Urban Advantage and the development of core science teaching practices

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Introduction

Urban Advantage (UA), operating in New York City (NYC) schools for more than a decade, is a partnership between the NYC Department of Education and eight cultural institutions, and provides intensive, sustained professional learning for participating science teachers, as well as science materials for classrooms and free access to informal science education institutions. Currently in its 13th year, 35% of all NYC middle schools are actively participating in UA and more than 50% of all middle schools have ever been involved. The UA program is tailored to the NYC public school system, which encourages all eighth-graders to complete a long-term scientific investigation. Thus, the program brings resources designed to support rich, meaningful experiences in science to teachers and students in under-served, high-poverty communities.

Previous research on UA has demonstrated that students that participate do better on a standardized test of science achievement administered at the end of eighth grade, with especially large gains for students of color and students attending traditionally low-performing middle schools (Weinstein & Whitesell, 2015; Whitesell, 2016; Weinstein & Shiferaw, 2018). The most recent impact analysis (2018) capitalized on the availability of unique student-teacher linkage and course data that allowed researchers to identify students taught by a UA teacher. This study found that UA was successful in improving students' performance in science—in models comparing students with and without a UA teacher in the same school, Weinstein & Shiferaw found that the program increased scores on the 8th grade ILS exam by 0.06 standard deviations. Students with UA teachers with up to two years of teaching experience are also about 3 percentage points more likely to score proficient on the ILS exam. Furthermore, positive benefits of UA remain through roughly 10 years of teaching experience and students educated by teachers who are currently not active in UA but participated in the past also outperform their peers with teacher who never participated in UA.

Given the positive impacts of the program on students' achievement in science, a key question is *which features of the professional learning are most responsible for the positive effects for students*? Previous research in the Urban Advantage program has focused on the role of specific resources in helping or hindering the implementation of Urban Advantage ideas (Wilson et al., 2014). This work was framed around the conventional, personal/intellectual, and environmental/social resources that help teachers do their work (Cohen, Raudenbush & Ball, 2003) and sought to understand how teachers' learning and instructional practice were mediated by the presence and skillful use of these resources. In this work, teachers' resource profiles suggest that uptake from the professional learning experiences was affected by: (1) environmental/social resources, particularly professional leadership and collegial support (2) personal/intellectual resources, most notably teachers' views about students; and (3) conventional resources. The major conclusion from the work was that program facilitators should attend to variability in teachers' resources and adapt to school context.

Research on science teacher professional development, more generally, has identified a set of general characteristics of effective PD, regardless of career stage. For example, Desimone (2009) outlines five critical features of professional development. First, the PD must focus on specific content. Research points to a link between activities that focus on subject matter content and how students learn that content with increases in teacher knowledge, improvements in practice, and even student achievement. The second feature of effective PD that Desimone (2009) identifies is that the PD must engage teachers in active learning. Opportunities for teachers to engage in active learning are related to the effectiveness of PD (Garet et al. 2001; Loucks-Horsley et al., 1998). Whereas passive learning is characterized by lecture, active learning can take a number of different forms. For example 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). The third feature of effective PD identified by Desimone is coherence with schools, district and state reforms and policies (Elmore & Burney, 1997; Firestone, Mangin, Martine & Polovsky, 2005). The fourth feature of effective PD is that the experience should be of sufficient duration, both in intensity and contact hours. Research has not indicated an exact "tipping point" for duration but shows support for activities that are spread over a semester (or intense summer institutes with follow-up during the semester) and include 20 hours or more of contact time. Finally, Desimone (2009) identifies "collective participation" as a critical feature of effective PD. In other words, PD should involve multiple teachers per school, grade or department. Thus, there is potential interaction and discourse during and following the PD experience with increased probability of collective learning (Banilower & Shimkus, 2004; Borko, 2004; Loucks-Horsley et al., 1998)

Wilson (2013) outlines additional features of professional development for science teachers that may matter. For example, she highlights that activities must be close to practice (Fischer et al., 2016; Penuel, Fishman, Yamaguchi, & Gallagher, 2007), participants physical and psychological comfort must be taken into account (Freeman et al., 2004), teachers should be immersed in inquiry experiences and witness models of inquiry teaching (Supovitz & Turner, 2000), and curriculum materials should be educative for teachers and students (Davis & Krajcik, 2002). Finally, strong principal support has shown to be important for the success of professional development for science teachers (Banilower, Heck & Weiss, 2007).

Not surprisingly, research indicates that novice and early-career teachers are less effective than more experienced peers (Clotfelter, Ladd, & Vigdor, 2007; Rockoff, Jacob, Kane, & Staiger, 2011; Wayne & Youngs, 2003). On average, individual teachers make rapid gains in effectiveness during the first several years on the job. It is hard to tell how, exactly, teachers improve in their first few years of teaching, but a hypothesis is that they gain content knowledge, classroom management techniques, and methods of instructional delivery as they gain experience. Studies on the returns to teaching experience find that, on average, teachers make rapid gains in effectiveness early in their careers, but that additional experience is associated with more modest improvements (Boyd, Lankford, Loeb, Rockoff, & Wyckoff, 2008; Harris & Sass, 2011; Papay & Kraft, 2013; Rockoff, 2004; Wiswall, 2013). However, this *profile* masks heterogeneity among teachers as well as systematic differences across schools.

We know very little about how much and in what ways teachers continue to improve *later* in their careers (Harris & Sass, 2011, Papay & Kraft; Wiswall, 2013). There are many factors to consider. For example, teachers improve at different rates in different types of schools (Kraft & Papay 2014). Principals play a key role in supporting professional growth among teachers by serving as instructional leaders who provide targeted feedback and facilitate opportunities for teachers to build and reflect on their practice (Blasé & Blasé, 1999; May & Supovitz, 2011; Waters, Marzano, & McNulty, 2003).

Conceptual Framework

This work seeks to identify features of UA professional learning that may be responsible for its positive impacts on students' achievement in science. Research shows that having an effective teacher is one of the most influential factors that improve students' academic achievement (Chetty, Friedman & Rockoff, 2011; Darling-Hammond, 2011; Glazerman et al., 2010;). There is little consensus about what evidence is needed to identify more or less "effective" teachers (Ball & Rowan, 2004; Bell et al., 2012; Hill, Kapitula, & Umland, 2011). However, there is growing evidence that a teacher's *instructional practice* may correlate with student interest and achievement better than other potential indicators of quality such as advanced degrees or teaching experience. A recent program of research has focused on identifying *high-leverage teaching practices*, or practices that research indicates improve students' learning. High leverage teaching practices, also called *core teaching practices*, occur with high frequency, can be enacted across different curricula or instructional approaches, preserve the integrity and complexity of teaching, are research-based and have the potential to improve student achievement, and are possible for novices to enact (Grossman, Hammerness & MacDonald, 2009). Recent work in science education has identified several core science teaching practices, many of which fall under the categories of planning for engagement with big ideas in science, promoting interactive and dialogic science classrooms and collecting evidence of and responding to student thinking (Kloser, 2014; WIndschitl et al. 2012). We hypothesize that aspects of UA PL may help teachers develop high leverage practices in science. Furthermore, teachers may develop their science teaching practice along a continuum, with novice UA teachers differing from veteran UA teachers in what they learn and, ultimately, implement in the classroom.

Research Questions

This study was designed to look closely at the nature of the PL experiences the teachers engaged in through UA and how these experiences influenced classroom practice. We asked teachers about which tools, pedagogical routines, and resources most influenced their practice. Teachers spoke about which tools, routines, and resources were the most powerful and how they adapted them. Specifically, this study was designed to examine UA teachers' learning and classroom practice *across levels of experience in UA*. In UA, teachers participate in a common learning experience in Year 1, and then are able to progress through levels of PL that focus on different content and scientific practices. We collected data to answer the following research questions:

- How does the sustained professional learning experience support teachers' developing high leverage science teaching practices?
- Are there differences in science teaching practice between new and veteran Urban Advantage teachers? If so, what are the differences in practice and to what can we attribute them?

Methods

Sample

The sampling approach aimed to capture a range of experiences of teachers in various stages of PL, but also provide a deep dive into the experiences of four focal teachers. We solicited volunteers for participation in the research during PL sessions. The final sample included 12 participants; key participant characteristics are summarized in Table 1. Following initial interview, we invited four teachers to participate in the classroom observation portion of the work: a new teacher, a second-year teacher, a 'lead' teacher, and a veteran teacher. These four teachers served as 'cases' of UA participation that were analyzed in depth.

Table 1 Participant characteristics. All teacher names are pseudonyms.

ID	Years UA	Years Teaching	Gender	Certification	Case study
Ms. Pavao	1	2	F	Students with Disabilities	
Ms. Rivera	1	5	F	Spec. Ed.; Students with Disabilities	
Mr. Baker	1	1	M	General Science	Y
Ms. Ahmed	1	1	F	Earth Science	
Mr. Scott	2	6	M	Earth Science	Y
Ms. Young	2	2	F	Biology	
Ms. Long	3	7	F	General Science	
Mr. Reyes	3	8	M	Chemistry	
Ms. Russo	4	5	F	Chemistry; General Science	Y
Mr. Garcia	7	10	M	Biology; General Science	
Ms. Flor	8	21	F	Spec. Ed.	Y
Ms. Martin	11	11	F	Biology; General Science; Spec. Ed.	

Observations of the professional learning sessions

We observed, took detailed field notes, and wrote memos about professional learning workshops at the cultural institutions. The *observed* sessions are summarized in Table 2.

Table 2. Characteristics of observed Urban Advantage professional learning workshops

Name	Length of course	Focus of the PL
C1	10 hours	Introduction to Urban Advantage
C2: Zebra Mussels	30 hours	Using secondary data sets to investigate the effect of an invasive species
C2: Weather	30 hours	Using secondary data sets to investigate weather and climate patterns
C2: Plants	30 hours	Conducting controlled experiments to investigate plant traits
CTPL 205	10 hours	Developing scientific explanations about submersibles
CTPL 211	10 hours	Using reading and writing strategies to deepen science content understanding
CTPL 301	10 hours	Evidence and explanation and plate tectonics
CTPL 408	10 hours	Teacher practice in coaching and guiding investigation design
CTPL 452	10 hours	Examining teacher practice using video

Note: New UA teachers are required to complete Cycle 1 (C1) and Cycle 2 (C2) during their first year in the program. C1 is a two-day introduction and in C2 teachers work in teams to complete a long-term science investigation. Teachers are encouraged to progress through "levels" of PL (200, 300 and 400-level courses) and pick topics and investigation types that they feel will deepen their understanding and improve their classroom practice.

Interviews

We conducted semi-structured interviews with all participants. We asked them about their experiences in UA, how they use UA tools, routines and strategies for planning and instruction, and how they believe that UA is evident (or not evident) in their classroom (see Appendices A and B). We audio-recorded the interviews and transcribed them verbatim.

Classroom observations and collection of artifacts

For the four focal teachers, we observed a series of science lessons (3-5 lessons, representing a meaningful teaching sequence). We took detailed field notes, wrote post-visit memos, took photographs of classroom activities, and collected classroom artifacts (e.g. handouts, assignments, samples of students' work). We conducted pre- and post-observation interviews with case study teachers, during which we asked them about what they had planned for the learning experience, in what ways they drew on UA resources, and then (following observation) reflections on how the learning sequence went.

Analysis

We used pre-existing theory to develop an initial set of codes for interviews. We used the eight science and engineering practices identified by the NGSS (NGSS Lead States, 2013), as well as literature about ambitious science teaching practices (e.g. Winschitl, Thompson, Braaten, & Stroupe, 2012; Thompson, et al., 2016) and core science teaching practices (Kloser, 2013) to build an initial codebook. We used open coding to develop additional codes to describe the data. All qualitative analysis was conducted using the coding program Dedoose. We used triangulation across observations, interviews and artifacts to check and establish validity.

Findings

Structure of Urban Advantage Professional Learning

The first year of professional learning for teachers is focused on giving them experience conducting long-term investigations in science and helping them plan to support students in doing such investigations in their own classrooms. First-year Urban Advantage teachers complete 40 hours of professional learning, organized into two "cycles." Cycle 1 consists of a two-day workshop that serves as an introduction to the program. Teachers learn about the resources they have available to them (including the institutions themselves), the vouchers they will receive to take students to the institutions, and the equipment that they will receive. Teachers also conduct a science investigation as a science learner; that is, they are asked to immerse themselves in the experience of learning science and save their pedagogical questions for the debrief following the science learning experience. In an observed Cycle 1 session, teachers investigated "What are the factors affecting the trajectory of pinballs from a pinball launcher?"

In Cycle 2 of Year 1, teachers attend five sessions at one of the partner institutions during which they conduct a long-term science investigation, from the initial brainstorm of research questions to the final power-point presentations, with a small group of teachers. In the process of conducting the investigation, teachers are immersed in "Urban Advantage pedagogy," which consists of a set of routines, resources, and "tools," designed to help teachers support students' in conducting science investigations in the classroom. Urban Advantage supports four major types of long-term science investigations: controlled experiments, design investigations, field investigations, and secondary research investigations (see Appendix C). Institutions in the partnership bring their particular strengths to support certain investigation types. For example, the Gardens contribute resources and hold professional development about conducting controlled experiments with plants. In addition, Urban Advantage has designed a set of tools to support teachers and students in conducting investigations. For example, the Investigation Design Diagram (IDD, Fig. 1) scaffolds students' design of controlled experiments.

Investigation Design Diagram

Title:

Question:

Hypothesis:

Independent Variable:					
Change in independent variable:					
Number of repeated trials:					

Dependent Variable:

Constant variables:

Figure 1. The Investigation Design Diagram, which supports students in setting up controlled experiments and design investigations.

The Designing Scientific Explanations Tool (DSET, Fig. 2) is a graphic organizer for scientific explanations, prompting students to write their claim, supporting evidence, and scientific reasoning. The DSET was adapted from the BSCS's "Designing a Scientific Explanation Tool" (2012), which, in turn, was based on the McNeill & Krajcik (2008) Claims-Evidence-Reasoning Framework.

Developing a Scientific Explanation Tool (DSET)

What is your question?

Support for your explanation

Claim based on the evidence (What is the answer to your question based on your evidence?)	Evidence (Observations/data that answers your question)	Scientific Reasoning (Why you think this happened based on background research)

Scientific Explanation = Claim + Evidence + Science Reasoning My claim is (fill in with above claim) because (evidence and science reasoning)

Figure 2. Designing a Scientific Explanation Tool, adapted from the BSCS Designing a scientific Explanation Tool (2012), based on the work of McNeill & Krajcik (2008)

Following their first year in Urban Advantage, teachers select from a menu of professional learning experiences. In Year 2, teachers complete 25 hours of professional learning at one of the institutions, and in subsequent years they complete at least ten hours per year. In 200-level course offerings, teachers can choose to focus on a particular type of investigation (controlled, design, secondary research, and field work) that interest them. 300-level course offerings are a deep dive into content, using Curriculum Topic Study. In 400-level courses teachers reflect on their own practice, using student work samples and video.

Learning, Tools and Collaboration Across Stages of UA Teacher Development

The teachers we interviewed spoke of distinct experiences during different stages of their long-term professional learning. We have organized these experiences into three general "stages" of being an Urban Advantage teacher – new teachers (Year 1), mid-level teachers (Years 2 and 3), and veteran teachers (more than 4 years of experience in UA). Within each stage, we present findings how these teachers experienced the professional learning workshops, used Urban Advantage tools in their classrooms, and collaborated with other teachers within and outside the program. We selected learning experiences, tools and collaboration as focal themes because all interview transcripts had these thematic codes attached to them. Furthermore, after multiple rounds of coding and re-coding, we found that most of our codes could be captured under these three main themes.

Findings About *New* Urban Advantage Teachers

New teachers' learning in Urban Advantage.

For the new UA teacher, doing science investigations themselves allowed them to step into the shoes of the learner and anticipate the questions and struggles the students will have. Ms. Ahmed, a first year teacher, describes how doing an investigation herself helps her anticipate the struggles students will have:

> I think seeing me do an investigation using plants, which I have openly told them, like, 'I don't know biology.' will also be helpful, because I get a lot of the, 'I don't know this. I can't do this' kind of a thing. And it's like, 'Well, I couldn't either, but, here you go.'

Mr. Baker, another first year UA teacher, describes the experience of asking a clarifying question in a PL at the risk of showing his ignorance. This simple experience made him think about how to create a supportive environment for his students to ask questions.

> I approached [the Facilitator] and said, 'Well, the zebra mussels, they seem to be cleaning the river. Isn't that good thing, a nice, clean river?' And he said, 'Well, that'd be wonderful and beautiful, but that's not the natural state.' So that brought me another perspective, inquiry and the asking of questions and how to maybe get people to ask questions as they're going along. So that was helpful. And as I am conducting this, I'm trying to use that energy with my kids. So in that regard, it helped me think more like a scientist, and I felt like [deep breath] "SCIENCE"

He also described how the experience of doing science alongside science educators increased his sense of confidence as a science educator, saying, "Being with all these, you know, accomplished educators, doctor of science, whatever, it gave me more strength in that area—to teach like a scientist even if I'm not a scientist."

After conducting science investigations in real world settings, teachers described having a larger set of phenomena in science to draw on for lesson planning. Mr. Baker, a first year UA teacher, described how UA helped him bring in more real world examples into the classroom:

> There's ways we can incorporate to flesh out what they're doing and make it a little more livable and vibrant and connect with them to the real world….I incorporated that when we were talking water flow and water cycle and how we are influencing the environment. I brought up the zebra mussels as an invasive species and how these things affect us.

They also spoke of how conducting experiments in a real world setting shifted their perception of the world. Mr. Scott, a second year UA teacher, reflected on how a professional development workshop helped him think about a phenomenon he had experienced, but had not previously identified as a phenomenon that might be relevant to teaching science:

> We took data on the different growths with the different levels of salinity that we exposed them to. I thought it was pretty cool. We charted it to make different kinds of connections, like how saltwater may effect roadside plants. You know saltwater they would put on a highway and then how that would effect the growth of nearby plants. And then in my head I thought about my golf course experience and how saltwater could effect the turf grass there. That kind of got my mind going a little bit.

Teachers described their first year in UA as a time of learning, experimenting, and making mistakes. They related becoming aware that they have “only scratched the surface” of how to teach science as a set of practices and that it takes time to absorb all the strategies and practice to implement them successfully. All four of our new UA teachers discussed this process. A first year UA teacher, Mr. Baker, explains:

> I'm learning it as I'm going. It's almost as if we're running parallel, and I'm just trying to pull things in as I'm going….I probably haven’t delved as much as I wanted to, simply because trying to fold in new things on the fly, this would be something I would do over the summer. Then really fold it in from the beginning.

Finally, three teachers across our sample acknowledged being overambitious in their first year and admitted they had to pace themselves. Ms. Pavao acknowledged:

> I needed to learn a lot about how the investigations work so I could really help the students. I had to relax a little because especially with the students I work with, they needed a lot of support and we needed to slow down a lot.

Beginning to use UA tools in the classroom with limited flexibility.

In coding the transcriptions of teacher interviews, an excerpt was tagged with the code “UA tools in the classroom” if the participant discussed the use of a specific instructional tool supported by Urban Advantage in their science classroom. The code was broad, including cognitive scaffolds to support aspects of the long-term science investigation (e.g. DSET, IDD, I-squared, hypothesis frame, four question strategy), scaffolds for supporting literacy (e.g. text boxes, anticipation guides), specific formative assessment probes (e.g. from Paige Keeley), and discussion protocols (e.g. NSRF protocols such as chalk talk, ladder of feedback). However, Urban Advantage professional learning does not follow a prescribed curriculum for teacher or students; thus, the “tools” used in UA are distinct from specific curriculum materials. UA tools, notably the DSET and IDD, are paper and pencil (as well as digital) tools for organizing thinking and writing. Materials that the teachers encountered in the PL represented important tools for learning to teach science in an ambitious way. Embedded within these tools are conceptions of what it might mean to teach (and do) science. Teachers’ use of tools will vary depending upon their own beliefs, knowledge of the subject, context in which they teach. Teachers’ knowledge of their subject matter, in this case science, will affect how they respond to the tools (Grossman, Smagorinsky & Valencia, 1999; Grossman, P. L. & Thompson, C., 2008).

As our analysis revealed, the way in which the teachers took up the tools was related to their experience in the program. Teachers discussed a wide variety of tools; however, the investigation design diagram and designing a scientific explanation tool were discussed the most, with all teachers mentioning each tool at least once. Furthermore, teachers’ discussions of tools connected to their talk of teaching practice, leading us to believe they were important in the development of practice. All first year teachers that were interviewed had completed Cycle 1 and

Cycle 2, and thus had been introduced to the Investigation Design Diagram (IDD) and the Designing a Scientific Explanation Tool (DSET) and used the tools while completing a group long-term science investigation. Ms. Rivera and Mr. Baker completed five days at the American Museum of Natural History about conducting a secondary research project using data about the zebra mussel population in the Hudson River. Ms. Pavao and Ms. Ahmed completed five days at the Brooklyn Botanic Garden conducting a controlled experiment about plant growth.

Ms. Pavao was an outlier in the sample in that she seemed to have little recollection of the tools in the PL and did not report using them yet in her own classroom. Ms. Rivera was familiar with the IDD and DSET because her school used these in the middle school science classrooms that she pushed into, even before she had started UA herself. When the interviewer probed her about use of the tools, she said she used the tools but did not elaborate on how, when or why, saying, "I already knew the DSET because that's just a tool that my school really uses a lot. We use the investigation diagram for experiments."

Mr. Baker also had UA colleagues at his school, so even though this was his first year in UA, he had some familiarity with the tools. He was eager to integrate the IDD and DSET into his instruction, though admitted that he struggled with supporting his students in writing. Many of his students were functioning below grade level in reading and writing and needed a lot of support to structure a hypothesis, even with the scaffolding provided by UA. He described his attempts to integrate scientific explanations in this way:

> We don't touch on [the DSET] enough, and I try to come back and revisit. [The students are] just getting the hypothesis, which I had to kind of re-introduce to them. So getting to that next higher level of the argument, we're not there yet. And it's probably something

> that we probably won't achieve this year, even though I'm going to try to get them when they do long-term investigation project, see if I can guide them to that (Baker, Y1).

Mr. Baker had strong interest in integrating the tools, though had not thought through how exactly to modify the tools to meet the needs of his students. He wanted to integrate the UA approach, but was still figuring out how.

Ms. Ahmed was a first year teacher, as well as being a first year UA teacher; however, she received her Master's degree in teaching at the American Museum of Natural History and thus had previous exposure to Urban Advantage and the tools. Furthermore, all of the science teachers at her school were currently participating in Urban Advantage PL, so there was shared understanding of the UA approach to science teaching. When asked about her use of UA tools in her classroom, Ms. Ahmed described how she was phasing in the use of the scaffolds, piece by piece, in her own classroom.

> So, right now at about the halfway point of the year we're implicitly doing these things where we're looking at the investigation designs, even in the labs we do in class. But we do not feel that our students are quite ready yet to identify all these things on their own or to have the ability to fully complete, for example, an IDD.

Ms. Ahmed also discussed that students in all grades (6^{th}, 7^{th} and 8^{th}) visited and re-visited independent variable, dependent variable, and hypothesis construction during their first unit of the year. She described cross-grade focus on the components of an investigation this way:

> So across the grade levels, we taught in our first unit independent variable, dependent variable, how to write a hypothesis and how to write a testable question, all following the UA structure and the UA rubrics. So like how does independent variable affect the dependent variable, basically.

New teachers' collaboration.

The first year of UA professional learning involves frequent opportunities to collaborate with other teachers and this aspect of collaboration was frequently cited as an important feature of their first year experience. Many first year UA teachers are new to teaching science, or new to teaching period (approximately 75% of first-year UA teachers are also in their first year of teaching in the NYCDOE) and really appreciate the support and camaraderie that developed in first year workshops. Mr. Baker describes his experience:

> It was much more collaborative – the four of us were together for like three or four – these PDs became very friendly. So that was nice to do. I like how that all went through, from the very first talk we were connecting everything to doing the research and picking a subject. Putting it all together real quick. And I thought, "Oooh, look at this. It's very nice . . . So in that regard, it was nice to work with everyone and see how they approach things . . . .

Mr. Baker also reported that the experience of being able to share their challenges with their peers took the pressure off the feeling of "having to know it all already." He reported, "I even see at this level the teachers are having fun with it. And there was a lot of leeway for people to make mistakes and learn from their mistake and collaborative working."

Reflecting on his first year, Mr. Scott, a second year UA teacher (and sixth-year teacher in the NYCDOE), explains why the collaboration with other science teachers was so valuable for him.

> I'm the only science teacher in this building, for me to kind of bounce ideas with other science-, I mean, I need that. Especially, I wish I had it earlier in my academic career. Like this is my sixth year doing this as a teacher, and I wish I would have been able to, as

> a first-year teacher I didn't have any kind of mentor here at this school because I was the only science teacher. The fact that I was able to talk to other science teachers was very beneficial to me because it was something that I lacked.

After the experience of hands-on collaborative learning in Cycles 1 and 2, teachers described then sharing UA practices with their colleagues in the school building. This appears to be an important way that knowledge about the program is spread to new teachers. Especially for teachers just starting out in teaching, or teachers who are new to teaching science, the sharing of these resources and practices is valued tremendously.

Ms. Ahmed, a first year UA teacher, described how a more veteran teacher in her school serves in a mentor role to the new UA teachers. Ms. Pavao described how UA teachers in her school shared with each other what professional learning workshops might best suit them. AndMs. Young, a second year teacher, described how working with her co-teacher who is in UA helped her.

> We work so closely together. Because she's been in the program and because even the teachers before me were in UA, they left a lot of their resources that we can still use, and that we do use in the curricula.

Findings About Mid-stage Teachers

Mid-stage teachers' learning in PL.

As teachers transition into their second year, the focus of the professional learning shifts to planning science investigations over the course of the whole school year. Teachers reported learning how to scaffold their science investigations, starting with simpler and shorter investigations and moving toward more complex and longer investigations. Ms. Long, a third year UA teacher, identified Cycle 2 as the point at which her teaching began to noticeably shift:

> I would say that honestly after Cycle 2, that was the time that I was able to think about teaching the students in a very different way. You know, like the idea of what is a long-term science investigation, how can we use the institutions that partner through Urban Advantage to teach students, etc. The investigation that I did during Cycle 2—I literally did that here with my students. They had to do a behavioral study and because I had gone through it step by step with the professional development itself, it just gave me more of an ability to think about what the experience was going to be like for students, where they're going to struggle and what I can do in advance of that to make it easier for them to understand what we were doing.

She also expressed pride in seeing final product of her students' science investigations – presentations that displayed a comprehensive improvement in the quality of their work. Reflecting on his first few years in UA, Mr. Garcia describes the kinds of workshops he found most useful in his early years in UA:

> "The ones that took you through an entire long-term investigation from beginning to end, combined with the fact that there were lead teachers and partners who genuinely liked what they were doing and were actually trying out these strategies in their classroom and bringing their anecdotes or their stories of what worked and what didn't work to the workshops I think was what I really gravitated towards because I could see them modeling this, I could hear what worked and what didn't work, and then I can go and experiment in my classroom."

Teachers continuing in UA reported that deepening and refining their practice of inquiry-based pedagogy was an ongoing process. Mr. Reyes, a 3rd year UA teacher, acknowledges he is still making the shift from a teacher / content oriented pedagogy to an inquiry-based, hands-on pedagogy.

> "I'm still not fully adapted. I think I'm most comfortable and I guess it's just easier to stand in front of the class and give direct instruction and just tell them the facts. …But I do see having my students actually doing something, contributing is really, really important for their interest and then also for their actually learning this stuff. So, anytime I can incorporate an activity or an investigation or something hands on into my lessons, I definitely want to. But there's 180 days in the year and maybe I have maybe 50 or something days where we're doing something hands-on, we're doing some investigation or something. So, I still have a lot of growth in me to do."

Mid-stage UA experience teachers talk about the IDD and DSET.

UA teachers with two to three years of experience in the program discussed using the IDD and DSET regularly, as part of their practice of supporting students in undertaking scientific investigations. UA teachers had at least one year of experience in UA—they had completed Cycle 1 (introduction) and Cycle 2 (full scientific investigation) the previous year, and had participated in Year 2 PL already. Both Mr. Reyes and Ms. Young described using the investigation design diagram to guide students through in-class investigations. Mr. Reyes, a third year UA teacher, described changing the format slightly so that it made more sense to her and her students. She said she did not quite understand how an experiment could have "levels" and thus tended to disregard this part of the IDD: "…when we're designing an experiment, yes, I have them write their questions. So, it's kind of like the same components of the IDD. Something

I don't do that's similar to that is the levels of the investigation. I thought that was confusing [in the PL]."

Ms. Young, Year 2, also described being slightly unclear about the two different versions of the IDD, saying:

> "There's the one with the analysis and the conclusion part, and then we even use the rubric because it breaks everything down for you. I'm trying to think. I feel like there's more. I know there are different variations of that one template, and I've used both of them."

Despite being confused about the "levels" part of the IDD, both teachers used the IDD to frame frequent small investigations in class. Mr. Scott, Year 2, spoke most enthusiastically about structuring his lesson plans each day around the IDD and the DSET. He said:

> "I use the investigation process constantly. I use, even just how does blank effect blank, the format of the question, we use that regularly as an aim of my day. Even if we're not doing an investigation per se, I use that format of an aim – how does one thing effect the other thing? How does one variable effect the other variable? I do that most regularly."

Mr. Scott had incorporated the IDD into his everyday teaching practice to an even greater extent than Mr. Reyes and Ms. Young. He seemed to attribute his enthusiasm and adoption for the IDD to the fact that his students enjoyed "answering scientific questions" more than just hearing a lecture and also that he had the freedom to change his practice as he saw fit—he was the only middle school science teacher at his school and his principal was supportive and enthusiastic. He had also firmly embraced the DSET and framed much of his discussion in class using Claims, Evidence and Reasoning. He described his practice this way:

> I really like the scientific explanation setup with claim, evidence, and reasoning. I do that quite regularly also. Even if it's not data that we've generated in our own class investigation. I've used data that we collected a source or in research and then we could make a claim and backup reasoning from that data as well. I really use that tool quite often.

The tools played an important role for teachers learning to develop their practice around supporting investigations; perhaps none more than Mr. Scott, a Year 2 UA teacher. Mr. Scott did not enter teaching with extensive previous science research experience and he was the only middle school science teacher in his school. Of the newer UA teachers (Years 1 & 2), he was most effusive about his embrace of UA tools in the classroom and spoke specifically about how they altered his teaching practice. He was in his fifth year of teaching overall, and remarked that prior to joining UA the previous year, he relied almost exclusively on the textbooks and review questions to structure his science classroom. In his first year of Urban Advantage he found that he was drawn to the focus on "investigation" and, in addition to repeating small Urban Advantage investigations from PL in his own classroom as well as supporting students in completing long-term science investigations, he began re-framing his classroom around the investigation model, using the IDD and DSET to structure his cycles of learning for students. Mr. Scott described the shift this way:

> [UA] has really helped me provide quality investigations to my kids. Posing quality questions and backing up questions with a source, I think that's a very powerful tool. We generate this data in the classroom and then we make a claim about the data we generate. Then we back up that claim and we back up that data from an outside source and I think that process is incredibly powerful and that has benefited me as a teacher. If someone

> asked what I got the most out of, I would have to say that. It's making a claim, backing that claim up with data that we created, and then we back that up with a source.

Similar to Mr. Scott describing this process of shifting his science teaching to be more driven by the investigation paradigm, than by the read-the-textbook- and-answer-the-questions paradigm, many of the early stage UA teachers described embracing the structure the IDD and DSET provided, adopting that structure into their classroom, applying it to a more diverse set of pre-existing activities. More experienced teachers discussed the tools in an even more flexible way, and described the ways in which they used portions of the tools for different investigations and altered the language or structure to fit better with school-wide initiatives.

Ms. Long, a Year 3 teacher, also described the DSET as an important tool in her classroom. She discussed using the DSET as a way of supporting significant discussions in her classroom about what counts as evidence. Here, she describes her thinking:

> Generally speaking, I've found the DSET tool, even though it's only a graphic organizer, its ability to help students distinguish between a claim, data as evidence, as reasoning not only in terms of writing it and writing a cohesive response to something, but in terms of what is classified as evidence, what are ways to think about different forms and representations of data, I found that to be a tool that I've used or scaffold the most.

Like Mr. Scott and Ms. Long, Ms. Young reported success with implementing instruction framed around the two main graphic organizers. She described feeling proud of the way her sixth-grade students learned how to analyze data and form a conclusion. She said:

> So being able to see them come in with nothing, to having these resources structure their writing so that they come out of 6th grade being able to write an analysis or a conclusion.

> Even seeing the logical progression of things, it's not just like one section is really good, it's like it all flows together.

As a group, the mid-stage UA teachers, discussed using the IDD and DSET frequently in their classrooms, not only as tools to be used during investigations, but also as organizing frameworks for their lessons and classroom discussions. Despite all using the tools frequently, these teachers differed in the degree to which they understood the nuances of the tools. For example, Mr. Reyes and Ms. Young confessed to harboring some confusion about various versions of the IDD and thus ignoring portions of that tool. Mr. Scott understood that the tools could be used more generally to frame a lesson or stimulate a discussion; that it was acceptable to only address a part of a tool in a given lesson. Ms. Long not only used the tools frequently, but also described using the DSET as more than a tool to scaffold her students writing, but as a way to elicit students' ideas about what counted as evidence in an explanation.

Mid-stage teachers' collaboration.

Co-planning with other teachers in the school often evolves into unofficial UA mentoring, giving second and third year UA teachers opportunities to support less experienced teachers. Continuing UA teachers spoke of how they shared what they learned in UA PL with colleagues, and as a result, often became mentors and pedagogical leaders in their school. Ms. Long, a third year UA teacher, describes how she shares the practices she has learned in UA with other teachers in his school.

> Whether you're studying the effect of the IV on the DV or maybe you're saying, "I think – " or whatever it is, or writing a scientific explanation I'll use these frameworks to help

> other teachers understand how to help their students engage in a lot of these practices that make the learning meaningful for students.

To help teachers prepare a school wide science fair, Mr. Scott, a second year UA teacher, shares his knowledge about what makes a strong science investigation:

> Since UA, I've really stressed to the other teachers in the building about having a testable question that generates data. And I've taught the others. We do the science fair from 3rd to 8th grade and then I've taught the Urban Advantage investigation model to the 3rd, 4th, 5th, and 6th grade teachers before they do their science fair intro.

Ms. Russo, a fourth year UA teacher, who is now a lead teacher, describes how she plans with her co-teacher who is not in UA.

> I work with a special educator and her and I will plan together and figure out what we're doing because we teach in the same classroom with the same students…she's not officially part of UA but I'm sharing things with her. So she's kind of being exposed to some of the UA strategies. I just really believe in them. I think they're good.

Veteran Teachers

In the group of teachers that were classified as “veterans,” Ms. Flor had been teaching the longest (21 years) and been a part of UA for eight years. Ms. Martin had been teaching and been a part of UA for 11 years. Mr. Garcia was a ten-year veteran of teaching and a seven-year veteran of UA. Mr. Garcia was also a “lead teacher” in UA, meaning he planned and co-facilitated PL for teachers for the past two years. Ms. Russo had been teaching five years and a part of UA for four years. However, given her lead teacher status, she had logged more UA hours than other four-year UA participants and her responses to the interview questions revealed that she had developed a strong understanding of science, teaching, and the UA program; thus, she was classified as a veteran.

Teachers that have been in Urban Advantage for four or more years have a wide variety of courses that are available to them, from deep dives into content to sessions about coaching students' through long-term investigations to about reflecting on practice using video.

Common experiences in UA professional learning workshops

The veteran teachers in our sample all discussed how they continue to share ideas and resources with their peers as they continue on in UA PL. All four of the veteran teachers described feeling comfortable reaching out to other science educators, especially since they have worked with some colleagues in the workshops for years. Ms. Flor said, "I end up talking to everybody in the room eventually and getting ideas and sharing ideas." Ms. Russo stated, "I also find it valuable in UA workshops to talk with other teachers. Sometimes they're like, 'Oh yeah, I know this website that's good for this,' and just having that professional network has been really valuable." Mr. Garcia also described how he continues to use the workshops to network with other science educators:

> Yeah, if they've said something that they're doing in the classroom and I reach out and ask, 'Can I see an example of that? Can you send me a picture of it? Can I see your lesson for that?' And that's the kind of questions that I've gotten, so I think it's – the way that UA set it up provides a good opportunity for that sort of communication.

Two of the four veteran teachers (Ms. Russo and Mr. Garcia) were in leadership roles within UA itself, as "Lead Teachers." Lead Teachers apply for the position and, if selected, co-facilitate professional learning for teachers. They co-plan with the informal educators at each institution. They participate in professional learning along with PL facilitators. They both had co-presented at local, regional and national conferences.

Veteran teachers' use of tools.

All four veteran UA teachers discussed the IDD and DSET as tools that were frequently used in their classrooms, for both small class investigations, and longer-term independent investigations. They talked about the tools as being introduced at the beginning of the year and then integrated into the work throughout the year. Ms. Flor and Ms. Martin's discussion of the tools focused primarily on the frequency of use. For example, Ms. Flor discussed the progression of use of the IDD and DSET like this:

> We did a whole project in the classroom with the DSET and the IDD. [The 6th-grade] teacher is really good at introducing everything, and then we work together as a team. We do little mini-projects, just so they get used to it, so that when they do their own projects, now they have all the tools, they know how to use them.

Ms. Martin also discussed frequent "labs" (she elaborated that she classified activities that involved data collection as "labs") for which she relied on the IDD and DSET to structure the setup, data collection and analysis:

> So when my kids are writing up like just regular lab reports every week because we have a double lab period once a week for my Regents class. And so, depending on the lab that we're doing like they're all required to write up, to like include an IDD or use the DSET to write their discussion. So I would say that like its used, for me it's used like very regularly because I have very regular – I do labs very frequently.

Mr. Garcia and Ms. Russo also discussed regularly integrating the IDD and DSET into their science instruction. However, these two veterans also offered ideas about how these cognitive scaffolds supported students in emulating the practices of scientists. This grasp of the way that the scaffold functions to support students engage in the discourse of the discipline helped Mr. Garcia and Ms. Russo motivate students to use the tools. Because they had more experience participating in and leading UA PL, they had more experiences with scientific investigations. Thus, they understood what explanations/arguments looked like across disciplines, and could highlight the key features of the tools for students, and make appropriate alterations to the scaffold to fit the particular content area or specific investigation.

Both Mr. Garcia and Ms. Russo admitted that the IDD was not their favorite UA tool, but the one that they felt was perhaps the most useful. They discussed their students not liking it because it was "repetitive" – by the time they got to the stage of filling out the investigation design diagram, they had already written their title, question, and hypothesis somewhere else, so there was some copying over that felt tiresome. However, they both spontaneously described the more important function of the IDD being that of a summary of the investigation as a whole, or the way a scientist might present an "abstract" that briefly and efficiently described the motivation, findings, and conclusions of the work. Ms. Russo said:

> [We use the IDD] when we do investigations, yes. But I think the IDD's kind of like a summary of the other pieces. So it like includes the title, includes the question, includes the hypothesis, which are all kind of other parts.

Mr. Garcia spent more time in the interview musing about the IDD and his and his students' reactions to it.

> The investigation design diagram is something I think the students don't like . . . I argue against that by saying if you were going to a conference, a pharmacology conference to see, for example, the top researchers in their field, talking about new drugs to cure diseases they're going to have a little snapshot somewhere on their poster that says, 'This was what we were investigating. These were our variables. This is what we wanted to look at, and here was our short conclusion.' But a brief snapshot, an abstract that is representative of the investigation itself, and that's like the student version of the IDD.

Having this deeper understanding and appreciation for the IDD allowed Mr. Garcia and Ms. Russo to effectively adapt the IDD, sometimes having students complete only sections of the tool or changing the format of the tool depending on the specific scientific discipline.

Mr. Garcia and Ms. Russo also spoke about their appreciation of the DSET as a scaffold for students reasoning in science. Whereas some of the more novice UA teachers discussed the DSET in purely mechanical ways (you put the claim here, you put the evidence here, etc.), Mr. Garcia and Ms. Russo discussed the importance of the Claim-Evidence-Reasoning Framework (McNeill & Krajcik, 2012) and the ways in which this framework was similar to and different from argumentative writing in other disciplines. Both of them had altered the DSET slightly to fit with their own schools' initiatives regarding literacy and argumentative writing. Mr. Garcia called his version of the DSET "mutated," meaning he had changed the language and format slightly to make it work for him and his students:

> There's a version of it right there. Yeah, yeah, that's my version of the DSET that's a mutated version of it, I guess. But that is one thing I've implemented. There's the CER, for evidence in science knowledge.

Ms. Russo spoke about collaborating across departments in her school to help the DSET match the ways that students wrote in other classes:

> So yeah, they use the DSET and so for some of that it's just like changing what we call things so they match what our kids know. So like in UA they say like claim evidence and reasoning. And at my school we would say something like thesis, explanation, connection, so just like modifying the language because our literacy team streamlines across content. So making sure I honor that but also the tools are good. And we've actually, as a literacy team, taken some of the UA tools and used them for some of our cross content literacy work, so text boxes, for example we use this year and modify that structure to help our kids with literacy skills.

All four veteran UA teachers discussed using the IDD and DSET frequently in their science instruction, for investigations of various scales. They spoke about using it across disciplines within science and also collaborating with teachers in other departments to help students see the connections between, say, the DSET in science and argumentative writing in English Language Arts. Finally, Mr. Garcia and Ms. Russo discussed understanding the IDD and DSET as more than writing scaffolds, but more as organizing frameworks for structuring students' work in science.

The role of veterans in promoting collaboration.

One veteran UA teacher, Ms. Flor, described how she unabashedly encourages new teachers in her school to join: "I was like 'Every unit you can go somewhere and study something to back up what you're teaching in the classroom and that's really helpful.' And they get jealous and I'm like, 'So join. Join, you can go on your own trips [laughs] . . . ." Another veteran teacher, Ms. Martin, also believes that UA works best when a number of teachers in a school are involved: “When I meet other teachers they probably think I’m like a spokesperson for UA because I tell them all the time, you need to get all of your teachers involved. Like you can’t just have one teacher.”

UA experience helps develop veteran leadership in a school.

The four veteran teachers reported that continuing to attend workshops allowed them to go deeper into specific aspects of science education, such as science literacy. They described gaining experience using tools and strategies that are transferable across grades and disciplines. As a result, all the veteran teachers found themselves in positions of leadership within their department and their school. Ms. Martin has become responsible for coordinating the professional learning activities for her science department. She explains her role:

> We’re really planning ahead this year–I’m asking each teacher in each grade level to reach out to institutions to figure out what courses are being offered so you can figure out what workshops [to take] so where you can build it into your units.

Ms. Flor described how she works with her colleagues to come up with new ideas for real world experiments:

> We've been together a while. And it's like let's try this, let's try that, let's go test the water at Prospect Park, and collect a water sample at the pond. And you know that's another kit I got through Urban Advantage. And they're like, okay, let's go do it. And then we'll do a mini-lab with it. Testing the soil, testing the water, all those testing kits I got with my UA money.

Mr. Garcia described how UA has allowed him to develop an expertise in the practice of peer feedback among students in science writing. He also described how UA has become the curricular framework for his school's science department over time.

> If more grade levels within your school are implementing it then it becomes a cyclical process where teachers can layer in more depth to those strategies as the students progress through sixth, seventh and eighth grade. And that's something that we're constantly trying to get time for. I think that's something that we want to do more of: how can we align a lot of the UA stuff that we're doing in sixth grade with the UA stuff that's happening in seventh and in eighth. And it is – that's an ongoing process. It is happening to some extent. We would want it to happen a little more.

Interviews with the veteran teachers revealed how UA can contribute to pedagogical change at the whole school level. A pattern emerged in which collaboration at UA PL workshops made collaboration with peers in one's school easier. Collaborating with peers in one's school, combined with deepening one's expertise through long-term professional learning, developed teachers who were curricular leaders in their school. These teachers in turn were then in a position to train other teachers. For these schools, UA pedagogy gradually became the framework for their science curriculum.

Discussion

This work contributes to the literature on how professional learning impacts science teachers' classroom practice and points to critical features of professional learning that might be leveraged to improve practice at large-scale. This work begins to illuminate which features of the professional learning appear to be effectively translated into the classroom, and how changes in teacher practice as a result of the PD may cause the "Urban Advantage" effect on students' science test scores. In addition, findings from this research can directly inform the Urban Advantage program itself and similar programs. The work answers questions about which aspects of the program are indispensable and which aspects should be developed even further, since they appear to have a strong impact in the classroom.

Getting different things from professional learning at different stages

Urban Advantage's existing professional learning coursework reflects five key ideas based in research on teacher learning: a conception of teachers as professionals; an understanding of teacher learning as occurring on a continuum; an investment in teacher learning in community; a recognition that teacher learning involves inquiry and research conducted by teachers; and an emphasis upon the centrality of examinations of student learning.

First, UA is built upon a conception of **teachers as professionals**. UA conceives of teaching as more than a set of skills that teachers need to develop; it is a profession: "one that highly capable individuals enter and remain in throughout their careers, and one that provides them with the kind of satisfaction and rewards that other professionals, such as lawyers and engineers, enjoy." (Darling-Hammond et al., in press). As a professional, continued learning is not only part of the responsibility of teachers (New York City DOE, 2014), but also a generative, enriching opportunity to mirror the work that we hope students will do.

Second, UA is built upon an understanding that **teacher learning occurs on a continuum**. As teachers grow and develop their practice, they are working on different features of their work and may have quite different needs. In fact, the 'central tasks' of learning to teach vary over time as teachers develop through the course of their careers (Feiman-Nemser, 2001). A novice teacher in the first few years of their teaching is working on developing an early repertoire of good practices, becoming familiar with the curriculum, school and district context, and developing a professional identity, while a more veteran teacher is ready to deepen his or her work is poised to engage in inquiry, deepening content knowledge, and deeper examinations of teaching and learning. At the same time, the continuum does not promote a view of teacher development as having a 'end' in which teachers have 'arrived' and are done learning. As Feiman-Nemser argues, "Obviously, learning continues for thoughtful teachers as long as they remain in teaching." (2001, p. 27).

Third, UA is grounded in research that finds that **teachers learn best collectively**, and that finds that if teachers learn alongside peers, this community not only helps support the learning of individuals but also builds capacity and leverages schools' collective work (Bryk et al., 2010; Croft et al., 2010).

Fourth, UA reflects research on teacher learning that emphasizes the importance for **teachers to engage in inquiry** in their own study of practice, to inquire into their work, and to study teaching strategies, student learning, and content.

Finally, the program reflects a belief that among the most powerful learning experiences for teachers are **examinations of student learning**, and that such experiences analyzing student learning can --and should-- be at the center of teacher learning (e.g. Greenleaf et al., 2011; Heller et al. 2012).

As professionals, UA teachers *have agency and choice* in determining the courses they take and how they aim to pursue their own professional learning, sustaining their interest in their own growth and supporting their conception of themselves as active learners who can direct and are responsible for their own career development (NYCDOE, 2014). As they move through their careers, UA teachers can take courses that are coherent and connected; that enable them to deepen their content knowledge and pedagogical knowledge but also that enable them to deepen their understanding of teaching over time and that are designed to reflect *their needs and interests at various stages of their careers,* as they grow from more novice, to more experienced, to veteran and master teachers.

Findings about new teachers

We found that new teachers in UA engaged in experimentation with UA resources and tools. Tried on scientist hat. Took a few things into their classroom. Research on the needs of relatively new teachers reveals that teachers in the first few years of their careers are developing a professional identity as a teacher; needing to learn about local expectations and curriculum; learning to design responsive curriculum and instruction (Feiman-Nemser, 2001). In relationship to this development, UA works closely with teachers new to the program to provide 48 hours of professional development across three different cycles in their first year, and teachers continuing in the program receive ten hours of differentiated professional development each year. Even though not all teachers new to the program are actually 'novice' teachers (although certainly many are quite early in their career), in UA we ask that they experience this immersive professional learning to prepare them to focus upon specific content, to learn how to support students in long-term investigations, and to do long-term, deep inquiry themselves. This substantial support really helps relatively new teachers begin to grasp and have some grounding in an early repertoire of beginning science teaching practice.

As novice UA teachers grow and learn, they are able to take a set of courses that enable them to deepen their content knowledge, along with their pedagogical content knowledge, and their pedagogical practices. Courses like the 100 level courses support teachers to learn about how to design experiments for their students; and to begin to learn to use a set of 'tools' that support students' ability to construct scientific explanations and to design experiments. Teachers also have an opportunity to deepen particular kinds of teaching practices related specifically to these investigations. Research suggests that for newer teachers to continue to learn and grow, they need to use their practice as a site for inquiry; early sets of UA courses begin to build teachers' experiences around conducting research (Ball & Cohen, 1999).

Mid-Level Coursework

After the early stages of learning to teach, teachers enter a stage of 'experimentation and consolidation' (Berliner, 1986; Huberman, 1989). Consistent with that research, as teachers gain more experience doing specific kinds of investigations, the 200-level courses are designed to help teachers make connections between helping students do deep, long term work in science and the school curriculum/Common Core. They are also intended for teachers who have deepened their understanding of the four types of investigations; but are designed to give teachers opportunities to deepen their practice around helping students develop strong scientific arguments. This coursework also provides UA teachers with opportunities to link their experiences working with children's investigations, to connect to the Common Core, and to firm up the connection between the work on investigations and local curricular requirements.

Reflecting research that finds that more experienced teachers seek ways to deepen their content knowledge (Feiman-Nemser, 2001), Level 300 courses are designed to provide targeted opportunities for teachers to deepen their content knowledge in a set of specific topics. In this set of courses, the focus begins to move even more deeply into examinations of student thinking, with a particular emphasis upon identifying students' misconceptions and lay understandings.

UA Professional Learning for Experienced Teachers

Finally, research finds that the third stage teachers enter—roughly corresponding with the 7th year of teaching—reflects "mastery and stabilization." (Berliner, 1986; Huberman, 1989). Over time, most teachers at this point have developed instructional routines, know what to expect from students, have 'settled into teaching patterns with confidence" (Feiman-Nemser, 2001). Reflecting this development, experienced UA teachers at the 400 level set of courses have opportunities to begin to pursue their own investigations of their teaching. In these sets of courses, teachers gain experience using protocols for looking at student work, such as the "tuning protocol" (Blythe, Allen & Powell, 1999). These courses are aimed at providing opportunities for focused examinations of student work, with the purpose of surfacing student thinking and helping teachers fine-tune their ability to shape instruction and to research and explore the complexity of student thinking and learning.

Veteran, experienced teachers who know students well, and are steeped in pedagogical and content knowledge—and who are committed to and passionate about continued learning—are our deepest resources in the public schools. Providing *experienced teachers with continued opportunities for growth* is a key idea in UA. In fact, as their practice has 'stabilized' in some ways, it is the most productive opportunity to begin to deepen, question, and push more learning—to help teachers who may be hungry for more opportunities to learn and to avoid settling into work and teaching and becoming static in their development.

Next steps for this work will include analyzing observations and artifacts from the four classroom case studies. This paper focused on teachers' self-reported learning and instructional decisions; however, we recognize that a central limitation to these conclusions is that they do not take into account what teachers are actually doing in their classrooms.

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Appendix A

Semi-structured Interview Protocol

Background information

Educational background

1. Tell me about how you decided to become a teacher. Tell me about how you chose or were chosen to be a science teacher?

2. Tell me about the schools at which you have taught? How many years have you been teaching? Which grades?

3. Tell me about your previous preparation in science
   - Did you take classes in science in college?
   - Did you major in science in college?

4. Tell me about your preparation for teaching
   - Tell me about your teacher preparation program (structure of program, classes taken, student teaching experiences)

5. Tell me about your previous experiences with scientific investigation or scientific research, separate from the Urban Advantage Program.

Teaching context

6. Tell me about your school
   - Students
   - Academic program
   - Frequency of science instruction

Initial ideas about high leverage teaching practices

7. In your mind, what are some specific things that great science teachers do in their classrooms?
   - Why do you think these are important things to do?

Involvement with Urban Advantage

Summary of involvement

8. Tell me about your involvement with the Urban Advantage Program
    - When did you start participating?
    - How long have you been in the program?
    - Which PD courses have you taken? (can verify in database)

9. Could you tell me about a memorable PD experience?

Teachers' perception of the extent to which they integrate UA tools, routines, and resources

10. How do you use UA tools in your classroom, if at all?
    - How do you use the DSET, if at all?
    - How do you use the IDD, if at all?
    - Are there other specific tools or prompts from UA that you use regularly in your classroom?

11. How do you use UA routines in your classroom?
    - [need to clarify this]

12. How do you use UA resources (science equipment) in your classroom, if at all?

13. How else do you think UA influences your teaching, which might be less noticeable to an outsider?

Planning for the observation of the teaching sequence in Spring 2015-2016

14. I would like to think ahead to when we will return to your classroom to observe a series of science lessons . . .
    - Which science units will you teach in February, March, and April?
    - Is there a unit or sequence of 3-5 days that you think would work well to observe? Why do you think this is a good lesson to observe?
    - What are the next steps we need to take to continue? (quick intro to the Scoop method, sketching out a plan for the spring)

Appendix B

Semi-structured (Post) Interview Protocol

Debrief of the "Scoop" observation and materials

1. How does this series of lessons fit in with your long-term goals for this group of students?
2. How representative of your typical instruction was this series of lessons (with respect to content, instructional strategies and student activities)? What aspects were typical? What aspects were not typical?
3. How well does this collection of artifacts, photographs, and reflections capture what it is like to learn science in your classroom? How "true-to-life" is the picture of your teaching portrayed by the Scoop?
4. If you were preparing this notebook to help someone understand your teaching, what else would you want the notebook to include? Why?

Perception of alignment with the Urban Advantage

5. Were there places in the teaching sequence that very clearly connected to things you have experienced in the Urban Advantage Program?
6. Did you use any UA tools, routines, or resources in the sequence of 3-5 lessons?

Developing ideas about high-leverage teaching practice

7. Did you receive any support with planning this lesson? (e.g. from instructional coach, fellow teachers, UA staff, etc.)
8. Were there particular moments in this unit when you felt that something you did really "worked" for your students? Why did you think this was an effective teaching move?
9. Were there particular moments in this unit when you felt that something really didn't "work" for your students? Why do you think this teaching move was not effective?

Thinking aloud about student work

This protocol will be based on Ericsson and Simon (1993). Teachers will be presented with a small collection of student work (TBD – likely a selection of *pieces of* previously completed exit projects, e.g. scientific questions, procedures, graphs, and/or conclusions).

10. The task will be to rank order the sample work. Participants will be asked to "think out loud" as they complete the task.

11. Following the think aloud task, teachers' will be asked the following questions:

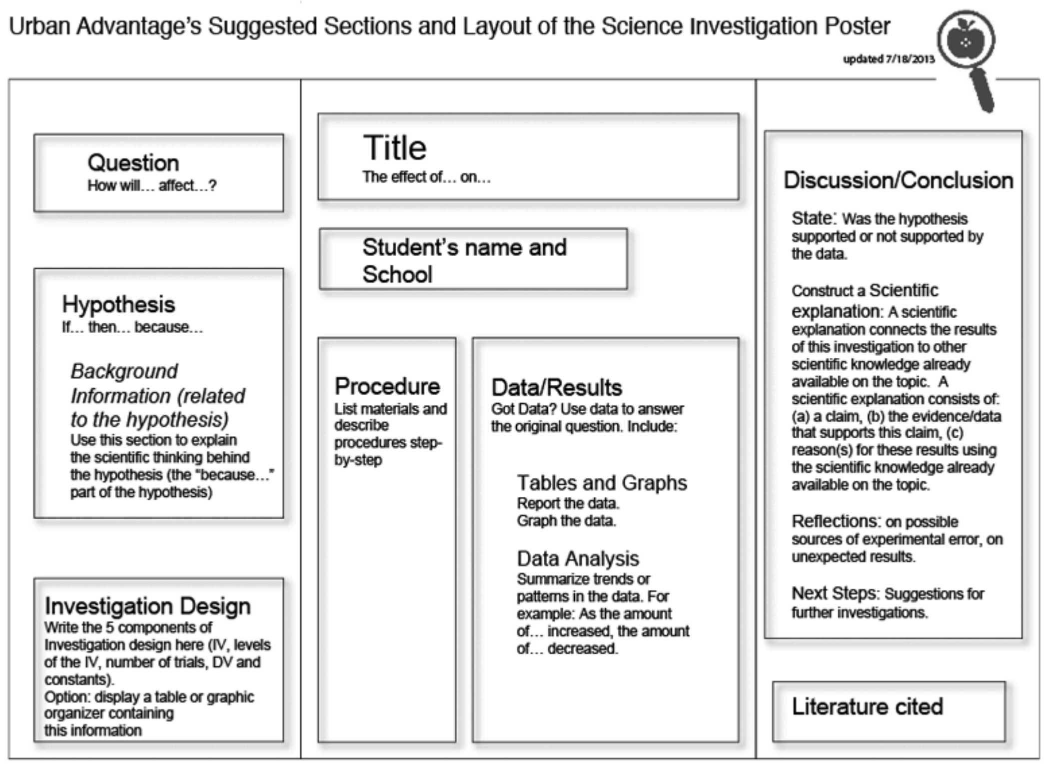
- What are your initial thoughts about each [question, procedure, graph, conclusions]?

- What overall pictured do you get? Where is this hypothetical class at?
- Can you group these [questions, procedures, graphs, conclusions] based on strength of response? In other words, create a rough rank ordering (provide note cards with answers that teachers can move around).
- Explain your ranking. What feedback would you give to each student?
- If these responses represented your class, what might you do to have more students do better on the [aspect of the investigation]?
- Could you briefly outline a single lesson in which you try to help your students improve on this science/engineering practice?

Final debrief

12. Do you have any questions for me? Can I contact you later this spring if I have questions about the work you collected or about the things we talked about in our interviews?

Appendix C


Urban Advantage's Suggested Sections and Layout of the Science Investigation Poster
updated 7/18/2013
Question
How will… affect…?
Hypothesis
If… then… because…
Background Information (related to the hypothesis)
Use this section to explain the scientific thinking behind the hypothesis (the "because…" part of the hypothesis)
Investigation Design
Write the 5 components of Investigation design here (IV, levels of the IV, number of trials, DV and constants).
Option: display a table or graphic organizer containing this information
Title
The effect of… on…
Student's name and School
Procedure
List materials and describe procedures step-by-step
Data/Results
Got Data? Use data to answer the original question. Include:
Tables and Graphs
Report the data.
Graph the data.
Data Analysis
Summarize trends or patterns in the data. For example: As the amount of… increased, the amount of… decreased.
Discussion/Conclusion
State: Was the hypothesis supported or not supported by the data.
Construct a Scientific explanation: A scientific explanation connects the results of this investigation to other scientific knowledge already available on the topic. A scientific explanation consists of: (a) a claim, (b) the evidence/data that supports this claim, (c) reason(s) for these results using the scientific knowledge already available on the topic.
Reflections: on possible sources of experimental error, on unexpected results.
Next Steps: Suggestions for further investigations.
Literature cited