additional support provided by Microsoft. It is a multi-year project that focuses on a group of selected K-12 STEM educators who currently work in the Chicago Public Schools. The MSUrbanSTEM program was the result of years of ongoing discussion and relationship building between the global information technology company Wipro and MSU. Wipro as a company has a strong history of commitment to education, primarily in India, and was seeking to expand its work into the USA. MSU, with its land-grant tradition and commitment to both public schools and urban education, served as a good fit for this partnership. CPS emerged as a key partner in this process, given MSU's ongoing relationship with the school district. This partnership emerged through a range of interaction between these institutions, which helped develop understanding and trust while aligning shared interests and values. In addition, Microsoft, a late addition to the project, provided key technological support to the program through the donation of tablet devices to all the fellows.

CPS, like many large urban districts, is presented with numerous challenges when offering its students quality-learning opportunities. Some of these challenges exist outside the classroom, such as poverty or socio-political forces, while other challenges exist within the four walls of a school, including behavior management, poor teacher preparation, and underfunded teacher training. Ultimately, these factors

combine into a heavy weight bearing on under-represented students' shoulders, preventing them from learning opportunity and success beyond K-12 education. This is especially true when engaging students in STEM-related instruction where cultural, racial, economic, and gender divides are ever-present (DePass and Chubin, 2014).

The MSUrbanSTEM program seeks to respond to these challenges by working with CPS to identify diligent teachers working in these under-served schools, and to work with them over a year to develop their capacities as teachers as well as teacher-leaders.

Identifying the MSUrbanSTEM Fellows

CPS worked alongside designers, instructors, and researchers at MSU's College of Education to recruit K-12 teachers and administrators to apply for the program. In order to be eligible to participate in the fellowship, applicants were required to possess a current Professional Educator License with the Science and/or Mathematics endorsement. Additionally, applicants needed to have 3 full years of Licensed/Certified classroom teaching experience. Applicants were also asked to submit two professional letters of recommendation and a short essay that spoke succinctly to their desire to commit to this program. The directions for the essay read:

The essay can be formatted any way you creatively desire. Through your essay, please address the following questions: What innovative practices are you currently implementing in your STEM classroom? How will this opportunity connect to your classroom? What are your goals for participation? What are your expectations for participation in the program? How will your participation in this program help Chicago Public Schools in the short and long term?

The MSU selection committee (consisting of faculty and instructors at MSU) looked specifically for people who answered in a way that was aligned with the program goals, with a particular emphasis on leadership, a willingness to learn and share, and the potential for long-term impact of their work in their schools and district. In the selection process, the MSUrbanSTEM team also focused on the letters of recommendations submitted, and the applicants' ability to think in an innovative and creative manner about teaching and learning in the STEM disciplines.

The year-one cohort, the focus of this chapter, consisted of 25 STEM educators selected from a pool of 148 completed applications. The second cohort expanded to 49 new fellows and with the goal of accepting 50 more teachers in the next cohort. Each cohort experiences one full year of professional development starting in summer, while completing three Master of Arts in Educational Technology courses, with an emphasis on STEM learning and leadership. Upon successful completion, the fellows earn a graduate certificate in STEM and Leadership from Michigan State University.

THEORETICAL APPROACH TO CURRICULUM AND DESIGN

The design of the MSUrbanSTEM fellows' education curriculum is the most important and innovative aspect of the MSUrbanSTEM program and is based around the power of experience (Dewey, 1938), the knowledge of practice (Schön, 1983) and the understanding of best practices related to professional development for teachers in general, as well as those teaching in STEM disciplines and urban environ-

ments. Dewey was concerned not only with subject matter, but with subject matter as it relates to the student in a growing experience (Dewey, 1902). This program pursues this goal through the design of an innovative experience, for the fellows, which emphasizes a deep relationship with content, pedagogy, and technology (TPACK) and encouraging the idea of deep thought and wonder. The MSUrbanSTEM program does this through a combination of face-to-face and online work, starting with an immersive two-week face-to-face meeting in summer and continuing predominantly online (with four full day face-to-face meetings on Saturdays) through the fall and spring semesters. This structure allows the fellowship program to build relationships across and between the fellows and this structure allows the MSUrbanSTEM instructors to continue working with the fellows as they are back in school implementing their projects in their local contexts. It also aligns with the ideas expressed by Capraro et. al (2016) related to sustaining professional development initiatives in STEM for urban teachers. Some features that teachers felt contributed to success in their classrooms included the hands-on nature of the PD, the ability to readily turn their ideas into curriculum use, [and] the individual feedback they received from the PD trainers (p. 191). Kelley and Williams (2013) research around professional development of teachers supports these ideas and adds, "Teacher preparation and their continuing professional development need to incorporate time for teachers to learn content and to apply their new understandings into curricular plans. Teachers need to be active participants in their learning as they develop knowledge, skills, and dispositions related to students, learning, curriculum, pedagogy, and assessment" (p. 4).

John Dewey's concept of an educative experience is perhaps the most important part of his writings on education and learning. Experience, according to Dewey, is the essence of all learning. He described the example of using a map as a representative of learning. A map of land is an arranged view of previous experiences, which serves as a guide for future experiences. However, a map is not the same as experiencing the navigation through a body of land on your own. Though the map may be extremely accurate, it cannot take the place of the journey and, therefore, is limited in its ability to teach the viewer. This metaphor by Dewey serves as an effective illustration for understanding what experience means to the MSUrbanSTEM approach to the learning process.

In his paper, *Child and the Curriculum (1902)*, Dewey titles the paper with the two items that must come together through experience, in order for learning to take place. Experience alone is not simply education since not all experiences are necessarily educative in nature. To Dewey, the learner must immerse themselves with the curriculum, through real life experiences, in order to learn. "Subject matter, like students, is the changing history of human inquiry and invention. Disciplines and school subjects represent experiences of wonder, discovery, conjecture, and assertion conducted by human beings in their own quests for certainty and understanding" (Shulman & Quinlan, 1996; p. 402). This idea of not being limited to specific content but rather to alter and humanize the content to be taught so that students can connect to it via their own past experiences, and prior knowledge is key to understanding the design of the MSUrbanSTEM program. Additionally, the fellowship program brings this mentality to professional development activities treating the fellows as professionals who are continually seeking to grow and develop their knowledge even while recognizing that this requires an openness of spirit, a sense of vulnerability, and a tolerance of ambiguity as they move out of their comfort zones. The MSUrbanSTEM program recognizes that as learners, teachers are also creators and designers of educative experiences for their students. This approach is consistent with Lieberman and Pointer-Mace's (2009), idea that, "when professional development opportunities start with other people's ideas first, they deny what teachers know. Starting with teachers' practice invites them into the conversation and opens them up to critique, to learning and to expanding their repertoire." Desimone, (2009) adds, "Opportunities for teachers to

engage in active learning are also related to the effectiveness of professional development (Garet et al., 2001; Loucks-Horsley et al., 1998). Active learning, as opposed to passive learning typically characterized by listening to a lecture, can take a number of forms, including observing expert teachers or being observed, followed by interactive feedback and discussion; reviewing student work in the topic areas being covered; and leading discussions (Banilower & Shimkus, 2004; Borko, 2004; Carey & Frechtling, 1997; DarlingHammond, 1997; Lieberman, 1996)." The MSUrbanSTEM program, seeks to develop active learning approaches using all of the above strategies and more (described in greater detail below).

Enter Technology

Technology integration in the classroom is an important goal of the MSUrbanSTEM program. It is also an important issue in education (U.S. Department of Education, 2010), especially given the fundamental importance ascribed to developing technology and information literacy in students by 21st Century Frameworks (Kereluik et al. 2013; Partnership for 21st Century Skills, 2007). Technology integration and developing information literacy skills in students must begin by developing teachers' Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006). This development however is an intricate and complex process, evidenced by the fact that most technologies are not designed for educational purposes (Koehler & Mishra, 2008). Teachers must adopt the role of designers to creatively re-purpose and re-design technology into educational technology to meet their specific classroom needs. Most importantly, TPACK promotes the creative and imaginative integration of technology into the classroom, and in the design of the year-long fellowship, partners with Dewey's concept of educative experience to create a year-long practice that not only changes fellows' approach to teaching, but also increases teacher abilities and skills within and beyond the classroom. The following section will highlight how the MSUrbanSTEM program integrates a range of ideas (including Dewey's idea of educative experience, TPACK, an encouragement of wonder, and an embracing of confusion and ambiguity) in their face-to-face summer program, and how they stimulate the fellows to do the same during the school year.

STRUCTURE AND CURRICULUM

The MSUrbanSTEM project is structured into three separate phases: summer, fall, and spring, that correspond to three graduate level courses leading to a graduate certificate. Each phase has a specific purpose. The five-week summer session is further broken down into two phases: an eleven-day face-to-face session followed by 3 weeks online. The summer face-to-face sessions, which go all day for 11 days over two weeks (excluding weekends), lays the foundation for building a sustainable learning community with a daily structure created to disrupt what the fellows had come to know as "adult learning," and to initiate the key concepts of wonder, and tolerance of ambiguity, even while building on their existing skills, knowledge and experience. During the fall and spring semesters most interaction with the fellows is online, with two day-long face-to-face sessions bookending each semester. The fall semester follows the summer with a focus on applying key program themes to fellows' daily practices, emphasizing the implementation of their individual teaching projects. Finally, the spring semester allows the fellows to reflect on their projects, and focus on leadership and opportunities to share their teaching experiences (see Table 1).

Table 1. Calendar structure of MSUrbanSTEM program

	Face to Face	Online	Theme	Key Concepts
Summer	11 days	3 weeks	Explore	Wonder & Confusion
Fall	2 days	15 weeks	Create	Individual Teaching Projects
Spring	2 days	15 weeks	Share	Reflection & Leadership

Through the curriculum, the MSUrbanSTEM instructors seek to explore a variety of topics and issues related to teaching and learning in the STEM disciplines and the potential of using educational technology to transform learning. This exploration included incorporating ideas related to the value of disciplinary learning, challenging misconceptions that people may have, promoting the importance of understanding the aesthetic aspects of teaching and learning, through pushing the fellows to engage in activities that emphasize backward design, performances of understanding, and playing with a range of technologies. In sum, the goal was to encourage transformational thinking amongst the fellows not just about content, or pedagogy or technology but rather all three considered together in an integrated manner. The MSUrbanSTEM team felt that the best way to do this was to provide integrative activities that allowed fellows to engage in structured, yet open-ended (and sometimes even intentionally disruptive) tasks that were purposely designed to challenge the fellows into expanding their zone of proximal development.

Summer: Introducing Confusion with Creative Pedagogies

During the summer face-to-face session, MSUrbanSTEM instructors introduced and encouraged a student-centered working environment. In order to do so, instructors acted in the role of a facilitator as opposed to the "sage on stage." This would include knowledge of activities that require students (fellows) to be active participants in class, influenced by the Deweyan approach, and drawing from what Wright (2011) said:

Working against this shift in role are the expectations of the students, who rely on the teacher to make all the decisions, as well as the pedagogical literature, which is preoccupied with teaching over learning, almost exclusively focusing attention on what the teacher should do. (p. 94)

There were several ways in which creative pedagogies were implemented in the instructional practices with the intent to positively disrupt the learning process for the fellows, to introduce a tolerance of ambiguity, and to encourage student-centered learning. Such practices were supported by an emphasis on wonder, the enactment of improvisation in the classroom, and arts-based learning strategies. The authors describe a few of these strategies below.

A World of Wonder

There are many reasons why STEM education is regarded as being important. Some of the more instrumental reasons have to do with preparing citizens for the jobs of tomorrow as well as maintaining U.S. competitiveness in an increasingly globalized world (Langdon, McKittrick, Beede, Khan, and Doms,

2011). A contrasting approach seeks to go beyond the idea of STEM knowledge as merely a tool that serves humanity, but rather sees the STEM disciplines as being among the greatest achievements of humankind. This perspective seeks to connect learners to the deep sense of "wonder" and curiosity that drives learning in science, mathematics, and engineering. Such a perspective builds on Dewey's (1980) sophisticated understanding of the role of aesthetics in learning. In particular, these approaches emphasize the beauty of STEM ideas, and seek to integrate the thoughtful with the visceral power of scientific ideas.

The MSUrbanSTEM program applied a range of strategies to instantiate such ideas of aesthetics and wonder into the fellowship. For instance, every day a group of fellows would share, what they called, a WOW (World of Wonder) moment with the class. This could be an everyday observation (about raindrops, or vending machines, or some mathematical pattern) that puzzled or stoked their curiosity. They would then have to follow up with some research and investigation to better understand these phenomena, and then share it with the class. The goal behind this activity was to stimulate fellows to view and question the world around them with a critical STEM lens, instilling a sense of wonder within the fellows. The philosophy is that if teachers do not share this feeling of wonder, it is difficult for teachers to authentically convey the message to their students. As the instructors described (and enacted), good teachers see their disciplines everywhere in the world around them. These WOW moments were the first activity of each day as the fellows shared their curiosities and investigations from daily life. By the fall semester, when the fellows went back to school, they were having their students share their stories of wonder. They created and curated "Walls of Wonder" where students could go and stick up stories of things that made them wonder. In fact, when the fellows interviewed authors for a book review (described below), they often asked these authors what made them wonder about the world. In some sense this emphasis on wonder came to be a powerful lens for thinking about the program throughout the year.

Improvisation in the Classroom

At the midway point of the summer session, MSUrbanSTEM invited Second City, a world-renowned acting troupe, to introduce the fellows to improvisational teaching methods. This method was developed through a collaboration of educators and actors with the idea that "the ensemble creates the experience, moment to moment, in an ongoing process of discovery" (McKnight and Scruggs, 2006, p. 7). Educators who use improvisational methods in their teaching classes recognize that they are teaching in increasingly diverse classrooms where it is critical for students to have "an active and engaged voice" (p.17). Teaching in this sense is an intelligent combination of planning and improvisation, where the teacher is both designer and performer, structured and idea-driven even while open to the contingent opportunities that emerge during a teaching session.

The MSUrbanSTEM instructors prepared their fellows for a 3-hour improvisational session by having them read *Creative Teaching: Collaborative Discussion as Disciplined Improvisation*, by R. Keith Sawyer (2004) which mentioned that "improvisation highlights the collaborative and emergent nature of effective classroom practice, helps the MSUrbanSTEM instructors to understand how curriculum materials relate to classroom practice, and shows why teaching is a creative art" (p. 12). Fellows were able to see how improvisation could encourage creativity in students. The fellows were asked to write summer reflections and one fellow named Lillian, made this note in her reflection paper:

I must admit that I initially balked at the idea and thought it was a waste of time. I thought the group was running out of things to teach and was using Second City as a fluff-filler for time. However, spending

half the day with Second City and learning improvisational exercises made me see how this can be used to encourage creativity in students. Not only were we being creative but also we were having tons of fun in the process! My thinking of "fluff filler" was challenged and made me see the usefulness in teaching!

As a result, Lillian began to consider how to incorporate improvisation into her teaching practice. Improvisation demands creativity and a tolerance of ambiguity—both attributes that MSUrbanSTEM believes are critical for teachers as they deal with the complexities of teaching and learning.

Quick Fires

Quick Fire challenges, originally developed by Leigh Graves Wolf in 2006, were inspired by the reality TV show, Top Chef, where the final challenge in each episode requires chefs to cook a dish with certain constraints (i.e. ingredients, themes) within a tight time frame. In a Quick Fire challenge, the fellows are given a limited set of tools, tight constraints of time and resources, and a difficult, open-ended goal. For instance, fellows would be asked to create, in just 45 minutes, a stop motion animation to explain a scientific misconception; or create, in 30 minutes, a photographic illusion to reflect some leadership tensions that had been previously discussed. These challenges were often seen by fellows as being "scary" because of the short amount of time allotted for the assignments but over time the fellows learned to collaborate and work together as a team, plan, delegate, and create the artifacts required. Over the first two weeks the fellows completed a range of challenges, which got increasingly difficult and constrained over time. In the first few Quick Fires, the goal was merely to complete the submission, but as time went on, and the fellows got more comfortable of these tight deadlines, and the frenzy of activity became exciting for fellows in pursuit of their goals. Additionally, the quality of work started to improve and fellows often went above and beyond meeting the initial challenges, to accomplish what was labeled as the "extra spicy" (i.e. optional items that were offered in addition to the original goal that would allow the fellows to enhance the final product). What started with intentional confusion for the fellows in the early days of introducing the Quick Fire, gradually turned into an understanding of this confusion on their part. The confusion or ambiguity, as in every teaching situation, never really goes away. It is not a problem to be solved but rather a dilemma that needs to be resolved. Over time, the fellows got more comfortable, recognizing the perpetual existence of these dilemmas, tensions and constraints (such as time or expertise), learned to embrace it, and in fact, to see it as a spring-board to greater creative freedom.

The Deweyan approach to learning is also highlighted by the activities that require the fellows and instructors to get out of their seats and think on their feet. The Quick Fire challenges and the improvisation are creative ways of using experience to not just learn or describe some ideas in STEM, but rather to be able to instantiate them in some artifacts, such as short videos that help students understand common misconceptions in science and mathematics, parodies of nursery rhymes that also convey information about subject matter, or creative photography that helps highlight mathematical concepts. This is a powerful coming together of technology, pedagogy, and content— particularly given the limitations of resources and time. Further and more importantly, the MSUrbanSTEM instructors often participated in the challenges as well, thus becoming partners in the process of learning rather than being the "know it all" teacher. The timed Quick Fire activities forced fellows to (relatively) serenely accept completing an educational activity without all of the answers and/or resources at hand. This therefore endorses the mind-frame that it is ok to not have all of the answers and opens the door for more learning. This somewhat unorthodox teaching practice encouraged an ongoing process of discovery and the promotion of

art based learning strategies, admitting that neither the instructors nor the fellows, know everything that there is to know about pedagogy or content. It is indeed a process of becoming comfortable in the "broken images" (to quote Robert Graves again) and that is, more often than not, all educators have to work with.

Fall: Understanding Our Confusion in the Act of Teaching

As the summer session ended and the fall began, the goals of the instructors were to support fellows as they applied ideas from summer into their classroom practice and support their reflective and wonder-driven inquiry of their practice. Binder (2012) shares, "Teachers regularly make detailed inquiries through observations, field notes, collected samples, and "interviews" with students in order to inform their decisions about curriculum implementation" (p. 118). The key assignments for the fall aimed to provide a structured, supportive vehicle to perform action research in their classroom around ideas they believed to be important. Wilson and Peterson (2006) emphasize the importance of inquiry in a teacher's daily practice. Specifically, they note the importance of understanding that their students are as learners and the role of inquiry in resolving questions about their students. Additionally, they explain the importance of constantly engaging in inquiry around content knowledge so that they understand how to best represent knowledge to their students. The sections below describe some of the key projects that the fellows engaged in over the fall and spring semesters.

DreamIT

The DreamIT project was a year-long project that all the fellows were to implement in their classrooms. The five weeks in summer (two weeks face to face and three weeks online) allowed the fellows to set the foundation for this project, which was then instantiated in iterative cycles through the fall and spring. The emphasis in the DreamIT was the authentic implementation of the key ideas that had been discussed over the summer, as appropriate for their specific contexts and classrooms. It is important to emphasize that the main problem of practice that the fellows worked on emerged from their individual local context and their own interests and experience. Each fellow identified a problem related to teaching, learning, or leadership, in STEM, that existed in his/her teaching context that they wanted to explore over the course of the school year. They typically focused on big ideas such as seemingly intractable misconceptions in science and mathematics, students who are unmotivated to learn, pedagogical issues related to specific content, and other problems of practice.

Once the topic was identified, the fellows engaged in a backwards design activity by starting with the *big ideas* in their discipline that they wanted their students to "get" and then worked back from assessments of this knowledge, to what they would need to do to get their learners to succeed. The DreamIT project aims to lead to some sort of transformation or innovative change for teachers, students, and/or the learning environment. In order to implement the change, fellows were asked to get feedback from colleagues and students via the use of focus groups. Then fellows were to explain how the focus groups influenced the implementation of the DreamIT project.

Many of the DreamIT projects that were conducted were innovative and exciting. Pamela, from the 2014 cohort, shared a speech at the end of the year banquet, that highlighted the awesome work of her colleagues and how they met the goals of the MSUrbanSTEM program by integrating technology in the classroom, building content knowledge, collaborating, and embracing wonder. In her speech at the end of program banquet, she beautifully summarized her cohort's experience:

Jenny and Gillian's students learned the beauty of wonders as they tried to make meaning of the world around them by asking questions, investigating the answers, and publishing their findings… Johnson and his students reverse engineered vacuums and programmed robots as they explored the engineering design process… Doris' students participated in the Global Ozone Project in which they collected air quality data that was then shared publicly with scientists and students from 100 schools in 25 countries… and Diana's lesson plans were featured on the American Association of Chemistry Teacher's' website during the month of February.

Pamela's testimonial covers only some of the projects that the fellows did, but is representative of the scope and creativity that the fellows engaged with over the fall and spring semesters.

Book Reviews and Interviews

This aspect of the work done over spring was to maintain continuity with the idea of wonder and aesthetics that had been explored over the summer. Fellows were asked to choose 1 to 3 popular STEM-related books that were written by a living author. As they read the book, they were also asked to compile a list of questions that they might want to ask the book's author, or compile a list of related topics about which they wanted to learn more. Fellows were asked to seek out the contact information for the author (i.e., from the book's publisher, Google, LinkedIn, the author's homepage, the author's agent, etc.), contact the author, and request an interview. Based on fellows' proficiencies with social media, they were able to connect with the authors (as well as other readers of the book) via Twitter. The fellows published the interview on the website as well as their review of the book. Some students expanded on this idea by inviting their students to read the book and help in the development of interview questions. When possible, some authors agreed to Skype with classes and address the questions of the fellows and their students. While some fellows were quickly able to contact the authors of the books they read to secure a book review, others contacted several authors until they connected with an author who was available, during the fall semester, to discuss their book.

Some of the books that were read and authors interviewed, include: "A Planet of Viruses" by Pulitzer Prize winner, Carl Zimmer; "Secrets, Lies, & Algebra" by Wendy Lichtman who has published in many renowned national sources; "The Design of Everyday Things" by Dr. Don Norman, who sits on the editorial board for the encyclopedia Britannica, and "Guitar Zero" by Gary Marcus who was a New York Times editor's choice author. These are only some of the fascinating authors who were interviewed by the fellows, showing a range in STEM interest but all falling under the umbrella of wonder-driven topics.

DreamIT

The year-long DreamIT projects taken on by the MSUrbanSTEM fellows were ambitious, authentic, rich and complex, for exactly these reasons were not easily implemented and completed. The fellows often required more time, more resources than they had planned for, and sometimes the fellows realized that they had misjudged their students' and colleagues' interest in the project itself. Sometimes these factors emerged through the focus group sessions that the fellows conducted with students and/or colleagues. These discussions often pointed to issues and concerns but as often led to valuable feedback from their colleagues and students on how they could improve their projects. The focus group requirement was purposeful in the curriculum, as it supports the collaborative aspect of teaching, and the idea that the

teacher is not always right and that the teacher can grow. Many of the fellows had outstanding DreamIT projects, some had outstanding visions, while others were outstanding in execution, but they all faced challenges and were helped by their colleagues, fellowship cohort members, fellowship instructors, and their students to become more effective educators from their experiences. The MSUrbanSTEM instructors encouraged the importance of constantly engaging in inquiry and action even when challenged by events and unexpected constraints—once again reflecting the ongoing attempt to understand and embrace the complexity and ambiguity inherent in the educational process.

Spring: Teaching as a Public Practice

Wilson and Peterson (2006) describe learning as a social phenomenon, and point to various learning theories that draw their strengths from the social dimensions of learning, specifically, social constructivism, sociocultural theory, and activity theory. They also point to the idea that teaching is a form of inquiry, where teachers "must act as scientists, investigating students' thinking, finding ways to learn about how particular students are actively constructing their understanding" (p. 13). In order for this to take place, the authors argue that teachers must be given time to learn not only from their own experiences in class, and interactions with students, but also from their colleagues. Not only does this idea improve teaching practice, it allows teachers to actively participate in scholarship around the art and science of teaching. These ideas are instantiated in the fellowship program by pushing the fellows to engage in teaching as a public practice through the use of social media tools, as well as by encouraging the establishment or further development of a web presence. Though the fellows had already begun to share their experiences via social media in the summer and fall, it was in the spring semester that this aspect of their work was strongly foregrounded. Lastly in the spring, MSUrbanSTEM instructors asked the fellows to engage in personal, as well as collective, reflection around their teaching practice, and share those reflections as personal journal entries as well as publications to be shared with the world.

Social Media Integration

The MSUrbanSTEM program believes one way to help fellows to practice the idea of teaching publicly was to help them develop and/or foster the use of social media in their teaching practice as well as their professional development experiences. Ferriter (2010) makes several arguments why teachers should be proficient in the use of social media, specifically Twitter, in their teaching practice. He states, "teaching professionals have found ways to use Twitter to share resources and lend quick support to peers with similar interests." By building a network via social media of professionals in similar content or grade areas, a teacher can construct a repository of resources for various ideas, which include lesson planning, curriculum mapping, motivation and engagement strategies.

To integrate social media in the fellowship, MSUrbanSTEM instructors set up a private Facebook group that restricted membership to fellows and the leadership team of the program. The Facebook page was designed to be a safe space where fellows could share work they created collectively and individually while in the program, as well as resources they found that connected to STEM education.

Through Twitter, the instructors promoted the use of sharing images of their completed work or resources related to STEM with tags (including the #MSUrbanSTEM hashtag) that captured the essence of what they were trying to say. These included their World of Wonder stories as well, again an attempt to make public some of the key motivations for learning and doing STEM. The fellows were

also instructed to search via hashtags to find out what links and people were associated with different hashtags. Via this exercise, fellows were able to discover professional development communities that participated in live discussions via Twitter on a weekly or monthly basis. Twitter was also incorporated into other assignments. Fellows were encouraged to use Twitter as a way to connect with authors they were interested in interviewing, and sharing quotes they found meaningful.

Web Presence

At the time of starting the fellowship, while a few fellows had no web presence, some fellows used web space provided to them by their school/district in order to help facilitate communications between themselves and students, as well as parents. This was consistent with trends observed by Unal (2011): "Among the teachers that currently have a website, communication with students was stated as the most popular use (73%), followed by communication with parents (51%)" (p. 44). Other fellows had created sites using applications such as WordPress, Edublogs, Weebly, Wix, or Squarespace.

The fellowship program encouraged fellows to examine not only how they viewed themselves as leaders in their professional context, but also how they were viewed in out-of-school professional settings. This meant examining their professional virtual presence, as well as their networking strategies. Reminding fellows of the idea that teaching is a public practice, fellows were asked to re-envision their sites as a portfolio of their work in addition to supporting their teaching practice. Their websites now represents a repository where they can share all of their demonstrated learning, skills, pedagogical practices, competencies, and reflections in one central location. Fellows were also asked to consider integrating their social media accounts into their website. Connecting a stream of tweets related to their work, education, and STEM interest to their website, helps in the branding of their site as a professional resource for teachers interested in STEM educators.

Publishing Two Books

A few of the most interesting artifacts created by the fellows were the two books they collectively wrote. These books were written almost entirely by them, though scaffolded exercises supported by the instructional team. The first book, "Roots of STEM," was written in the first two weeks when the fellows met face-to-face. It consisted of a collection of exceptional lesson plans for STEM learning selected by the fellows from their own experiences. This was a purposeful decision to honor the prior knowledge and experience the fellows brought to the fellowship. The book began with a teaching demo that gave a snapshot of the fellows' experience. Each teacher selected a lesson that they felt showcased their best work and shared a condensed 30-minute version with a small group (4-5 colleagues) in the cohort. Upon completion the group engaged in dialogue about the lesson for 20 minutes using the Critical Response to Teaching Demonstration (CRTD) from Swenson and Mitchell (2006). The CRTD allows for participants to provide feedback on the lesson that is shared. The idea was that through sharing their best work, the fellows would have a collective opportunity to be exposed to new ideas in regards to pedagogical approaches and content approaches. The final products were collected and printed in a book titled, "The Roots of STEM".

The second book they created was in the spring semester and was titled "This I believe." In this book, each of the fellows shared a favorite quote, a favorite book, and a description of their experience with the MSUrbanSTEM project, and their plans for the future. Finally, each of their pieces ended with

a short statement about some deeply held belief about teaching and learning in the STEM disciplines that began with "This I believe…" Both of these books were printed (using an Espresso Book Machine) and shared with the fellows, the funders, and other administration and leadership at CPS. Though e-book versions of both books were available on the MSUrbanSTEM website, the tangible, printed book became a highly coveted artifact; its physicality in stark contrast to most of the digital work that the fellows were engaged in.

Leadership Identity

As Berg, Carver, and Mangin (2013) observed, over the past few decades, teachers have begun to play an increasingly important formal and informal leadership role in various contexts of their professional settings. However, "education research has not coalesced around the topic of teacher leadership, nascent theories are not tested across settings, and teacher leader-related policies and practices are generally not documented in ways that can inform others" (p. 196). In the spring semester, the fellows were asked to explore the idea of being "Tempered Radicals," by reading and exploring the ideas in a book of the same name (Meyerson, 2008).

As Meyerson describes it, Tempered Radicals "are people who want to succeed in their organizations yet want to live by their values or identities, even if they are somehow at odds with the dominant culture of their organizations." As 'outsiders within,' they have both a critical and creative edge. They speak new truths and they think "out of the box" because they are not fully in the box. Meyerson further defines Tempered Radicals, as, "Everyday leaders who are quiet catalysts and who push back against prevailing norms, create learning, and lay the groundwork for slow but ongoing organizational and social change." (Kindle Locations 3307-3309).

The Meyerson text helped provide the foundation for fellows to develop a personal manifesto—in the form of an essay and video through three stages. In the first stage, fellows were guided through a conversation, which asked the fellows to examine the type of leader, or radical they viewed themselves. Further, the fellows explored how they interacted with challenges in their professional context. Lastly, they reflected on the distinction between institutional (a narrow focus on tools, skills and plans) or missional thinking (a broader focus on goals and values) and each has a role to play in teaching and leadership. Using these ideas fellows were asked to develop short- and long-term professional S.M.A.R.T. (i.e. specific, measurable, achievable, realistic and time-bound) goals.

The fellows did not just engage in thinking and writing about leadership. In keeping with the MSUrbanSTEM approach of engaging in activity — the fellows worked in groups based on a range of STEM based themes, connected to ideas they had explored through the year long program. Finally these groups developed interactive presentations that illustrated how these ideas were enacted in their daily practice, which they presented at the 2015 Annual Conference of the American Educational Research Association (AERA). The ability to speak about their work to an audience of world-recognized researchers and scholars, at one of the most prestigious educational conferences in the world, was a significant achievement and a matter of great pride for the fellows (and the MSUrbanSTEM administrative, research and instructional teams).

Leadership as Sharing and Collaboration

During the spring semester the MSUrbanSTEM team continued to promote the mindset of accepting misunderstanding and understanding confusion when approaching teaching and learning. This message is deeply threaded in the fellows' efforts to share their work with the world and the fellowship program's conceptualization of wonder as a form of inquiry. The MSUrbanSTEM team specifically encouraged teaching to be seen as an art, informed by psychological and design principles but not determined by it. New approaches to pedagogy and representation of content can be creative, different, and even uncomfortable, and it is desired that the fellows share these practices with the world. So when the fellows shared their work on social media outlets, they didn't simply share their classroom successes and only discuss the ease of their project implementation, but they also were encouraged to share their challenges and to share what they learned as a result of the adversities they faced.

Many of the teachers found they had to reach outside of their classrooms to obtain the resources needed to accomplish their DreamIT projects. One fellow wanted her students to share her passion for mathematics. Specifically, when asked to write a reflection about her DreamIT project, she explained:

Every year I come across many students that 'hate' math or think it's such an impossibly complex thought process that only a few chosen students understand. I see students the first day walk in already given up with the lessons I haven't even taught. It is incredibly frustrating. (Kallie)

Her DreamIT involved encouraging students to see math everywhere by photographing instances of math in their world. The challenge arrived when making sure her middle school students had access to technology outside of the classroom to take pictures. She worked with administration, parents, as well as started a "GoFundMe" page in an effort to garner the funds necessary to get technology in her classroom. Her goal included having students share their work publicly, through Twitter, which was not encouraged by administration. Kendra was able to advocate with research and examples from her summer experience in MSUrbanSTEM as to how student learning could be benefitted by the use of social media. She collaborated with administration to develop a fact sheet aimed to help parents and students determine whether the benefits of using social media in the classroom outweighed the risk.

Further, in connection with teaching publically, all of the teachers did not share or use social media equally, and all fellows not utilize their web sites to the same capacity. However, all of the fellows received ideas from MSUrbanSTEM that allowed them to re-imagine and re-think their efforts and sometimes even their goals. Much like the term, "tempered radicals," the MSUrbanSTEM program always wanted the fellows to think differently when approaching their daily classroom practices. The end result, often discussed during the meetings both face-to-face and online, is not that the fellows had an absolute and complete understanding of the complexities of teaching but rather that they are progressing on the journey. The confusion inherent in wicked problems of teaching and learning in the STEM disciplines in urban contexts remain, but through the process, the MSUrbanSTEM team hopes to develop a more nuanced and thoughtful approach.

EVALUATION

While the program design and instruction may be the most exciting aspects of the program, the program designers also collected a range of data over time, to demonstrate if at all the program had made a difference to the fellows and their practice. Some of the findings shared in this chapter will concern the fellows' leadership qualities, teaching efficacy, knowledge and use of TPACK, and expertise in the use of technology as a result of being participants in this program.

The MSUrbanSTEM program aims for its fellows to develop abilities that will enhance the classroom experience and each of their students' quality of learning. The MSUrbanSTEM researchers used four separate instruments to measure the fellow's abilities, as well as conducted in depth qualitative analyses of the artifacts created by the fellows. They used a modified version of the TPACK instrument (Schmidt et al., 2009) for measuring technology integration into pedagogy of STEM content; the Teacher efficacy scale (TES, Woolfolk & Hoy, 1990) to measure fellows' beliefs in self-competence as a teacher, the Educational Leadership Self Inventory (ELSI, CSBE, 2001) for fellows' leadership and collaboration beliefs of self, and a Technology expertise survey that was created by the MSUrbanSTEM team.

In the first year, fellows were asked to take all four assessments at four times throughout the year to measure any changes in their self-perceptions as educators. The first cohort completed the surveys immediately prior to the face-to-face summer session, and once in September when starting their school year. They later took the surveys once in December to finish the first semester and then they completed the surveys in May/June of the following year. Overall, it is inferred that these measures can speak to the self-perception of the fellows, which offer an illustration of their own sense of competence and ability to be innovative, open minded, and effective educators.

Instruments and Findings

Teachers understanding of TPACK allows them to rethink their academic environment and more effectively use technological resources to their advantage (Koehler et al., 2011). The TPACK instrument is 47-item questionnaire with 10 sub sections including: technological knowledge (TK), content knowledge (CK) of four separate subjects (including math and science), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and TPACK. The TPACK has an alpha ranging from .75 to .92 for each of its sub sections.

TPACK findings from the first year show that there was a significant difference in scores at each time point. The MSUrbanSTEM researchers completed a one way repeated measures analysis of variance over four periods. Mauchly's test indicated that the assumption of sphericity was not violated, $\chi^2(5) = 4.177$, $p = .525$, therefore Greenhouse-Geisser tests are reported ($\varepsilon = .859$). The results show that the fellows' perceptions of their TPACK was significantly affected by their participation in the MSUrbanSTEM program $F(2.58, 41.24) = 18.8$, $p < .001$. Additionally, they saw statistically significant differences in all seven subscales, which represent that the fellows' ability to integrate technology into STEM content as well as their ability to integrate technology and STEM content into their pedagogy had increased as result of being in the MSUrbanSTEM program.

Further, in the measurement of technology use, the fellows were asked to complete an internally designed, MSU Educational Technology program's technology survey. This technology survey was created at MSU specifically to learn about the general technology competence, familiarity, and use of technological software and task capabilities. The survey includes questions about web skills and so-

cial media presence, ranging from questions like, "How confident are you putting an attachment in an email?" and "…protecting your computer from viruses?" to "How confident are you creating an app for a smart phone?" or, using "3-D printing capabilities." This survey has been used in the past to measure how master degree seeking students in educational technology have grown as a result of being in the master's program. This same survey was modified and used to measure the abilities and competence of the MSUrbanSTEM fellows as well.

The authors conducted a one way repeated measure analysis of variance across only two time points (July/beginning and June/end). Findings from the first year cohort's technology survey results show that the group significantly grew in their knowledge of and use of technology due to their participation in the MSUrbanSTEM program $F(1, 20) = 28.88$, $p < .001$.

Arguably the most important instrument used in this study was the Teacher Efficacy Survey (TES, Woolfolk & Hoy, 1990). The TES is a 22-question instrument where the participants are asked questions related to their view of their own teaching ability and impact on students despite circumstance. The questions are split into two categories, general personal efficacy, and teaching efficacy. Examples of questions from this survey include, "the influence of a student's home experience can be overcome by good teaching?" and, "I have enough teacher training to deal with almost any learning problem?" All questions were asked on a 6-point Likert scale from strongly agree to strongly disagree. The alpha for the teaching efficacy scale is .74 and the alpha for personal efficacy scale is .82.

Findings from the TES indicate that there was a significant difference in scores from at each time point. After completing a one way repeated measures analysis of variance over all four of the periods of time, Mauchly's test indicated that the assumption of sphericity was not violated, χ^2 (5) = 4.934, p = .425, therefore Greenhouse-Geisser tests are reported (ε = .837). The results show that the fellows' perceptions of their own efficacy as a teacher was significantly affected by their participation in the MSUrbanSTEM program $F(2.51, 42.69) = 3.046$, $p = .047$. Though significant, there were lesser effects (lower F statistic) of the efficacy instrument compared to the ELSI (soon to be discussed) and the TPACK, and this could be because only one of the subscales showed a significant change in the fellows perceptions of efficacy. Results show that fellows' perceptions of their general personal efficacy was significantly affected by their participation in the MSUrbanSTEM program $F(2.52, 42.88) = 5.995$, p = .003, but their perceptions of their teacher efficacy was not significantly affected by their participation in the MSUrbanSTEM program $F(2.63, 44.63) = 1.027$, $p = .382$. While personal efficacy had questions that reflected how well the fellows feel they can carry out a task, teacher efficacy had questions that reflected how confident a teacher felt in altering a student's outcome despite the student's home and family context. Therefore, indicating that the fellows may perceive themselves as more efficacious people as a result of being an MSUrbanSTEM fellow, yet they still understand the limitations of the context on the students they teach.

Finally, for the last survey, the MSUrbanSTEM researchers used the Educational Leadership Self-inventory (ELSI, CSBE, 2001). The ELSI was created by the Connecticut State board of Education and is based off of the principal instructional management scale (Hallinger, 1982) and was adapted in 1999. The ELSI was then used to measure teachers and administrator's ability to collaborate, meet goals, and deal with overall obstacles in a school setting and the scale normed on the importance ratings of 251 Connecticut school principals who participated in "successful school principals" study. This instrument was specifically used because it allows the researchers to learn more about how the fellows are growing as collaborators in their school setting and if they are sharing and spreading the ideas that they have

learned from the MSUrbanSTEM program. There are 69 Likert scale questions on the ELSI and there are 12 subscales.

The ELSI findings express that there were significant differences in scores across the four time points after conducting a one-way repeated measures analysis of variance. Mauchly's test indicated that the assumption of sphericity was not violated, χ^2 (5) = 6.545, p = .257, therefore Greenhouse-Geisser tests are reported (ε = .816). The results show that the fellows' perceptions of their own leadership abilities as a teacher was significantly affected by their participation in the MSUrbanSTEM program F(2.45, 48.93) = 9.075, p < .001. Further, 10 of the 12 subscales were found to have significantly increased. The two sub scales that increase the most were the professional development subscale and the school culture subscale. The five questions in the professional development subscale ask about the fellows taking initiative to create opportunities for self and colleagues to grow or develop. The questions on school culture cover the participants' actions concerning collaborating with colleagues in order to create a cohesive school wide education environment. Other sub scales that significantly increased were; educated person, learning process, teaching process, school goals, school standards and assessment, integration of staff evaluation, PD, and school improvement, organizing school resources and school policy, and school community relations subscales.

In addition to the four instruments, the MSUrbanSTEM team is currently conducting a qualitative thematic analysis looking at the various artifacts created by the fellows (specifically the DreamIT projects and book reviews). Qualitative analyses allow the researchers to get an in-depth look of what the fellows are doing with their students, how they are integrating technology in their pedagogy, how they are collaborating with their colleagues, and what they are passionate about while learning from this MSUrbanSTEM teaching experience. A brief preliminary analysis confirms that fellows are growing as STEM leaders, they are collaborating with other teachers, and are incorporating the main pedagogical ideas presented to them in their own classrooms. Fellows are also making interdisciplinary connections, incorporating project-based learning, and using technology in creative ways to support their student learning. Their projects reveal that they are finding innovative solutions to the challenges they face as urban educators with limited time and financial resources.

The fellows create a range of on-going reports about their DreamIT projects. These reports reveal a complex zig-zag process of iterative design and re-design as the fellows face challenges, receive feedback from their focus groups, and so on. There is a great deal of failure and challenging circumstances that emerge in these reports. What is impressive, however, is the manner in which the fellows persist in their work, taking challenges in stride, picking themselves up from momentary stumbles and moving on. It appears that they become more comfortable with the complexities of leadership and their role in the classroom and their school. Thus they seek no clear answers but rather are accepting of the wicked nature of the problems they face, the "broken images" as it were. Yet, they seek to grow and develop, even while continually seeking to experiment to develop a better and more realistic understanding of the process while holding steadfastly to broader and deeper goals.

CONCLUSION

The changes observed in the fellows (either in direct interaction with them or from seeing the data) have been fascinating and truly motivating to the designers of the fellowship. To see the fellows explore, put themselves at risk, fail, and continue to persevere in contexts that are not the most conducive to learning

has indeed been inspirational to the MSUrbanSTEM team. In fact, this emphasis on learning from failure almost took on the appeal of a badge of courage—with the statement "failure is the only option," and this almost became a motto of the program. The idea being that if you haven't failed, you really haven't pushed yourself hard enough. This, of course, is in sharp contrast to the dominant narrative in education and in social popular culture, which is fundamentally averse to failure (Kohn, 2000). Much like the philosophy of learning from John Dewey, the fellows learn by doing the science or doing the math, not just from reading (though much reading does happen), or from listening to lectures (and they have some of those as well), nor from receiving handouts and powerpoint slides (and their websites host a few of those too). All of these components exist but the central aim is to do and share the work, and learn by doing, while bringing what you learn to the educational experience.

The MSUrbanSTEM team also does not pretend to have all of the answers. They do, however, offer suggestions for brainstorming, collaborating, wondering, and thinking outside of the box in order to help the fellows reach their teaching goals. Building on the fox and hedgehog quote by Archilochus, with which the authors started this chapter, Isiah Berlin divided writers and thinkers into two categories. Hedgehogs know, argue, and predict that all knowledge is related to one central vision, while foxes entertain ideas that are complex and do not try to explain all phenomena with one theory. There is research to show that in complex domains, where cause and effect are hard to tease apart and where irregularity is normal, foxes do better than hedgehogs in forecasting. This is because foxes are eclectic in their choice of ideas, humble in their relative ignorance, not overwhelmed when the facts go against their current thinking, willing to learn from their mistakes and nimble in changing tactics when the world around them changes. In fact, there is research to show that in the area of political forecasting, the diffident foxes fare far better than overly-confident hedgehogs (Tetlock & Gardner, 2015).

The MSUrbanSTEM approach has been that of the fox and they seek to instill the same qualities in their fellows. They encourage their fellows to enter the classroom with multiple strategies, philosophies, and thoughts on how to teach and guide the students in the class. On any given school day teachers could be teaching up to 150 students while having to take into mind the various backgrounds, prior knowledge, and daily emotions of their students. Approaching the school like a hedgehog forces all of the students to fit into the teaching theory of the teacher, while the fox approach allows the teacher to effectively connect and meet the needs of their different students. As a teacher educator, one cannot predict the future behaviors and needs of each of the students that the teachers will meet. Teacher educators can however equip teachers to become comfortable with this ambiguity, to understand that, such is the nature of the field of education, and in fact it is this diversity and "confusion" that gives much of this work its infinite richness and variety. Additionally, the MSUrbanSTEM equipped teachers will not be surprised by the ambiguity or confusion of the process. The goal therefore, is to continually explore, create, and share and in that process come to a "new understanding of our confusion."

Clearly there are many gaps in the program designers' understanding of this complex process of teacher professional development. Their work in this area, over the years in the design of a Master's program in educational technology, and now culminating in the MSUrbanSTEM program, has had a strong focus on practice. Their understanding of the efficacy of their processes is therefore limited — and the data and results they have presented above, as in other venues (Koehler et al., 2011), are a good start. Clearly more needs to be understood about the process. One of the challenges faced by the project is its holistic nature, where assignments, readings, activities, work together in a multi-threaded, multi-dimensional manner, where issues related to aesthetics, beauty and wonder play as important a role as the develop-

ment of content, pedagogical and technological knowledge. Studying such complex interactions is not easy— and this should be an important goal of any future explorations and research.

To end, the authors would like to quote from Robert Pirsig's 1974 classic rumination on technology and values, *Zen and the art of motorcycle maintenance.* He writes:

Technology presumes there is just one right way to do things and there never is. And when you presume there is just one right way to do things, of course the instructions begin and end exclusively with [one predetermined product … But if you have to choose among an infinite number of ways to put it together then the relation of the machine to you, and the relation of the machine and you to the rest of the world, has to be considered, because the selection from among many choices, the art of the work is just as dependent upon your own mind and spirit as it is upon the material of the machine. Pirsig (1974, p.160)

As the authors look over a year of work with their fellows, they see that the focus of the MSUrbanSTEM program has been as much on the science and engineering aspects of STEM learning as it has been on the "art of the work" seeking to develop in their fellows a sense of autonomy and respect for their knowledge and skills, an openness to wonder as a prime motivator for learning, and a tolerance for ambiguity and ultimately a faith in the process that would lead to continual growth and development. The MSUrbanSTEM team views their work in this area as informing future projects in teacher professional development. These are complex issues, and as the authors wrote at the very beginning of the chapter, how they frame these issues is of critical importance. The authors hope that through this paper they have been able to provide a rich description of their approach, and the broad philosophical foundations of their work.

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KEY TERMS AND DEFINITIONS

Creative Pedagogies: Teaching and classroom practices that require an unorthodox and/or innovative approach to scaffolding students in their learning process.

Dewey: John Dewey is an educational reformer whose work emphasized the importance of teachers psychologizing subject matter, learning best by doing the work instead of simply reading about it, and teachers valuing the knowledge that each student brings to the classroom.

Experience: A concept endorsed by John Dewey, which encourages teaching and learning is most effective when the learner/student is able to partake in the phenomena being taught, as opposed to only reading about or hearing about the phenomena.

Fellowship: An earned reward or amount of money designated to a scholar for their educational work.

MSUrbanSTEM: A yearlong teacher leadership fellowship program that uses an innovative approach to teacher professional development in order to create multimodal classrooms.

STEM Instruction: Science, Technology, Engineering, and Math teacher pedagogies and practices.

Technology Integration: The incorporation of everyday tools into classroom practices to enhance the teaching and learning process.

Teacher Leadership: Teacher and administrator's ability to collaborate with colleagues, parents, and students in school related projects at the school or district level. Also teachers' habits in sharing their classroom results, practices, and experiences with their community in various ways.

Teacher Professional Development: Teacher instruction programs that help teachers to grow and learn as educators.

TPACK: The creative integration of technology, pedagogy, and content knowledge into everyday teaching practices.