Teaching for Understanding in Earth Science: Comparing Three Professional Development Designs for Middle School Science Teachers

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Abstract

This paper compares and contrasts three professional development designs aimed at middle school Earth science teachers that were implemented in a large urban school district. The designs were similar in their alignment to research-based practices in science professional development: each design was of an extended duration and time span, included follow-up support to teachers, and incorporated active learning approaches in the professional development. In addition, the designs had a high level of coherence with other reform activities and with local standards. The main difference among the designs was in the roles of teachers in designing, adopting, or adapting curriculum materials. Evidence from teacher survey data indicated that teachers' experiences were consistent with the hypothesized similarities and differences among the designs.

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Introduction

An enduring goal of science education of the last 50 years has been to develop student understanding of core scientific concepts by exposing them to well-designed curricular experiences (Atkin & Black, 2003). Only a few years after the National Science Foundation first began investing in science curriculum development, Bruner (1960) argued that the goal of science education should be to give students "an understanding of the fundamental structure of whatever subjects we choose to teach" (p. 11). More recently, scholars have engaged in efforts to develop curriculum materials and other supports to help teachers *teach for understanding* (Cohen, McLaughlin, & Talbert, 1993; Gardner & Dyson, 1994; Treagust, Jacobowitz, Gallagher, & Parker, 2001; Wiske, 1997). The central premise behind this recent movement is that teachers should plan and enact instruction in which students have opportunities to learn about, experience, relate, and apply core disciplinary ideas (Gardner & Dyson, 1994; Wiggins & McTighe, 1998).

There is little doubt that professional development is necessary to prepare teachers to plan and enact instruction that develops students' deep understanding of subject matter. But beyond applying general principles from research (e.g., Loucks-Horsley, Hewson, Love, & Stiles, 1998) to designing effective professional development, how might professional development programs aimed at preparing teachers to teach for understanding be customized? How might such programs differ, and how do those differences matter, in terms of teachers' experiences and subsequent actions? Ultimately, what consequences are there of different designs for teaching and learning?

This paper compares and contrasts three approaches to preparing teachers to teach for understanding in middle school Earth science with respect to both the *design* of the approaches and the *enactment* of those approaches. All three designs reflected research-based principles for professional development, but they differed with respect to the role they gave to teachers in curriculum. In one design, teachers learned how to *adopt* high-quality curriculum materials developed by experts in Earth science and curriculum design. In a second design, teachers learned how to *design* curriculum experiences aligned to local standards using available materials and lessons they developed themselves. In a third design, teachers learned how to *adapt* expert-developed materials in a principled way to align to local standards. Survey data on the enactment of these designs presented in the paper indicated that teachers' experiences were consistent with the hypothesized similarities and differences among the designs.

Theoretical Framework

The growing body of empirical research on effective science professional development guided the theoretical framework for the study. Below, we review evidence for an emerging consensus about the importance of professional development that is of an extended duration and time span, includes follow-up for teachers, involves them in active learning, coheres with local standards and goals for student learning, and focuses on the content of instruction. We also point out that professional development models differ with respect to the roles teachers are expected to play in defining the content of instruction that is targeted by professional development. Here, there is less evidence to support a particular approach.

Duration and Time Span

A common criticism of professional development activities designed for teachers is that they are too short. Curricular reforms in science are extremely demanding and often require teachers to make big changes to implement them well (Bybee, 1993; Crawford, 2000). Frequently, the result is that teachers either assimilate new teaching strategies into their current repertoire with little substantive change or they reject those suggested changes altogether (Coburn, 2004; Tyack & Cuban, 1995). There is growing consensus that to make real changes, teachers need professional development that is interactive with their teaching practice, allowing for multiple cycles of presentation and assimilation of, and reflection on, knowledge (Blumenfeld, Soloway, Marx, Guzdial, & Palincsar, 1991; Kubitskey & Fishman, 2006).

Professional development that is of longer duration and time span is more likely to contain the kinds of learning opportunities necessary for teachers to integrate new knowledge into practice (Brown, 2004). For example, in their study of NSF-funded Local Systemic Initiatives, Supovitz and Turner (2000) found longer durations of professional development were needed to create "investigative cultures" in science classrooms, as opposed to small-scale changes in practice. Other large-scale studies of professional development have linked longer duration and time span to changes in teacher knowledge and practice (Desimone, Porter, Garet, Yoon, & Birman, 2002; Garet, Porter, Desimone, Birman, & Yoon, 2001) and to higher levels of curriculum implementation (Penuel, Fishman, Yamaguchi, & Gallagher, 2007).

Follow-Up

Even when they are of an extended duration, workshops and institutes rarely provide teachers with sufficient information and support for making changes to practice and for curriculum implementation. One reason why workshops are insufficient is that when teachers return to the classroom, they often encounter difficulties with planning and implementation that they have trouble solving on their own (Guskey, 2002). Professional development staff associated with curricular innovations can support teachers through follow-up coaching and workshops to help them address their concerns (Penuel, Shear, Korbak, & Sparrow, 2005). Further, their efforts at follow-up are a means for monitoring implementation and for applying indirect pressure on teachers to try new practices associated with the professional development (Guskey, 2002; Rowan & Miller, 2007). When teachers experience this kind of follow-up, researchers have found teachers are more likely to make changes to their practice and to implement curriculum activities more consistently (Penuel et al., 2007; Penuel & Means, 2004; Radford, 1998; Tushnet et al., 2000).

Active Learning

Within science education, it is widely believed that to learn how to support student inquiry in the classroom, teachers need first-hand experiences of science in action either as part of their professional development or as part of apprenticeships to scientists (Gess-Newsome, 1999). This need arises in part because most teachers today learned science from textbooks and tend to hold conceptions of the discipline and of how students learn that are inconsistent with how science knowledge actually unfolds through ongoing investigations by scientists (Boone & Kahle, 1998; Marek & Methven, 1991). Some research studies have presented evidence that supports the strategy of more hands-on, active learning, in that they have found a relationship between professional development activities in which teachers engage in inquiry and positive student achievement outcomes (e.g., Fishman, Marx, Best, & Tal, 2003).

There are other ways in which it may be important to promote teachers' active learning within professional development. Curriculum designers often have concerns about the ways teachers enact their curriculum, claiming some adaptations of materials constitute "lethal mutations" of those materials' intent (Spillane & Jennings, 1997). It is this lack of understanding of underlying principles that some hypothesize prevents effective use of curriculum materials by teachers, especially those that rely on student-centered approaches to teaching (Lieberman & Miller, 2001; Singer, Krajcik, Marx, & Clay-Chambers, 2000; Wiggins & McTighe, 1998). The act of planning, enacting, and revising curricular units engages teachers more deeply with their teaching, so that they can come to understand more fully the principles of effective curriculum (Spillane, 1999, 2004). It is not surprising, then, that research has found that professional development that incorporates time for instructional planning, discussion, and consideration of underlying principles of curriculum may be more effective in supporting implementation of innovations (Penuel & Means, 2004).

Coherence

Coherence refers to teachers' interpretations of how well-aligned the professional development activities are with their own goals for learning and their goals for students. These interpretations are critical in at least two respects. First, teachers filter policy demands and messages from professional development about teaching through their own interpretive frames (Coburn, 2001; Cuban, 1986; Cuban, Kirkpatrick, & Peck, 2001). Second, the social context of schools has a strong influence on teachers' interpretive frames and thus their decisions about how to enact (or resist) particular innovations (Rivet, 2006). If teachers perceive the demands to be aligned with their district's goals and with social pressures within the schools, they are more likely to perceive professional development focused on a particular innovation as congruent with their own goals, and thus commit to adopting or adapting the innovation (Lumpe, Haney, & Czerniak, 2000). Past research has linked teachers' perceptions of coherence to changes in knowledge and practice (Garet et al., 2001) and to curriculum implementation (Penuel et al., 2007).

Content

There is widespread agreement that the content of professional development matters, and evidence from a wide range of studies supports this claim (Cohen & Hill, 2001; Desimone et al., 2002; Garet et al., 2001; Hill, Rowan, & Ball, 2005; Penuel et al., 2007). Furthermore, when the content is closely linked to what teachers are expected to do in their classrooms, teachers are more likely to make use of what they learn, since it meets their needs for curricular activities they can use with students in the classrooms (Cohen & Hill, 2001; Haney & Lumpe, 1995). When professional development content is also linked with specific curricular materials, those materials can be designed to extend what teachers are able to learn from formal professional development (Davis & Krajcik, 2005; Schneider & Krajcik, 2002).

Beyond this consensus regarding the importance of content, professional development models vary widely with respect to the role teachers are expected to play in shaping the content of the teaching that is the focus of professional development. Traditionally, models of professional development have focused on preparing teachers to implement specific curricular materials, without adaptation. More recently, however, a number of projects have explored how curriculum revision or planned curriculum adaptation may be used to promote the improvement of teaching quality, to enable high-quality implementation, and to increase student achievement (e.g., Linn, Songer, Lewis, & Stern, 1993; Singer et al., 2000). Still other models of professional development put teachers in the role of designers of curriculum and professional development experiences (e.g., Lotter, Harwood, & Bonner, 2006; Wiggins & McTighe, 1998).

To date, there has been little exploration of how professional developers that assign different roles to teachers in making determinations of the content of instruction might design experiences for teachers to meet a common goal. More typically, researchers adopt a single approach for their project and study its effects. In the study on which we report on this paper, however, professional developers created three different designs for a single large urban district, all aimed at meeting the district's goal to prepare teachers to teach for deep understanding. In the next section, we discuss these professional development designs, and in the results section present preliminary evidence from the study about how teachers' experienced the different designs as enacted.

The Professional Development Designs

Below, we describe each of the three designs with respect to its expected time span and duration, nature of follow-up, use of active learning strategies, coherence with the district standards, and content.

Preparing Teachers to Adopt the Investigating Earth Sciences Curriculum

Investigating Earth Systems (*IES*) is a 10-module middle school curriculum, funded by the National Science Foundation and developed by the American Geological Institute (AGI). The inquiry-based Earth systems science curriculum consists of a student edition with investigations and content; a teacher's edition with science background, students' misconceptions, teaching tips, materials management advice, assessments, *National Science Education Standards*-alignment; and online teaching resources. *IES* was written by a team of curriculum developers, scientists and teachers and was pilot- and field-tested over 3 years by middle school teachers across the United States. It was first published by It's About Time/Herff Jones Publishing in 2001, and has been adopted by the state of California, as well as such major school districts as Denver Public Schools, Chicago Public Schools, and the Clark County School District in Nevada (Las Vegas).

The content of the modules is organized around five "Big Ideas" in Earth science, but it is important to note that professional development for *IES* has a specific purpose: it is designed to prepare teachers to implement specific modules that fit a school district's middle school Earth science standards. In this way, through the selection of particular modules, *IES* attempts to provide materials that will allow teachers to meet their state's or district's requirements with respect to content coverage. In DCPS, AGI worked with district leaders to select the four modules that were most closely aligned to the Sunshine State Standards: *Dynamic Planet* (sixth grade), *Rocks and Landforms* (sixth and seventh grades), *Water as a Resource* (seventh grade) and *Astronomy* (eighth grade).

For the current study, AGI staff provided a 2-week initial workshop to all teachers assigned to the *IES* condition. The first part of the training covered topics that underpin the curriculum: typical module structure, nature of inquiry-based science and the Earth systems approach, managing materials and students working in collaborative groups, teacher support, *IES* website and assessment components used in *IES*. In the second part of the summer training, teachers worked in specialist groups to focus on activities and content from the particular *IES* modules they would be using with their students. During four follow-up training sessions throughout the academic year, AGI staff met with teachers to discuss issues and successes they experienced during the implementation. Teachers also had the opportunity to share student work and assessments and discuss adaptations they made to accommodate their students' ability levels.

Active learning strategies are evident in *IES* workshops in that leaders introduce teachers to inquiry principles early in the training and then give teachers frequent opportunities to set up and try hands-on investigations, both in the roles of students and as teachers. The training also includes practice with managing materials, setting up and using student journals as assessment tools, and using investigations as performance assessments. The teacher's edition of *IES* plays an important role in training, as teachers are encouraged to use the components of the teacher's edition to plan, implement, assess, and reflect upon their Earth science instruction.

With respect to coherence, both the fixed content of the modules and practical realities of implementation limit the degree to which perfect alignment to local goals could be achieved through the professional development. Significantly, teachers in sixth and seventh grade each taught a "partial" module (*Rocks and Landforms*) since the module targeted concepts that spanned two grade levels of standards. The alignment to Duval's local standards was, moreover, imperfect, in that some concepts (e.g., long-shore currents) were not in the modules themselves. For these topics, AGI staff identified web-based resources to supplement module content. In addition, AGI staff note that during the first year of implementation, teachers tend to follow the modules strictly, without adding or supplementing content. Therefore, they could be expected to make limited use of these supplemental resources, as they struggle with new, student-centered methods of instruction.

Earth Science by Design

Earth Science by Design (*ESBD*) is a year-long program of professional development created by TERC and AGI with funding from the National Science Foundation. *ESBD* prepares teachers to apply the principles of *Understanding by Design* (UbD) (Wiggins & McTighe, 2005) to the teaching of Earth system science. The primary goals of the *ESBD* program are a) to teach for deeper understanding by focusing on "Big ideas" and using an "Earth as a system" approach, b) to design and apply appropriate assessment techniques, such as preconception surveys and authentic performance measures, and c) to use visualizations and satellite imagery to promote student understanding. Teachers completing the *ESBD* program reorganize existing curricular materials, such as those from their textbooks or those they may have developed themselves or collected from colleagues at professional conferences, into coherent units of instruction that target essential questions and enduring understandings and that culminate with a performance assessment. Each teacher participating in the *ESBD* program is expected to reorganize one unit of instruction that they implement with their students. During this study, sixth grade teachers collaborated to organize a 9-week unit focused on the dynamic nature of planet earth (i.e. earthquakes, volcanoes, plate tectonics, forces of change). Seventh grade teachers organized a unit around water and eighth grade teachers had astronomy as their unit topic.

In addition to an initial 2-week workshop, teachers in the *ESBD* condition participated in 2 days of follow-up professional development in the fall after the summer workshop and 3 days of follow-up in the spring. The model calls for local staff developers to lead these activities; consistent with that model, staff from the district led the workshop and fall follow up activities, without any assistance from developers of the program. The three days in the spring included 1 day in which staff mentored teachers as they revised and edited their final unit plans and reflected on their implementation results. The other 2 days comprised a conference in which teachers gave presentations about their units. In addition, teachers received mentoring from staff during the school year, which consisted of help with the design of their units and help with managing other aspects of their participation in the study.

The content of the *ESBD* condition focused on the UbD approach to curriculum development. During the first week of the *ESBD* summer workshop, teachers engaged in activities and discussions to consider the nature of understanding, to struggle with what is worthy of understanding, and to begin to understand the "Earth as a system" approach to Earth system science. They also learned the process of "backward design" and practiced constructing a unit using the *ESBD* online unit planner. *ESBD* teachers gained practice with developing assessments of student learning intended to "convict" students of understanding.

During the second week of the workshop, *ESBD* teachers were given time to work collaboratively to produce the unit that they would be implementing the following school year. Teachers began by drafting essential questions and enduring understandings that their units would target. Next they developed a performance assessment that would reveal students understandings (as well as misunderstandings) of the unit. Last, by considering the lessons they had used when they taught the unit in previous years, they began to reorganize their units. *ESBD* teachers included activities and laboratory exercises in their units, only if the content of the activity or exercise directly targeted essential questions and enduring understandings. Often, teachers removed a lot of unnecessary lessons from their units and had to supplement them with lessons from professional resources other than their textbooks. Teachers were required to incorporate visualizations and Internet resources into their units.

Opportunities for hands-on practice in the *ESBD* condition's professional development activities took the form of trying out visualizations and engaging in unit planning. Teachers began the second week of the summer workshop reviewing an *ESBD* unit and engaging in one of the unit's activities that provided experience working with satellite data. Throughout the second week, teachers had time to craft their units, with mentoring from one of the two district staff. They also spent significant amounts of time trying out visualizations and Internet resources. In addition, they received feedback on their unit plans from colleagues in the workshop. On days 6, 7 and 8, three video presentations from previous *ESBD* teachers were used to engage teachers in whole-group discussions focused on the challenges of implementation.

The *ESBD* condition had the greatest potential coherence of professional development with teachers' local context, since teachers began with the standards and could use any materials whatsoever in their units that were aligned to those standards. District staff helped teachers map the Florida Sunshine State Standards and the district standards to the Enduring Understandings and Essential Questions for their units. At every possible opportunity during the professional development program, staff emphasized that teachers should make sure that their goals for students were aligned with the standards. In addition, teachers worked in small groups on their units, collaborating with other teachers who had responsibility for teaching the same standards that they did.

The *Hybrid* Approach

Teachers in the *Hybrid* condition participated in a year-long program of professional development, comprised of a 2-week summer workshop, 2 days of follow-up professional development in the fall after the summer workshop, and 3 days of follow-up in the spring. AGI and TERC staff collaboratively led the workshop and fall follow up activities. In spring, the 3 days were led by DCPS staff and included 2 days of a spring conference in which teachers gave presentations about their units. In addition, teachers received mentoring from district staff during the school year, which consisted of help obtaining teaching materials and kits, help with the design of their units, and help with managing other aspects of their participation in the study.

The content of the *Hybrid* condition professional development blended content of the *IES* workshop and the *ESBD* workshop. Like the teachers in the *ESBD* workshop, teachers in the *Hybrid* condition engaged in activities and discussions to consider the nature of understanding, to struggle with what is worthy of understanding, and to begin to understand the "Earth as a system" approach to Earth system science. They also learned the process of "backward design" and practiced constructing a unit, just as the *ESBD* teachers did, using the *ESBD* online unit planner. Like *ESBD* teachers, *Hybrid* teachers also gained practice with developing assessments of student learning intended to "convict" students of understanding. But unlike the *ESBD* teachers, the *Hybrid* teachers made use of the particular *IES* modules that were aligned to their grade level in constructing their units. Moreover, teachers received instructions that at least 50% of the *IES* investigations were to be used in constructing their units.

Throughout, UbD concepts underlying the design of the *IES* materials were emphasized. For example, on day 3 of the workshop, AGI and TERC staff introduced the idea of "essential questions" (part of the UbD framework and the *ESBD* Summer Institute Guide). Teachers worked in groups of four to brainstorm essential questions. In addition to creating their own Essential Questions, teachers recorded the "key questions" from the *IES Rocks and Landforms* module into their brainstorming work. After reviewing the candidate Essential Questions, each group selected four to incorporate into their sample unit.

Opportunities for hands-on practice in the *Hybrid* condition's professional development activities took the form of practicing *IES* investigations and engaging in unit planning. During the second week of the summer workshop, teachers had time to craft their units, with mentoring from one of the three facilitator leaders. In general, they worked on their units in the mornings and in the afternoons engaged in hands-on investigations from the *IES* modules in order to familiarize themselves with these activities. They were able to ask questions of the *IES* facilitator and to become familiar with activities that they might wish to incorporate into their units. Approximately 45 minutes were set aside each afternoon for whole-group discussion of progress, problems, ideas, and issues that were emerging.

To increase the coherence of professional development with teachers' local context, staff helped teachers map the Florida Sunshine State Standards to the Enduring Understandings and Essential Questions for their units. In this activity, professional development staff emphasized that teachers should not start with the standards but rather make sure that their goals for students were aligned with the standards. In addition, teachers worked in small groups on their units, collaborating with other teachers who had responsibility for teaching the same standards that they did.

The Current Study

The current study examined the enactment of the three designs described above, from the viewpoint of participants in the three initial workshops linked to the designs. Participants completed surveys that asked them to characterize their particular workshop with respect to active learning, feedback, coherence, and reported knowledge and skill. One year later, after having the opportunity to implement their designs, we asked them to reflect on how the designs affected their instructional planning process. Descriptive and inferential statistics provided the research team with data to use to help interpret subsequent study results and the professional development team with data for judging the degree to which the enacted workshops were consistent with the professional development designs.

The fact that these post-workshop surveys served a larger analytic and practical purpose distinguishes them from typical surveys and points to the significance of this study. Until recently, the vast majority of professional development experiences were evaluated using simple surveys in which teachers rated their experiences in terms of satisfaction (Frechtling, Sharp, Carey, & Vaden-Kiernan, 1995). Researchers have only begun to apply broadly the idea that one can use professional development experiences as predictors in analytic models examining effects on knowledge and skill development and curriculum development (e.g., Garet et al., 2001; Penuel et al., 2007). Similarly, although evaluation researchers have long known that implementation or enactment of interventions, rather than their design, must be measured to interpret results of outcome studies (see, e.g., Cordray & Pion, 2006), we know of no instances of fidelity or consistency of implementation being applied to the study of a professional development intervention.

Although our approach to using professional development questionnaires is relatively new within the field, we do build from two key assumptions founded in prior research, which are reflected in our particular measures and our approach to analyzing the data. First, our assumption is that for survey data to be of use in subsequent quantitative models of the effects of professional development on teaching and learning, measures (where available) should be used that have been linked to changes to teaching practice. Hence, we rely on measures used by Garet and colleagues (2001) of the correlates of effective professional development. Second, following Fishman and colleagues' (2003) work, we assume that we need to be able to "trace" the imprint of professional development designs in patterns of teacher response to the enacted designs. In relation to the current designs, for example, we should see evidence in the surveys that teachers experienced the opportunity to learn about student-centered investigations in both the *IES* and *Hybrid* conditions, which emphasize investigations in their professional development designs. Because the analysis presented in this paper focuses on the consistency of designs and enactment, in many cases we report descriptive statistics at a smaller unit of analysis than we plan for analyses of effects on teacher practice and learning. This smaller unit allows us to document the traces of the professional development on teachers' experiences more readily.

Hypotheses about Consistency of Design and Enactment

Using the professional development designs and correlates of effective professional development as guides, we developed the following hypotheses about what would constitute enactment consistent with the designs for professional development:

H_1: A high percentage of teachers in the *ESBD* and *Hybrid* workshops will report engaging in unit planning as a form of active learning, since these conditions emphasize unit planning as a core feature of professional development.

H_2: A high percentage of teachers in the *IES* and *Hybrid* workshops will report engaging in demonstrations and practice with student materials forms of active learning, since these conditions emphasize learning how to use investigation-based curriculum materials with students.

H_3: A high percentage of teachers in the *ESBD* and *Hybrid* workshops will report receiving feedback on materials they have designed, since these conditions emphasize the design and adaptation of units, rather than adoption of units.

H_4: A high percentage of teachers across all conditions will report communication about implementation as a form of feedback, since unit implementation is a focus in all conditions.

H_5: A high percentage of teachers across all conditions will judge their participation in the workshop to be coherent or aligned to their goals for student learning, because there is a single district context and because the district's standards are aligned with the goal of teaching for understanding.

H_6: A high percentage of teachers in the *IES* and *Hybrid* conditions will report an emphasis on inquiry and increasing their skill in facilitating inquiry with students, since both these conditions rely on investigation-based curriculum materials.

H_7: A high percentage of teachers across all conditions will report that a primary benefit of participation is learning to facilitate their students' understanding of why they are engaged in a particular activity, because all conditions promote the goal of teaching for understanding.

H_8: More teachers in the *ESBD* and *Hybrid* conditions will report changes to their instructional planning, when compared with the *IES* condition, since *ESBD* and *Hybrid* designs both give strong emphasis to the process of instructional planning.

Research Methods

The overall study used an experimental design, in which teachers were randomly assigned either to one of the three (professional development) treatment conditions or to the control condition. Random assignment studies have the fewest threats to internal validity, and are thus more likely to yield unbiased estimates of potential impact compared with other designs (Shadish, Cook, & Campbell, 2002). The random assignment process took place after teachers volunteered to be in the study; therefore, it is important to note that the findings of this particular study can be generalized only to groups of teachers who volunteer for professional development. Other efficacy studies that study the impact of the interventions when teachers were compelled to participate would be needed to establish the potential under those conditions.

District Context

All research participants were teachers in the Duval County Public Schools (DCPS). DCPS currently serves 125,820 students in 164 schools, of which 28 were middle school, all of whose science teachers were eligible for participation in the study. Sixteen of the twenty-eight middle schools have a 50% or higher rate of eligibility for free or reduced-price lunch.

The district science curriculum for middle school adheres to the Florida Sunshine State Standards, which the State of Florida mandates all teachers must follow. The district has organized the standards into 9-week units, and Earth science standards are taught as part of one unit at each of the three middle school grades. Each grade level has one or more units based on earth space science concepts taught within a 9-week span. The district has “translated” the standards into Enduring Understandings (following the UbD model) and linked those understandings to each unit. Testing in science takes place only in eighth grade, and Earth and space science concepts cover roughly 25% of the items on that test.

Research Participants

A total of 41 sixth, seventh, and eighth grade teachers from 19 middle schools in a large urban district were assigned to one of the three professional development conditions. Teachers who volunteered represented 3 magnet schools (arts, science and math, and academic) and 10 schools with over 50% of the students on free or reduced-price lunch. Three middle schools that had a science teacher leader on staff had five or more teachers volunteer for the study.

Of the teachers that volunteered, 14 teachers were assigned to the *IES* condition, 13 to the *ESBD* condition, and 14 to the *Hybrid* condition. The differences among groups on the characteristics presented below in Table 1 are not statistically significant.

Table 1
Characteristics of Faculty Respondents to Questionnaire

	Condition		
	IES	*ESBD*	*Hybrid*
Gender			
Percent Male	25.0%	45.5%	27.3%
Percent Female	75.0%	54.5%	72.7%
*Race/Ethnicity**			
White	75.0%	45.5%	54.5%
African American	16.7%	45.5%	36.4%
Hispanic/Latino	8.3%	0.0%	18.2%
Asian	0.0%	0.0%	0.0%
Other/Unknown	9.0%	0.0%	0.0%
Teaching Experience			
Years Teaching	M = 12.7 yrs SD = 11.0 yrs	M = 14.4 yrs SD = 11.8 yrs	M = 5.85 yrs SD = 4.1 yrs
Years Teaching Science	M = 10.5 yrs SD = 8.2 yrs	M = 9.1 yrs SD = 5.9 yrs	M = 4.3 yrs SD = 3.1 yrs
Highest Degree			
Bachelor's	66.7%	81.8%	90.9%
Master's	16.7%	18.2%	9.1%
Educational specialist's	8.3%	0.0%	0.0%
Missing	8.3%	0.0%	0.0%
Teaching Assignment			
6	5	5	5
7	3	3	4
8	4	3	2

* Teachers could select multiple categories.

Sources of Data

Workshop evaluation questionnaire

We collected data on teachers' experiences of their professional development through a researcher-administered questionnaire at the end of each workshop. We analyzed individual items taken from two indices related to active learning (engagement and feedback) from an earlier study (Garet et al., 2001) of effective professional development. For both sets of items, we examined which items a majority of teachers said characterized their particular workshop. We also used Garet et al.'s scale for comparing perceptions of coherence among teachers assigned to different conditions. In the original study, the reliability of this scale was high (α = 0.86). To examine the focus on inquiry, we included an item asking teachers to report how much emphasis the workshop gave to scientific inquiry (scale: 0 = none at all; 3 = a lot of emphasis). To examine self-reported effects on knowledge and skill, we constructed an index comprised of items used in the earlier study (Garet et al., 2001) and items we developed specifically for the study. The reliability of this scale was high for our study (α = 0.87).

Professional development questionnaire

We collected data on teachers' reported changes to instructional planning through an online questionnaire completed 1 year after their workshop. The questionnaire focused on a range of topics related to teachers' instructional planning process and unit implementation. The analysis presented in this paper focuses on qualitative responses to an item asking them to describe how the professional development influenced their instructional planning process.

Results

Active Learning: Engagement

Table 2 shows those active learning strategies that at least half of the teachers in each condition endorsed as characteristic of their initial workshop. The teachers in each of the conditions reported different kinds of active learning strategies, which largely reflected the nature of the professional development designs to which they were exposed. For example, all of the participants in the *IES* condition, and just over half in the *Hybrid* condition reported that they conducted a demonstration of a lesson. As part of both workshops, teachers had the opportunity to demonstrate the implementation of an investigation to their colleagues. By contrast, all of the *ESBD* and *Hybrid* teachers reported that they developed a unit plan, but a few *IES* teachers did not do so. In both the *ESBD* and *Hybrid* workshops, teachers said leaders emphasized unit planning. Had we asked about the nature of the plans developed in the *IES* workshop, we might have discovered what we would later learn from the post-unit implementation survey, namely that these were "pacing guides" rather than full unit plans. Overall, there were fewer different strategies endorsed [is it endorsed or "reported"?] by over half the participants in the *ESBD* condition than in the other two conditions.

Table 2
Elements of Engagement Enacted in Workshops

IES	*ESBD*	*Hybrid*
Conducted a demonstration of a lesson, a unit, or a skill (14)	Developed a unit plan (13)	Developed a unit plan (17)
Gave a lecture or presentation (13)	Wrote reflections in a journal (11)	Practiced using student materials (16)
Practiced using student materials (13)		Wrote reflections in a journal (13)
Developed a unit plan (10)		Conducted a demonstration of a lesson, a unit, or a skill (8)
Led a small-group discussion (8)		Led a small-group discussion (8)

Note: Numbers in parentheses indicate how many teachers endorsed item. Only items that a majority of participants endorsed as characteristic of the workshop appear.

Active Learning: Feedback

Table 3 shows those kinds of feedback that at least half of the teachers in each condition identified as characteristic of their initial workshop. In contrast to teachers' reports of active learning strategies used, the kinds of feedback reported were much more similar across condition. Nearly all teachers in each condition spent extensive time discussing implementation in different contexts: with leaders, informally with colleagues, and formally with colleagues. More than half of all teachers in each condition also reported receiving coaching and mentoring as part of their professional development. The only clear distinction among conditions was that in comparison to the *IES* condition, a higher percentage of teachers in the *ESBD* and *Hybrid* conditions reported getting feedback on lesson plans they had developed. This contrast is not surprising and shows consistency with the professional development models, since the plan was for teachers in both the *ESBD* and *Hybrid* conditions to develop, get feedback on, and revise unit plans.

Table 3

Elements of Feedback Enacted in Workshops

IES	*ESBD*	*Hybrid*
Communicated with the leaders of the activity concerning implementation (13)	Developed curricula or lesson plans, which other participants or the activity leaders reviewed (12)	Developed curricula or lesson plans, which other participants or the activity leaders reviewed (17)
Met informally with other participants to discuss implementation of my unit (12)	Communicated with the leaders of the activity concerning implementation (12)	Communicated with the leaders of the activity concerning implementation (17)
Practiced under simulated conditions, with feedback (12)	Met formally with other participants to discuss implementation of my unit (12)	Met informally with other participants to discuss implementation of my unit (16)
Met formally with other participants to discuss implementation of my unit (11)	Met informally with other participants to discuss implementation of my unit (11)	Met formally with other participants to discuss implementation of my unit (15)
Received coaching or mentoring (9)	Received coaching or mentoring (9)	Received coaching or mentoring (9)
Developed curricula or lesson plans, which other participants or the activity leaders reviewed (9)		

Numbers in parentheses indicate how many teachers endorsed item. Only items that a majority of participants endorsed as characteristic of the workshop appear.

Coherence

Coherence ratings, that is, ratings of how consistent goals of the workshops were with district goals for students, were very high in all of the conditions. Teachers in all three conditions rated the workshops between 11.7 and 13.4 on a scale from 1 to 14, with 14 representing the highest possible rating of coherence. Ratings were highest for the *Hybrid* condition and lowest for the *IES* condition, but these differences were not statistically significant.

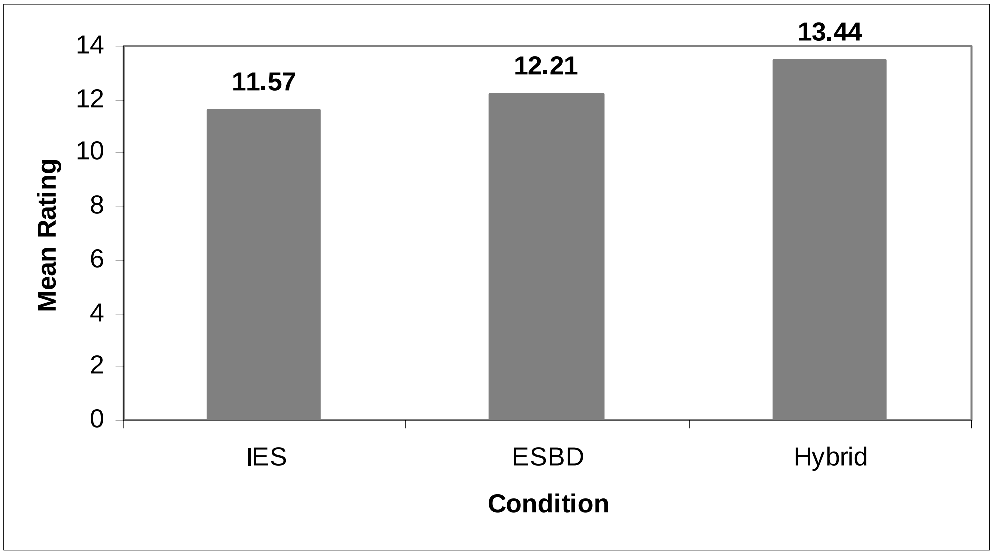

Figure 1. *Ratings of coherence of workshop*

Preparation for Inquiry

Teachers assigned to the two conditions that promoted inquiry-based approaches to teaching science rated their professional development higher in terms of how well their workshops prepared them for inquiry teaching than did teachers in the other condition. Teachers in the *IES* and *Hybrid* conditions rated the workshops at 2.1 on a scale from 0 to 3, with 3 representing the highest possible rating of preparation for inquiry. These ratings were higher than the ratings of teachers in the *ESBD* condition, which does not explicitly promote inquiry-based teaching as part of its model.

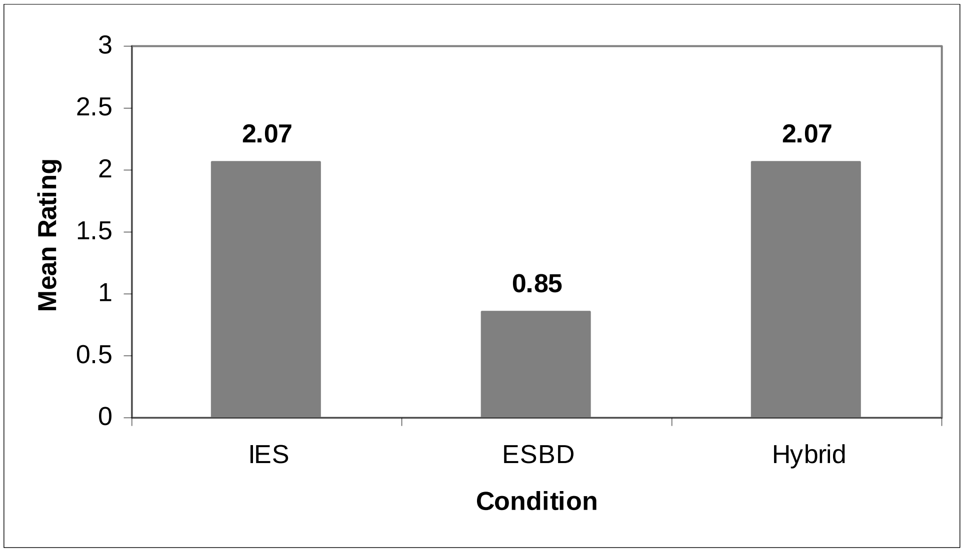

Figure 2. *Ratings of relative emphasis on scientific inquiry in workshop*

Self-Reported Changes to Knowledge and Skill

As Table 4 shows, there were some small differences in the nature of the self-reported increases to knowledge and skill across conditions. Participants in the *IES* condition reported the highest gains in the areas of leading student led-investigations and making those investigations relevant. Consistent with the UbD approach, participants also saw the workshop as increasing their ability to make sure students knew why they were engaged in particular activities. Participants in the *ESBD* condition, by contrast, were most likely to report gains in ensuring students knew the rationale for particular activities but were less likely to report gains in preparing them for inquiry-based science. The pattern of gains reported by teachers in the *Hybrid* condition most resembled participants in the *IES* condition: they reported gains related to the ability to implement both the UbD approach and inquiry-based science.

Table 4.
Mean Ratings of Workshop Participants for Self-Reported Increase in Knowledge and Skill

	IES		*ESBD*		*Hybrid*	
	M	*SD*	*M*	*SD*	*M*	*SD*
Knowledge of standards	1.4	0.85	0.92	0.95	1.5	0.87
Ability to lead student-led investigations	2.1	0.73	1.1	0.76	1.8	0.73
Ability to lead other hands-on or laboratory activities	2.0	0.55	0.77	0.73	1.9	0.78
Knowledge of how to make investigations relevant	2.1	0.47	1.5	0.97	2.0	0.71
Ability to make sure students know why they are engaged in particular activities	2.0	0.55	2.2	0.60	2.4	0.49
Ability to help students formulate scientific questions	1.9	0.47	0.93	0.86	1.7	0.85
Ability to help students construct explanations	1.4	0.84	0.92	0.95	1.6	0.80
Ability to help students engage in written scientific communication	1.6	0.85	0.85	0.80	1.3	0.77

With respect to teachers' self-reports of what knowledge and skills they gained from the workshops, there were significant differences among conditions (F (2,41) = 6.88, p < .01). Post-hoc comparisons show that the *ESBD* condition teachers rated their workshop significantly lower than teachers in the other two conditions (Figure 3).

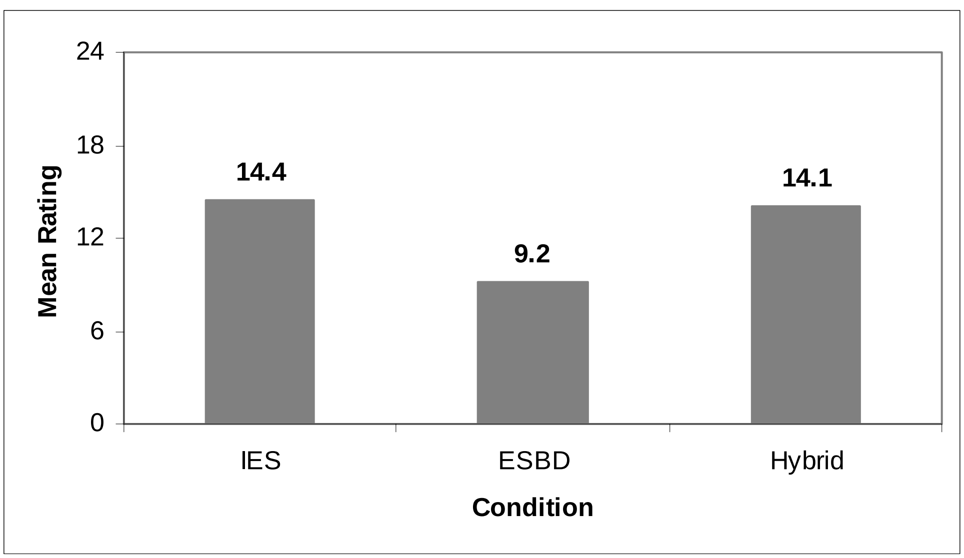

Figure 3. *Self-report on improvements in knowledge and skill from workshop*

Influence on Instructional Planning

As promoted in the professional development models, teachers in both the *ESBD* and *Hybrid* conditions reported that their participation in the project had had a large impact on their instructional planning process. Six of the *ESBD* teachers and six of the *Hybrid* teachers mentioned thinking more about what their students should know at the end of the unit when planning their units. In other words, these teachers gave much more weight to the "enduring understandings" they expected students to have at the end of their units:

> *The experience has taught me to "look down the road" first, to determine where I want the students to end and then to determine how they are going to get there, starting with the "end" in mind. (*ESBD *Teacher)*

> *When planning instruction I'm looking at a large unit with common goals and all activities aligned, instead of a piecemeal week-to-week fashion. (*IES *Teacher)*

A few teachers in both these conditions also mentioned that they made use of the data from preconceptions assessments given at the beginning of units to adjust their planned sequence of activities:

> *I review students' preconception responses to determine what I'd emphasize. TIDES has given me a deeper understanding of how to engage my student incorporating technology and visualizations. Its also help me to effectively uncover deep understanding, misunderstandings, and preconceptions my students developed. (*ESBD *Teacher)*

Finally, teachers in these two conditions also reported that they learned from the TIDES workshops *how* to go about planning.

> *I have a much better idea of how to go about planning. At first, I was not sure if how I was doing the thing was right, wrong, or if anyone new exactly how to plan. However, I am now more confident in how I do my planning and rely much more on my own material. (*Hybrid *Teacher)*

> *I planned the entire unit before actually teaching this year, rather than planning as I go as I had done in previous years. (*Hybrid *Teacher)*

> *My planning process became more of a "reverse sequence" method. (ESBD Teacher)*

Teachers in the *IES* condition did report that participating in the project had caused them to plan to incorporate more student-centered and hands-on laboratories and investigations in their teaching.

> *I am leaning more towards "inquiry-based" science. Students need to be more responsible for discovering and teachers need to stop hand feeding students information. (*IES *Teacher)*

> *I am using more hands-on activities to keep students interested and focused. (*IES *Teacher).*

These self-reported changes to instructional planning are consistent with the models of professional development they seek to promote. Both the *ESBD* and *Hybrid* workshops introduced teachers to a new approach to instructional planning. Although the two conditions differed in that the *Hybrid* teachers received curriculum materials with extensive opportunities for student investigations and the *ESBD* teachers did not receive these materials, teachers' reported changes to their instructional planning process were remarkably similar across conditions. The teachers in the *IES* condition had a distinctive profile, reflecting their efforts to incorporate more inquiry-oriented, hands-on activities in science with their students.

Notably absent from the *ESBD* and *Hybrid* teachers' reported changes to instructional planning were descriptions of new culminating performance tasks. Although the second step in the planning process emphasized in the workshops involves the design of a measure to assess enduring understandings that are the focus of the units, these did not figure in teachers' reported changes to practice. This fact suggests either that these aspects of the model may have been less salient for teachers or that the model aspects had not been adopted by teachers in the study.

Discussion and Conclusion

The pattern of results from both questionnaires suggests that, overall, the professional developers' enactments were consistent with their designs. As would be expected if the enactments were consistent with designs, the teachers in the *IES* and *Hybrid* conditions experienced more opportunities to learn about inquiry-based science and about how to implement those curriculum materials with students. Similarly, teachers in the *ESBD* and *Hybrid* conditions reported more opportunities to learn about unit planning, which is emphasized in the design of those two conditions. After a year, teachers in these two conditions reported significant changes to their unit planning process, a finding that is also consistent with the professional development designs for those conditions. All of the enactments were consistent with their designs in that teachers reported they had opportunities to discuss implementation and teachers judged workshops to be aligned with their own goals for student learning and with what the district expected of them.

There were, to be sure, some differences between what was expected and what teachers experienced. For example, a majority of teachers in the *IES* condition did report after the workshop that they engaged in unit planning; only by examining data from the implementation questionnaire was it apparent what the nature of effects on unit planning were. These qualitative data present a picture consistent with the design, but they also suggest that even in a condition focused on curriculum adoption, many teachers engaged in some form of adaptation of the curriculum materials in planning for unit implementation. In addition, teachers reported fewer active learning strategies and changes to knowledge and skill in the *ESBD* workshop overall. Teachers may have rated the workshop's effectiveness somewhat lower, to the extent that they had fewer opportunities for active engagement, an interpretation that would be consistent with earlier studies of the correlates of effective professional development (Garet et al., 2001; Penuel et al., 2007).

In sum, the study results suggest that researchers can use teacher questionnaires of the kind developed for this study to trace the design of different approaches to teaching for understanding in teacher experience. Those questionnaires need to incorporate measures of effective professional development and measures that can distinguish among different professional development designs. When researchers develop specific hypotheses about how teacher experiences will differ by condition, then they can analyze the data in such a way that if enactment is consistent with design, teachers' reported experiences will reflect those hypothesized differences.

A challenge remains to demonstrate that these "differences make a difference," that is, that differences in teacher experiences in professional development lead to improvements in teaching and learning. We are exploring this question in our larger study, but it is important to recognize that we cannot answer easily the question of whether teacher experiences cause changes in teaching and learning. We cannot randomly assign teachers to have different *experiences* of professional development, and so we will never be sure that those experiences are the causes of changes to practice or teacher learning. Furthermore, there are lots of influences on student learning besides professional development. Nonetheless, if results from survey measures of the kind we used in this study can be linked in correlational analyses to changes in teaching and learning, then researchers will likely see the utility of these kinds of measures in an even more positive light.

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