Professional Development for Middle School Science Teachers: Does an Educative Curriculum Make a Difference?

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Teacher professional development (PD) is central to the realization of the current reform efforts in science education. In this qualitative study, we investigated how educative curriculum materials supported middle school science teachers’ learning within the context of a comprehensive PD program focused on the enactment of a reform-based science curriculum. Over a 5-year period, we conducted interviews and collected artifacts from formal courses and complementary project activities. Our analysis revealed that the educative curriculum materials facilitated continued science learning, shaped and scaffolded teachers’ pedagogical practices, and extended the PD while the teachers were immersed in the act of teaching. Furthermore, the interrelated project activities along with the involvement of school and district administrators offered the teachers ongoing support and provided multiple opportunities to develop, reinforce, and extend their understanding of the science content, teaching practices, and principles of the curriculum. Our findings have practical implications for the role of educative curriculum materials within the context of comprehensive PD for science teachers.

The current reform of U.S. science education is based on a fundamental change in the conceptualization and teaching of kindergarten–Grade 12 science with its focus on students deepening their understanding of crosscutting concepts, disciplinary core ideas, and science and engineering practices (National Research Council, 2012; NGSS Lead States, 2013). Science educators contend that to realize a vision of all students engaged in meaningful science learning, kindergarten–Grade 12 teachers must develop their disciplinary knowledge and understanding of instructional strategies consistent with the underlying principles outlined in reform documents (Bismack, Arias, Davis, & Palincsar, 2014, 2015; Harris et al., 2015; Mesa, Pringle, & King, 2014; Wilson, Schweingruber, & Nielsen, 2015). As science educators understand more about what it takes for teachers to successfully adopt reformed science teaching practices, innovative professional development (PD) programs have become a central component in efforts to realize reform goals and improve students’ science proficiency (Wilson, 2013).

PD is a systematic attempt to bring about changes in the practices of teachers, deepen teachers’ science content knowledge, and increase science achievement among students. Researchers posit that the effects of PD on student achievement are mediated by improvements in teacher knowledge as well as shifts in instructional practices (Lakshmanan, Heath, Perlmutter, & Elder, 2011; Supovitz & Turner, 2000; Wilson, 2013; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). However, the minimal rate of change in students’ science achievement over time has led researchers and other observers of educational practices to agree that much PD has been largely ineffective in impacting teachers’ practices and student
achievement (Hanushek, 2005; Opfer & Pedder, 2011; Wilson, 2013). Despite this troubling claim, science education reformers increasingly focus on PD to understand and implement instructional practices embodied in new standards and curricula (Sandholtz & Ringstaff, 2011).

As sets of written materials guiding teachers in planning and instruction, curricula are intimately connected to the daily work of science teachers. Some curricula are designed with resources that support teachers as continuous science learners while expanding their pedagogical skills (Ball & Cohen, 1996; Beyer & Davis, 2009; Davis & Krajcik, 2005; Schneider & Krajcik, 2002). Understanding the impact of such educative curriculum materials on teachers’ knowledge, skills, and pedagogical practices within the context of a comprehensive PD program therefore has practical implications for achieving science education reform. This research is part of a body of work investigating a comprehensive PD program and its impact on transforming the science teaching practices of middle school science teachers. In this article, we critically investigate how one component of the PD, the educative curriculum, supported teachers’ learning and impacted their science teaching practices during the program. Specifically, we respond to the following question: In what ways do the educative curriculum materials support middle school science teachers’ learning within the context of a comprehensive PD program focused on the enactment of a reform-based science curriculum?

**Literature review**

**PD to support science education reforms**

In an effort to increase the use of standards-based curriculum materials, the National Science Foundation (NSF) funded large PD initiatives focused on preparing science teachers to use these materials and supporting districts in their adoption during the 1990s and 2000s. Guided by recommendations for designing effective PD that still hold today (Capps, Crawford, & Constas, 2012; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2009; Yoon et al., 2007), these programs offered PD that was intensive, sustained, content focused, and connected to teachers’ practice (Banilower, Boyd, Pasley, & Weiss, 2006). However, findings from the final evaluation of one of these initiatives, the NSF Local Systemic Change Teacher Enhancement Initiative, suggest that even when PD efforts effectively support science teachers’ implementation of a new curriculum, a supportive school and district context is critical to promoting and sustaining change (Banilower et al., 2006). Similarly, Sandholtz and Ringstaff (2016) identified similar contextual factors such as principal support and resource availability as critical for sustaining positive outcomes of a PD.

In addition, PD for science teachers has been found to be more effective when teachers are actively engaged and provided with opportunities for collaboration with colleagues (Desimone, Porter, Garet, Yoon, & Birman, 2002). Research has also identified guided reflection as another important feature of PD for science teachers (Capps & Crawford, 2013). In their review of empirical studies describing 17 inquiry-based science PD programs, Capps et al. (2012) noted that many essential features of PD for science teachers were widely incorporated (e.g., sufficient duration, extended support), but only five programs supported teachers in planning their lessons despite the consensus view that PD should connect to teachers’ practice.

Furthermore, research indicates that teachers’ content preparation and beliefs about teaching and learning significantly influence their use of curriculum and inquiry-based teaching practices (Powell & Anderson, 2002; Roehrig, Kruse, & Kern, 2007), which can in turn impact student learning (McNeil, Pimentel, & Strauss, 2013). For instance, a study examining the impacts of a 2-week summer institute combined with sustained support over the following school year found that high school teachers’ beliefs about the effectiveness of inquiry for promoting conceptual learning were associated with higher levels of integration of inquiry in their teaching (Lotter, Rushton, & Singer, 2013). No measures of student learning were included in this study; however, the authors suggested that tailoring PD to the needs of teachers would result in greater
improvements in teaching and learning. Another study describing an intensive 2-year program that emphasized developing elementary teachers’ content knowledge and pedagogical practices within the context of adopting a new curriculum documented sizable student achievement gains on state science assessments (Johnson & Fargo, 2014).

**Educative curriculum materials**

In their examination of the role of curriculum materials in education reform, Ball and Cohen (1996) argued that new curriculum materials have failed to meaningfully impact classroom instruction because curriculum developers have ignored the need for teachers to learn about reformed practices present in a curriculum before they are expected to use them. Ball and Cohen suggested that curriculum developers should consider how their materials are enacted by teachers, positing that “materials could be designed to place teachers in the center of curriculum construction and make teachers’ learning central to efforts to improve education, without requiring heroic assumptions about each teacher’s capacities as an original designer of curriculum” (p. 7). Ball and Cohen further argued that well-designed curriculum materials would assist teachers by supporting their learning about the subject matter, their students and how they learn specific content, appropriate methods and strategies, and coherent approaches to sequencing concepts in and across units of study during a school year. In other words, they called for curriculum materials that would help teachers in improving their disciplinary content knowledge, pedagogical knowledge, and pedagogical content knowledge so that they would be more capable of making curricular decisions benefiting students’ learning as well as adopting specific reformed practices.

Answering Ball and Cohen’s call for curriculum materials promoting teacher learning and aiming to avoid another era of unsuccessful science education reform, reformers have sought to develop educative curriculum materials to support teacher learning and go beyond simply providing instructions on how to implement lessons and activities in a curriculum (Davis & Krajcik, 2005; Schneider & Krajcik, 2002). Developers of educative curriculum materials within science education have adopted the following five design principles:

1. Addressing each area of knowledge necessary for exemplary practices—content knowledge, pedagogical knowledge, and [pedagogical content knowledge],
2. Situating teacher learning by meshing the content of the support to lessons for students,
3. Linking different knowledge areas within lessons,
4. Making knowledge accessible to teachers by including short scenarios in the language of teachers or students involved in the lesson to illustrate or model the intended practice when possible, and
5. Addressing immediate needs for understanding as teachers plan lessons that will be enacted within a short time. (Schneider & Krajcik, 2002, p. 224)

These design principles are based on both the recommendations of Ball and Cohen (1996) and contemporary perspectives on teacher learning (Borko, 2004; Putnam & Borko, 2000). Such perspectives hold that teachers’ learning is driven by their daily interactions with students in the classroom and shaped by any curriculum materials they have at hand, good, bad, or otherwise.

Studies of the first generation of educative curriculum materials suggest that such materials do support science teacher learning in some areas (Beyer & Davis, 2012; Beyer, Delgado, Davis, & Krajcik, 2009) and can enhance student learning when combined with curriculum-based PD (Taylor, Getty, Kowalski, & Wilson, 2015). Specifically, the materials can support teachers’ understanding of science content and relevant children’s ideas as well as how to implement inquiry experiences with students (Beyer et al., 2009). The materials, though, may not provide teachers with sufficient support in instructional decision making, such as when and how to effectively adapt materials for their own context, as recommended by Ball and Cohen (1996) and Schneider and Krajcik (2002). Additional
research analyzing how teachers interact with educative features and examining student work samples for the uptake of educative components suggests that teachers tend to utilize components that can be easily used with students in a lesson (Arias, Bismack, Davis, & Palincsar, 2016; Bismack et al., 2015).

**The Investigating and Questioning Our World Through Science and Technology (IQWST) curriculum**

The role of curriculum in influencing the teaching and learning process (Forbes & Davis, 2010; Taylor et al., 2015) and as a means of improving student achievement (Duschl, Schweingruber, & Shouse, 2007) has been given much credence in the science education literature. A key component of our program was therefore the implementation of IQWST, a standards-based middle school science curriculum (Krajcik, Reiser, Sutherland, & Fortus, 2012). The IQWST curriculum is designed around learning goals to actively engage sixth- through eighth-grade students in using scientific and engineering practices to understand natural phenomena. IQWST is organized so that students’ understandings of core ideas (e.g., energy, the particle nature of matter) and scientific practices (e.g., models, scientific explanations) are developed progressively (Krajcik et al., 2012; Schwarz et al., 2009).

Each year, students engage in four units of study (physics, chemistry, biology, and earth systems) organized around driving questions selected to support coherence and the hierarchical development of foundational knowledge within and across grade levels. Each unit has a teacher’s edition and a consumable student edition that provides a series of learning sets. Each learning set includes a group of lessons developed around subquestions and learning goals that serve to organize a unit. Lessons include hands-on investigations and readings as well as related discussions and written assignments to promote sense making.

In addition, the IQWST curriculum includes educative features to support teachers in enacting the curriculum (Davis & Krajcik, 2005). Six types of educative features are incorporated into IQWST: teacher background knowledge, teaching strategies, teaching alternatives, common conceptions (of students), prerequisite knowledge (of students), and lesson checkpoints. Specifically, the educative materials present teaching strategies and alternatives that support teachers as they progress through lessons and activities. Teachers are provided with suggestions and alternative activities to make productive and informed decisions about how to design instruction for their students. These materials also allow teachers to learn during and from their work as they develop their knowledge and beliefs about teaching content to their learners and expand their repertoire of instructional practices (Collopy, 2003; Schneider & Krajcik, 2002).

**Methods**

In this qualitative study, interpretive in nature, we investigated how a reform-based curriculum including educative features supported teachers’ learning and transformed their science teaching practices during a comprehensive PD program. As a case study (Creswell, 2013; Hatch, 2002), the parameters of the investigation were bounded by the comprehensive PD program and the implementation of the reform-based curriculum. We therefore examined the impact of the educative features on teachers’ learning and characterized the teachers’ perceptions of these features as they interacted with the curriculum within the context of a PD program.

**Participants and context**

A total of 35 middle school teachers from 11 mostly small, rural school districts and one large urban school district in a southeastern state were recommended by their school administrators to participate in a 5-year NSF math and science partnership Teacher Institute for the 21st Century at a large...
public university. This comprehensive PD program included (a) a science education graduate degree program, the Science Teacher Leadership Institute; (b) complementary PD activities, such as professional learning communities in which participants’ emerging needs were addressed as they implemented the IQWST curriculum (Krajcik et al., 2012); (c) in-person workshops devoted to immersing teachers in the structure and design of the curriculum as envisioned by the developers; and (d) district-level engagement and support. Through their participation, these middle school science teachers were prepared to improve science teaching and learning in their own classrooms and as Science Teacher Leaders (STLs) facilitate their peers’ professional learning.

The Science Teacher Leadership Institute was a 2-year job-embedded graduate program with coursework delivered both online and in person. The program included (a) nine credit hours of science content for teachers (physics and chemistry, biological science, and earth and space sciences); (b) 12 credit hours of science education focused on inquiry-based science teaching, science curriculum and assessment, and best practices for engaging underrepresented populations; (c) three credit hours of leadership training; and (d) six credit hours of a capstone project organized around teacher inquiry (Cochran-Smith & Lytle, 1999; Dana & Yendol-Hoppey, 2009).

The first two science education courses in the Science Teacher Leadership Institute, Inquiry-Based Science Teaching and Science Curriculum Development, took place during the teachers’ first summer in the program and prior to their first year teaching IQWST. These two courses were designed to immerse teachers in the practices and principles that informed the development of the IQWST curriculum, including current beliefs about how students learn science (Donovan & Bransford, 2005) and the elements of effective science instruction (Banilower, Cohen, Pasley, & Weiss, 2010; Duschl et al., 2007). In addition to assigned readings, online discussion forums, and traditional course assignments, the science curriculum course included a week-long in-person workshop in which the teachers experienced IQWST lessons as learners and then were guided to discuss the use of the science and engineering practices contained within the lessons (e.g., modeling, engaging in argument from evidence). The workshop introduced the teachers to the structure (e.g., driving question, embedded assessments) and the educative features of the curriculum (e.g., teacher background knowledge, teaching strategies) as well.

In weekly course assignments for the science curriculum course, teachers also examined specific units from IQWST relevant to their grade-level teaching assignment and explored the various components of the lessons and related support provided in the educative materials. For example, teachers in grade-level teams identified prerequisite knowledge that students needed to make sense of the new knowledge in selected lessons from their past experiences teaching lessons about similar concepts. They then referred to and discussed the specific educative components of the curriculum that described both the prerequisite knowledge and possible alternative conceptions.

The teachers’ interactions with the curriculum and its educative materials continued beyond the formal courses and into the new school year as they began teaching IQWST during monthly cadre meetings held on the university’s campus. These cadre meetings, designed and conducted as professional learning communities, addressed teachers’ learning needs as identified in their formal courses and their daily teaching of IQWST, often using support offered by the educative materials. We acknowledge that the work of teachers, though occurring mainly in their individual classrooms, does not happen in isolation. Therefore, our project activities were guided by the understanding that the PD activities, teaching practices, and student learning were nested within layers of influence—school culture, district directives, standards, testing, and national concerns (Elmore, 2007). School and district administrators, integral to the program’s effectiveness, were engaged in aligning the layers of influence in creating ongoing support for the reform efforts and assisted in designing a sustainable approach to transforming middle school science, thereby addressing the leadership gap described by Whitworth and Chiu (2015). School and district administrators attended quarterly District Leadership Development Series meetings in which they were introduced to the IQWST curriculum, engaged in conversations about the context-responsive roles and responsibilities
of STLs, and developed short- and long-term plans for science education reform incorporating the STLs as agents to transform middle school science in their districts.

**Data collection**

Over the 5-year period (2011–2016), we conducted numerous formal and informal interviews and individual and focus group interviews at cadre meetings to gauge the teachers’ perceptions and to clearly understand their teaching of the curriculum and use of its educative materials. Periodically in our cadre meetings teachers responded to questions such as “What are some of the dilemmas you are encountering in teaching the IQWST curriculum?” and “In what ways are the educative features contained in IQWST supporting your teaching?” Other data sources included artifacts from formal courses and other complementary project activities, including workshops and cadre meetings. Another valuable data source was provided by the external evaluators, Horizon Research, Inc. (HRI), in their annual report made to the funding agency and also to the project. HRI conducted classroom observations; administered retrospective pre-/post-surveys at the end of each semester; and interviewed the teachers as well as school and district personnel about the enactment of the curriculum, the use of the educative materials, and the impact of the program as a whole. To ensure consistency, the classroom observations conducted by HRI were guided by the same observation protocol as the project personnel. Furthermore, survey and interview questions were developed with input from project personnel. In addition to monitoring the quality of the project activities, HRI provided data that complemented the project’s reform efforts. All data presented in the HRI reports were anonymized.

To fully understand the progress of the teachers in achieving the established goals of the program in general and the impact of the educative curriculum materials, during Year 5 of the project, we embarked on a formal interview process conducted by a qualitative researcher external to the project. A predetermined protocol developed by project personnel (see the Appendix) served as a guide for this interview. Follow-up questions and probes were added as needed to elucidate or extend the teachers’ responses about the educative materials. Though we had amassed numerous data from interviews and observations over the 5-year period and secured signed institutional review board consent, the teachers were assured that their responses to the researcher external to the project would remain anonymous. That is, their identities would not be revealed to the investigators of the program or in publications without their consent. Of the 35 participants, 27 responded to the request for an interview. Each of the final interviews lasted approximately 45 to 90 min in the classrooms where the teachers taught IQWST, often with reference to the lesson for the day, state standards addressed, and the adequacy of the classroom facilities for supporting their science teaching. The interviews were tape recorded, transcribed, and analyzed guided by the research question (see Table 1).

**Table 1. Summary of data collection.**

<table>
<thead>
<tr>
<th>Data source</th>
<th>Timeline</th>
<th>Conducted by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial interviews</td>
<td>Prior to teachers’ acceptance into the program</td>
<td>Project personnel</td>
</tr>
<tr>
<td>Focus group interviews</td>
<td>Years 1–4 (three per year/cohort)</td>
<td>Project personnel</td>
</tr>
<tr>
<td>Classroom observations</td>
<td>Years 1–4</td>
<td>Project personnel</td>
</tr>
<tr>
<td>Retrospective pre-/post-survey</td>
<td>Years 1–4</td>
<td>External evaluators</td>
</tr>
<tr>
<td>Artifacts from courses and cadre meetings</td>
<td>Years 1–2</td>
<td>Project personnel, Course instructors</td>
</tr>
<tr>
<td>Formal individual interviews</td>
<td>Year 5</td>
<td>Researcher external to the project</td>
</tr>
</tbody>
</table>
Data analysis

All interview recordings were transcribed and analyzed using grounded theory methods of constant comparative coding (Charmaz, 2006). Teachers’ forum discussions and journal entries from online courses and their responses to questions posed in cadre meetings were also read and analyzed using grounded theory methods. Initial analysis was conducted by individual researchers but followed the basic procedure of coding to discern initial categories of interest. Initial categories, for example, included, things teachers say about the curriculum and the educative features; teachers’ perceptions of the PD activities; emerging issues, such as the volume of the curriculum; and change in teachers’ practices. Categories were further refined as we identified frequencies of occurrence across the data sources. After categories were established, common themes within and across categories were compared and contrasted (Creswell, 2013; Hatch, 2002; Lincoln & Guba, 1985).

Bronfenbrenner’s (1979, 2005) ecological systems theory was used as a guide to make sense of themes emerging from the data sets. That is, the themes were organized within the interrelated and interactive contexts of classrooms, schools, district administrative offices, as well as state and national policies and procedures. These contexts changed over time in relation to the data sources, further influencing teachers’ and district administrators’ conceptualizations of the curriculum as the framework around which the project activities revolved. The annual report submitted by HRI was then used to validate emerging themes; identify contexts, events, and perspectives; as well as capture specific narratives. Excerpts were selected and extracted from the narratives and labeled in accordance with the emerging themes. Once the themes were agreed on, selected quotes were brought to an audience of teacher participants for them to respond to, add to, react to, and identify with specific experiences and interpretations. This was a form of member checking (Lincoln & Guba, 1985) that sought to establish the accuracy and completeness of the interpretations and representations of the participants’ experiences.

Findings

In this research, we explored an approach to PD in which the IQWST curriculum with its educative features was the framework around which the project activities revolved. Specifically, we examined the role of educative features in facilitating the teachers’ learning while shaping and scaffolding their pedagogical practices. We present our findings around the three themes.

In support of teachers’ learning: Educative curriculum as a scaffold

At the start of the 5-year PD program, the teachers were very consistent in their description of curriculum as the district-adopted science textbooks. It is quite notable that some of the teachers in the PD program were involved in the textbook adoption process. They used the words curriculum and textbook interchangeably. However, once introduced to IQWST—with its focus on students’ examination of science phenomena; the science practice of claims, evidence, and reasoning; and the educative materials—the teachers began to express an elevated understanding of curriculum.

In focus group interviews conducted during the program, the teachers freely expressed their perspectives on the IQWST curriculum and the importance of the many educative features it contained. Specifically, they commented on the impacts of four of the six educative features in IQWST: teacher background knowledge, common conceptions, teaching strategy, and teaching alternatives. Reacting to the presence of the educative feature teacher background knowledge, the teachers generally expressed their appreciation for and noted the impact of this feature on their learning. For instance, one teacher stated,

I liked how the teachers’ guide laid out the science that we needed to know [emphasis added] and even though we may have learned it in the physics course, having it in the background knowledge has reinforced my understanding [emphasis added]. I can always go back to make sure I have it. This has helped me more than just
having the textbook to teach from . . . it has taken my understanding way above what the students were only reading in their textbook.

Appreciating the role of alternative conceptions in science teaching and learning, teachers shared comments that identified the impact of the educative feature common conceptions. For example, teachers stated, “IQWST laid it [alternative conceptions] out there for me nice and neat where I could just go through it. It’s much harder to develop your own lessons with doing that” and “When I am aware of the possible misconceptions the children have . . . already provided in the curriculum, I can easily plan to address them rather than making it up while teaching.”

Teachers recognized the support offered by the curriculum as developed but also the role of the educative materials in allowing further learning and flexibility during their teaching. Teachers showed an awareness of the educative features teaching strategies and teaching alternatives when stating,

The most helpful aspect [of the curriculum course] is the interaction with the actual curriculum and how it is put together and the areas that can further guide my teaching during the lesson [emphasis added]. Not all lesson [s] will go as planned and so having alternatives to achieving the same learning goal was a plus for the curriculum [emphasis added].

I taught the first two lessons of IQWST for the first time last week. While holding the class discussions and pressing students for information, I recalled how [the instructor] modeled the argumentation and questions. I know I was more effective because of the IQWST workshop but I also had the teachers' guide to provide more suggestions to my teaching [emphasis added].

The teachers reported that using the curriculum fundamentally altered their approach to science teaching. They described their reconstructed beliefs about teaching science and noted that they were now better science teachers, continually referring to the shift in their teaching as “the flip” from teacher-directed to student-directed learning and notably “moving from the focus on completing chapters in a text.” The teachers described how the curriculum impacted their role as facilitators of students’ science learning, with one teacher stating, “For me, the number one change was, I don’t have to be in control of everything in my classroom, I can put my students in control. That was a huge change in how I taught before.” In providing an example of how she had changed her practice, this teacher noted the impact of the educative feature teaching strategy:

In the physical science unit, we had a can that rolls back and forth, because it has a rubber band and a weight inside. It stops at a certain point and rolls back, and we talk about elastic energy. But at the beginning when the kids see that, they ask, “How does that work? Can you explain it to me?” And my first instinct is, “Let me explain it to you.” And the curriculum and the teachers’ guide forced me [emphasis added] to step back and say, “Let’s figure it out. I want you, without opening it, to try to think about all the science that we’re learning and try to explain it.”

**Tension point: Educative curriculum as a cumbersome text**

Despite the recognition of the educative materials as supporting their learning, some teachers described the educative component of the curriculum as cumbersome to the teaching process. According to one teacher, at first glance, “IQWST is four textbooks and having to incorporate and pay attention to the additional teachers’ guides just added more tasks to the teaching. We teachers have a lot to accomplish over the course of the day.” In responding to the surveys administered by the external evaluators, teachers shared similar concerns as expressed in the following statement:

The first time I used the curriculum, one side of me was asking how am I going to get through all those pages [emphasis added] . . . yes, the workshop did give me practice in teaching the lesson sets but when you look at the entire curriculum you have four big texts that you have to go through. The additional suggestions were too much especially when you look at all the nonteaching activities we have to do on a daily basis.
Another teacher explained that moving toward inquiry-based teaching and the requirements of IQWST also meant “trying to change the culture with students.” She noted that students were surprised that they were not being given the answers. They too had to adjust to an inquiry approach, which provided an additional layer of tension in using the new curriculum on top of navigating the educative curriculum materials. The teacher said,

You’re trying to make sense, of how to sift through [emphasis added] an IQWST manual, but you have to retrain your kids because they have no idea, they don’t know how to think. They’re so used to vocabulary questions, and more vocabulary questions… Patience is important with IQWST. Especially for sixth-grade teachers teaching this program, especially in that first unit. Wait times become extremely long, agonizingly long. But, you just have to wait; you just have to. You have to make them think.

However, the teachers noted that over time the curriculum and the educative features seemed less cumbersome. They were beginning to recognize the value of the educative materials and the potential support toward student learning. For example, consider this dialogue among teachers remembering their first encounter with the curriculum materials:

Teacher 1: At first I just thought what the heck with such an intense document and I joked about what the curriculum would look like if all the modules and the teachers’ guides were in one place.
Teacher 2: We would need a cart to pull it.
Teacher 3: But see, I liked that even though it looked like a lot, once you overcame the first year and got into the routine with what else was going on in the project it did not matter much… More so, I could see the difference with the students in my class.

**Educative curriculum: An essential feature of effective PD for science teachers**

Many of the teacher participants began their middle school science teaching careers after attending summer PD in their districts. They were beginning teachers, and the content of these programs was mainly related to district and school policies and procedures. With respect to classroom practices, some of the teachers remembered being instructed on classroom management and reading strategies, but none of them were involved in activities related specifically to science teaching. By and large, they found these experiences unhelpful. For example, one teacher stated,

My first PDs in my district were not good. We mostly sat and listened to talking heads all day with some PowerPoints. I remember when we were placed in groups to do some work, we were all concerned … I could not see how it was going to help me teach science to sixth grade. It is hard for me to tell you what I learned during those sessions but I remember leaving with a folder of handouts that I could not even begin to envision how they would fit into my day-to-day teaching. To this day, I am not sure how, even if I was to go back through the papers.

At the start of the program, the teachers spent much time comparing experiences across districts and identifying features that made for effective/ineffective PD. In one of the cadre meetings, based on their experiences and their perceived needs, the teachers created a poster that listed their perceptions of the elements of effective PD. Among others, these elements included the fact that PD content should be relevant to the immediate classroom with a focus on student learning, PD content should model good teaching practices, participants should be actively engaged, and the facilitator should value the experiences of the teacher participants. In addition, teachers expressed their dissatisfaction with PD that required them to “just sit and listen” or engaged them in “periodically making notes” and “working in groups with others mainly on tasks that appear as busy work.”

While noting that the curriculum helped to accelerate the change in their teaching practice, the teachers were very explicit in attributing their learning and the change in practice to the dynamic combination of the various components of the PD. Two teachers reflected,
It took time to get there though—I would say it is the combination of the courses and coursework, the monthly meetings, workshop and the curriculum that we had to teach and which was more than a text—it told us how we can follow the curriculum but it still left openings that allow me to make the best decision for my students.

IQWST and the teachers’ guide, and the workshop made a big difference to what was going on in my teaching and working with the teachers now in my [professional learning community] but I think that the biggest difference for me came because of all the parts of the program. The inquiry course turned my years of teaching upside down and the wonderful science professors turned me into a learner of science . . . and how many times did they [project personnel] observe our teaching? I do not think the change would have occurred if we never had all the pieces going on together even though it was intense . . .

In identifying crucial aspects of the PD, the teachers highlighted the usefulness of assignments that allowed them to work with the IQWST materials. For example, one teacher stated,

The assignments in the [curriculum] course had us dissect the IQWST curriculum . . . this was tedious, but extremely beneficial to my understanding of the material, especially the claims, evidence, and reasoning parts. It also made me intimately aware of how the curriculum is structured.

Furthermore, the teachers expressed that the workshop “had immediate application” to their classroom instruction and made it easier for them to understand and apply the content that was being discussed in the curriculum course. Much praise was also given to the modeling and opportunities to practice offered by the facilitators, with the teachers stating, “The workshop was good because I saw the lessons modeled. The facilitators gave us the opportunity to teach a lesson which really put it into perspective” and “The most difficult labs to . . . conduct and teach were followed up on in the cadre meetings and in the IQWST workshop.”

The teachers identified the monthly cohort meetings as being beneficial and instrumental in fostering the development of the community of middle school science teachers on the mission to transform science teaching, stating,

It [the cadre meetings component] sustains the movement . . . when we meet for our cohort meetings, it’s wonderful to see everybody because it gets you energized and excited, and then you share your accomplishments or you share what your struggles are and there’s people there that can understand, support, and help.

Those meetings always refocus us and they remind us of things that we may have forgotten or things that are truly important that we just haven’t been giving enough attention to. So without those continued meetings, I don’t think the program would run because I think it would just be like one of those fly-by-night, 1-day PD-type deals where when you’re done, you’re done. But, the cohort meetings helped to sustain us in changing the way science is taught. Because if I didn’t have those, I may very well have given up at the beginning of this year. Just been like, “I’m done. I’m just done.”

In addition, in describing the community as a “network of professionals,” the teachers noted that the cadre meetings encouraged them to stay in touch outside of the formal PD activities and use their collective expertise, with one teacher commenting, “Even when we don’t see each other between our cohort meetings, we can still get everything we need.”

Even though administrators were regularly engaged in the District Leadership Development Series, teachers noted varying levels of material and strategic support from their school and district administrators as they implemented the curriculum. Although the partial correlation between the curriculum and the state’s science standards concerned administrators, some teachers noted the flexibility of interpretations offered by the administrators because of their “involvement in the program”: “She could see that students were learning science in my classroom” and “She was a former science teacher who understood the importance of children doing science.” However, other teachers in schools in which administrative support of the PD was reduced expressed levels of difficulty, such as the “intense focus on covering state standards” and the “use of the teacher evaluation tools” to determine their effectiveness as science teachers. These instances often coincided with frequent turnover in school and district administration.
Discussion and implications

This study is part of a larger NSF mathematics and science partnership program that through PD seeks to increase middle school science teachers’ content knowledge and build their capacity to improve their instructional practices in ways that advance students’ science achievement. In this article, we reported on the ways the educative curriculum materials supported middle school science teachers’ learning within the context of a comprehensive PD program focused on the enactment of IQWST, a reform-based science curriculum. Specifically, we examined teachers’ use and perceptions of the educative curriculum materials (Davis & Krajcik, 2005) in concert with other PD activities such as a formal graduate degree program, workshops, and monthly cadre meetings. These interrelated project activities along with the involvement of school and district personnel offered the teachers ongoing support and collaboration (Loucks-Horsley et al., 2009) and provided multiple opportunities to develop, reinforce, and extend their understanding of the science content, teaching practices, and principles of the curriculum. Our analysis revealed that the educative curriculum materials facilitated the teachers’ continued science learning, shaped and scaffolded their pedagogical practices, and extended the PD while the teachers were immersed in the act of teaching. The findings also suggest that the teachers’ use and valuing of the educative features was directly related to their perceived needs and that many benefits were garnered from the guided and collaborative opportunities to explore and use the educative features in the PD program.

The reform-based curriculum was undoubtedly a crucial part of the project. The curriculum provided a common framework and vision for introducing all of the teachers to what reformed science teaching should look like, thereby providing a tangible model for them to test in their own classrooms. The educative materials, according to the teachers, allowed for continued support during the enactment of the curriculum. Yet the volume of the educative materials raised some anxiety among teachers at the beginning of the program. The anxiety levels were reduced, however, once the teachers began to recognize the extent to which the materials facilitated their learning of the specific subject matter and the learning of their students (Beyer & Davis, 2012; Beyer et al., 2009). In addition to assisting teachers in their planning, the educative materials supported the use of appropriate strategies for emerging dilemmas during the lessons. The impact of the educative materials on the teachers’ practices did not occur in isolation but was linked to supports and training emphasized in the formal courses and the complementary PD activities. For instance, being immersed in IQWST during the curriculum development course workshop and before they started teaching the curriculum allowed the teachers to deepen their understanding of the structure of and familiarity with the IQWST curriculum materials and gain confidence in their capabilities to begin teaching the curriculum at the start of the school year. In addition, the course assignments that required examination and use of the educative materials benefited the teachers, but teachers did not begin to value the impact until they themselves were enacting the curriculum in their classrooms. The educative materials became, according to one teacher, her “PD provider” (name of PD provider removed), thus facilitating continued learning. The educative curriculum materials therefore had a significant role in extending and continuing the teachers’ learning by providing much needed just-in-time support for teachers who were being asked to teach in completely new ways.

Although it may be difficult for developers to recognize which educative features are more central to supporting a particular group of teachers, it is also important to note that teachers’ perceptions shifted once they recognized the benefits to their teaching. Four educative features in IQWST supported the teachers’ science learning and enactment of the curriculum in this study: teacher background knowledge, common conceptions, teaching strategy, and teaching alternatives. The first two features addressed teachers’ need to continue the development of meaningful understanding of the science content knowledge required to teach the curriculum. These educative features furthered their learning by providing clear descriptions of accurate and inaccurate conceptions (some of which the teachers may even have had themselves). The second, third, and fourth features continued to support and facilitate the development of their pedagogical content knowledge, that is, the repertoire
of approaches they needed to teach the content to their students. Two additional features, prerequisite knowledge (of students) and lesson checkpoints, were not clearly discussed by the teachers but are also related to developing important pedagogical content knowledge. These two features may not have seemed as critical to this group of teachers, who for the first time were teaching a new curriculum that focused on meaningful science learning and the use and development of the science practices claims, evidence, and reasoning and modeling. Furthermore, these features related to the assessment of student readiness and learning, which was an area of weakness for this group of teachers, who relied heavily on traditional paper-and-pencil summative assessments and rarely used formative assessments of any kind.

As more curricula include educative materials, we recommend that PD providers purposefully identify the greatest learning needs of the intended group of science teachers. With this knowledge, the providers can plan how best to introduce and allow teachers to examine the educative materials in ways that recognize the utility in their professional learning and continued teaching. During initial experiences, PD providers should immerse teachers in experiencing the curriculum as learners while simultaneously guiding them to understand the purpose, types, and use of educative features. Subsequent experiences should provide teachers with guided practice in using the educative materials and opportunities to reflect on the supportive nature of these materials. Guided practice can be provided during simulated teaching experiences with their peers. Discussions should guide teachers to reflect on their use of the educative materials and perceived benefits and challenges. When teachers begin to use the curriculum for the first time in their own classrooms, these conversations should continue as well as help teachers to reflect on how the educative features can support their individual professional growth. Note that the teachers’ interactions with the educative features provided one cost-effective means of extending the duration of the PD, thus embracing an important element of effective PD (Capps, Crawford, & Constas, 2012; Desimone et al., 2002). Over time, teachers can be guided to set individual goals for learning guided by the educative features contained within their curriculum. This, if encouraged, will allow teachers to focus more specifically on refining aspects of their science teaching practices, such as working with learners with diverse learning needs or supporting literacy development. Evolving technologies for digital science curriculum may even afford teachers the ability to select and fade educative features that they find most or least beneficial for developing their practices and meeting individual professional learning goals. This is likely to be a new avenue of research into educative curriculum materials along with studies that identify more clearly the optimal level of educative support for teachers struggling to implement new science reforms and curricula.

The teachers’ practices were further shaped by the engagement and support of their school and district leadership and the availability of resources. Carefully designed quarterly District Leadership Development Series meetings with school and district administrators were an important aspect of our PD model. Administrative leadership and access to colleagues are important features of school contexts that shape learning opportunities (Wilson et al., 2015) and have the potential to accelerate and sustain change. Thus, we engaged the district and school administrators in ways that allowed them to experience the curriculum as learners, develop a vision of science in their individual schools and districts, and strategize how best to support the growth and development of the teacher participants. As their understanding of effective science instruction shifted, they became more supportive of the teachers’ evolving practice and worked to secure resources, provide the teachers with time to collaborate, and ensure sustainability beyond the duration of the program. The significant turnover among school and district administrators, however, eroded consistent support in some districts. To better ensure program continuity, we recommend encouraging the participation of multiple levels of administrators in program activities and planning strategies to orient new administrators and garner their support.

Rigid district policies related to accountability measures (e.g., state and district assessments, teacher evaluation tools) impacted teachers’ practices. The teachers’ learning, teaching practices, and response to the PD activities were therefore shaped not only by the activities provided in the
PD but also by the demands of their particular teaching contexts. In the end, teachers had to satisfy the requirements imposed on them, which in some cases constrained their ability to learn and grow. We recommend an in-depth study of the accountability systems in place during the planning stages of a PD project in order to best plan for how to work within these complex and inflexible systems.

As the PD program progressed, the teachers expressed that they had, and exhibited, more confidence in their ability to teach science. Rather than the widespread traditional teacher-centered strategies, teachers’ practices were reflecting instances of reform-based practices. Their teaching was being shaped by the collective PD experiences and curriculum features. However, voicing their concerns, the teachers hoped that their teaching efforts would be reflected immediately in students’ gains on mandated state and district science assessments. The teachers believed that their students were learning. They observed changes in what students said and in their written work during activities that required identification of claims, evidence, and reasoning. These were important features of the science curriculum, embraced in current reform efforts and to a large degree correlated with the state’s literacy standards, which the teachers were also required to teach. Examining the impact of the curriculum on middle school students’ science achievement is one aspect of our overall research agenda, and details on this impact are not reported in this article.

The primary goal of our PD program was to deepen teachers’ science content knowledge and develop and refine their practices over time using the reform-based curriculum as the framework. The teachers in this PD were all middle grades science teachers with varied experiences prior to participating in our program; however, there was much consistency among their beliefs and practices about science teaching and their learning needs. Monthly cadre meetings complemented and built on topics introduced in the formal courses and allowed for further deepening of science content knowledge and pedagogical practices that supported the effective implementation of the curriculum. In our PD, we were attentive to teacher learning needs over time while building and sustaining the group of teachers as a community of learners (Birman, Desimone, Porter, & Garet, 2000; Garet, Porter, Desimone, Birman, & Yoon, 2001; Loucks-Horsley et al., 2009). The presence and use of the educative materials therefore facilitated teachers’ continued learning and clearly supported a more effective implementation of the curriculum.

PD in the United States and abroad faces many challenges, including insufficient duration and lack of extended support for science teachers struggling to adapt new standards, curricula, and instructional practices within their own unique contexts (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Guskey & Yoon, 2009; Wilson, 2013). Our program as developed and enacted was intensive, sustained, and content focused (Yoon et al., 2007). To mitigate pitfalls of traditional PD, the program included the use of IQWST, a reform-based curriculum, and its supporting educative features as the framework around which all other activities were aligned. It is this alignment that attended to the reform vision of science learning and teaching that altered the trajectory of teacher learning. In addition, the program spanned 5 years and positioned the school and district administrators in ways to support the continuity of the curricular reform efforts beyond the end of the PD. Although our focus in this article was on the presence of educative materials and their impact on teachers’ science learning and teaching practices, the synergistic relationship among all of the activities in this PD model was instrumental to the overall changes that occurred. Furthermore, the use of educative materials has implications not only in the United States but also globally, where the use of these materials in support of science curriculum can extend effective PD for teachers, further supporting their continued learning.

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References


## Appendix

### On Becoming a Science Teacher Leader

**Interview Protocol**

Objective: To elucidate the perspectives of the STLs about the impact of (specific) project activities on the evolution of their roles and practices, their perceptions, issues and concerns, and the ways in which they are being used as agents of transformation in their schools and districts.

Questions:

When you were first recommended by your school leader for the U-FUTuRES project, what did you think your role as a STL would entail?

- How do you see your role now as a STL?
- How has the project supported your development as a STL? Explain.
- What project activities impacted the ways you have developed and conceptualized your role as a STL? Explain.
- In what ways did your peers in the cohort contribute to your personal development as a STL?
- In what ways are you being used by your schools and district?
- If you were to go through the U-FUTuRES project again, what are some activities you hope would still be a component of the project? Why?
- What are some activities that should not be included in the project? Why?
- In what ways has the label “STL” affected your positionality as science teacher in your school and/or in the district?
- Your school has recently employed a new science teacher. How would you explain your role as a STL to this teacher?
- What were the benefits of the U-FUTuRES professional development program?
- What were the challenges you encountered as you went through the U-FUTuRES professional development program?

*Note.* STL = Science Teacher Leader; U-FUTuRES = University of Florida Unites Teachers to Reform Education in Science.