Angela T. Barlow, Tasha M. Frick, Heather L. Barker, and Amy J. Phelps

Modeling Instruction: The Impact of Professional Development on Instructional Practices

Abstract

Modeling Instruction holds the potential for transforming science instruction and improving student achievement. Key to the success of Modeling Instruction, however, is the fidelity of implementation of its curriculum. This qualitative study examined the impact of Modeling Instruction professional development on participating teachers' instructional practices. Through classroom observations and interviews, participants provided insight into challenges that impact fidelity of implementation. Participants for whom the professional development had no impact shared an additive view of the professional development along with external challenges that represented a misalignment between participants' goals and those of Modeling Instruction. Participants within the medium impact group held either transformative or additive views of the professional development. These participants described external challenges, which were closely related to their internal challenges. These internal challenges represented a cognitive dissonance that led to low fidelity of implementation. Finally, participants within the high impact group held a combination of both transformative and additive views of the professional development. These participants felt that they were reform-oriented prior to beginning the professional development, although the observations for two of the participants did not reveal this. The remaining participant's observation confirmed that she indeed practiced reform-oriented instruction prior to beginning the professional development, which likely supported her high fidelity of implementation. Implications for professional development providers are offered.

Keywords: modeling instruction, professional development, fidelity to the model, transformative instruction, additive instruction

Introduction

Students in the United States continue to lag behind other nations in science achievement. The 2007 Trends in International Mathematics and Science Study (TIMSS) found that the average science scores for U.S. fourth graders were below those of four other nations. This deficit in science achievement was even more severe in eighth grade, with the U.S. scores falling below that of nine other nations. Furthermore, there has been no measurable change in U.S. science scores since 1995 (Gonzales et al., 2008). Similar disappointing results can be found in the 2009 Program for International Student Assessment (OECD, 2010). At a time when every citizen needs some level of knowledge in science, technology, engineering, and mathematics (NSF, n.d.), the need to improve student achievement in science is paramount.

"The most direct route to improving mathematics and science achievement for all students is better mathematics and science teaching" (National Commission on Mathematics and Science Teaching for the 21st Century, 2000, p. 7). Teachers have a clear impact on student learning (Marzano, 2003; Wright, Horn, & Sanders, 1997). A highly effective teacher can result in student gains of a full two months ahead of the students of an average teacher (Sanders & Rivers, 1996). In contrast, an ineffective teacher can result in students gaining little more than that which would have resulted from a year of maturation (Marzano, 2003). This effect on learning is compounded by consecutive years of being with an effective or ineffective teacher (Mendro, Gordon, Gomez, Anderson, & Bembry, 1998). These findings indicate that there is a strong need to aid science teachers in becoming effective.

Professional development is a means for supporting development of effective science teachers and in turn improving student achievement in science (Blank, de las Alas, & Smith, 2008). In their discussion, Blank et al. described key characteristics of effective professional development for science teachers, which included both a focus on content and teacher engagement in learner-centered pedagogies. These two key characteristics are foundational to Modeling Instruction professional development, the professional development under investigation in this research.

Modeling Instruction is a research-based curriculum that supports high school students' engagement in the processes and discourse of science (Jackson, Dukerich, & Hestenes, 2008). When implemented with high fidelity, the students of teachers utilizing the Modeling Instruction curriculum have demonstrated significant gains in achievement (Hestenes, 2000). Recognizing the significance of fidelity of implementation, Modeling Instruction emphasizes the importance of effective professional development. Through Modeling Instruction professional development, teachers have an opportunity to participate in the roles of student and teacher as designed in the Modeling Instruction curriculum. In doing so, these teachers not only strengthen their own understanding of the content but also their understanding of the pedagogy associated with modeling (Jackson et al., 2008).

In the final report of the NSF-funded project, Modeling Instruction in High School Physics, Hestenes (principal

investigator) reported on the success of the project, including the increase in both teachers' content knowledge and student achievement (Hestenes, 2000). Within this report, however, he noted that the differences in students' performance on the Force Concept Inventory could only be explained by the fidelity of implementation of Modeling Instruction by their teachers. With this in mind, the purpose of this research was to examine the impact of Modeling Instruction professional development on instructional practices. Specifically, we aimed to identify factors influencing the fidelity of implementation. To this end, the following research questions were posed.

1. How does participation in a two-week professional development focused on Modeling Instruction impact teachers' instructional practices?
2. What factors influence the fidelity of implementation of Modeling Instruction?

The significance of this research lies in its examination of teachers' instructional practices before and after participation in a modeling workshop. Through this process, the documentation of issues surrounding the fidelity of implementation will aid other researchers and professional developers who are supporting teachers in implementing Modeling Instruction. In addition, this research moves the field forward by identifying the factors that could potentially impact implementation of any professional development program.

Literature Review

Modeling Instruction

Modeling Instruction is a research-based instructional method developed for high school science educational reform. This program began at Arizona State University (ASU) specifically as a model-centered approach to traditional physics instruction (Wells, Hestenes, & Swackhamer, 1995). Jackson and colleagues (2008) summarized the modeling cycle, which consists of two stages through which the students work. The first stage, model development, begins with a laboratory investigation or demonstration, followed by small group collaboration, presentation of group findings to the whole class for clarification and justification, and then analyses to develop an overarching model. The next stage, model deployment, gives students the opportunity to apply their understanding to new problems and situations. Modeling Instruction is characterized by the development of understanding through cooperative inquiry and collective discourse (Wells et al., 1995).

Research over the past 20 years has continued to demonstrate the effectiveness of Modeling Instruction on improving student understanding of physics concepts as measured by the Force Concept Inventory (FCI) (Savinainen & Viiri, 2008). After one year of education under novice modelers, students increased their FCI scores an average of 27%, while students under expert modelers, increased an average of 43% (Hestenes, 2000). Malone (2008) reported that modeling students developed more "expertlike problem-solving skills," (p. 020107 1) leading to fewer mistakes and better understanding which translated into better achievement in physics. Similarly, researchers at Florida International University implemented modeling-type reform laboratory sections along with traditional laboratory sections in their introductory physics classes and found students in the reform laboratories increased their FCI scores more than those in the traditional laboratories (Brewe et al., 2010). Additionally, Modeling Instruction has been shown to provide benefits other than purely academic gains, such as increasing positive attitudes toward physics (Brewe, Kramer, & O'Brien, 2008) and facilitating the development of more student-to-student interaction while developing a sense of community within the classroom (Brewe et al., 2010). The triumph of Modeling Instruction in physics has been the successful dissemination of practice through professional development (Lee, Dancy, Henderson, & Brewe, 2012). Given the positive outcomes of Modeling Instruction in physics, modeling curriculums have been developed and shown promising results in both chemistry (Barker, 2012; Dugger, Principe, & Rudolph, 2012; Dye, Cheatham, Rowell, Barlow, & Carlton, 2013; Farrell, Moog, & Spencer, 1999; Lewis & Lewis, 2005) and biology (Dye et al., 2013; Dye, Nolan, Rudolph, 2012; McDaniel, Lister, Hana, & Roy, 2007).

Professional Development

The importance of professional development is highlighted with the knowledge that teachers play a critical role in the potential for student learning (Ding & Sherman, 2006). Professional development has been proven to be an effective way of reaching teachers with the most current practices for instruction (Lumpe, Czerniak, Haney, & Beltyukova, 2012), with the potential ability to change their instructional practices (Desimone, Porter, Garet, Yoon, & Birman, 2002). Donnelly and Argyle (2011) demonstrated that professional development focused on nature of science activities resulted in teachers increasing the implementation of those instructional practices in their classrooms while deepening teachers' content knowledge. Lumpe and colleagues (2012) showed that effecting positive changes in teacher beliefs and self-efficacy through professional development led to positive benefits for their students' achievement.

Although such studies demonstrate that quality professional development benefits teachers and their students, not all professional development has been found to be effective. Drawing on previous research (e.g., Garet, Porter, Desimone, Birman, & Yoon, 2001; Jeanpierre, Oberhauser, & Freeman, 2005; Penuel, Fishman, Yamaguchi, & Gallagher, 2007), Desimone (2009) synthesized five key components of professional development that positively impact teacher beliefs and practices leading to improvements in student achievement: content focus, active learning, collective participation, duration, and coherence.

The Modeling Instructional professional development under investigation in this study succeeded in integrating four of these components of quality

teacher training. First, the leaders focused on enhancing teachers' scientific content knowledge while allowing them to experience the Modeling Instruction methodology as learners. Additionally, the professional development provided numerous active learning opportunities for the participants, such as observing experts and being observed, receiving feedback, and leading and participating in scientific discourse. Collective participation was also achieved because many teachers from the same school attended together. Finally, the professional development project included more than 60 contact hours, far surpassing the recommended effective minimum of 20 hours (Desimone, 2009). Coherence, defined as ensuring that the learning was aligned with the teachers' beliefs and their school and district policies, was a goal of the professional development. However, it could be argued that this was not made clear enough and, therefore, did not play a role in impacting the participants.

Fidelity of Implementation

Professional development can have an impact on teacher instructional practices, which in turn can lead to improvements in student achievement (Schroeder, Scott, Tolson, Huang, & Lee, 2007). Research has revealed, however, that the level of student learning gains can vary widely among teachers, all of whom experienced the same professional development (Hestenes, 2000; Penuel & Means, 2004). One consistent hypothesis offered by researchers to account for these differences is that some of the teachers are not following the design of the instructional practices established during the professional development (i.e., low fidelity of implementation). The phrase "fidelity of implementation" has been widely defined as how well a new program implemented by practitioners aligns with how it was originally intended by the developers (Carroll et al., 2007; O'Donnell, 2008). The hypothesis regarding fidelity of implementation was supported by Taylor, Van Scotter, and Coulson (2007) who reported a strong relationship between high fidelity of implementation and student learning gains. High fidelity of implementation of an effective professional development program resulted in greater increases in student achievement when compared to that of low fidelity of implementation (Penuel & Means, 2004; Stein et al., 2008). Hestenes (2000) demonstrated this finding in Modeling Instruction, showing that students of teachers with a high fidelity of implementation had higher achievement gains than those of teachers with a low fidelity of implementation.

Identifying the factors that influence teachers' ability to more effectively apply the important ideas and skills from professional development to their classrooms can create insight into how to increase the fidelity of implementation of Modeling Instruction. Spillane, Reiser, and Reimer (2002) highlighted the importance of "sense-making" for teachers to be able to implement with integrity. They posited that the teachers' knowledge, beliefs, and attitudes interact with the situation and the policy itself to influence how effectively they understand the new policy, thus impacting their fidelity of implementation. Inability to implement with fidelity is often not due to outright rejection of the ideas, but rather a result of a mismatch between the intent of the facilitators and the understanding of that intent that is constructed by the teacher. This is more likely to occur when the teachers' existing knowledge structures and cognitive patterns are significantly different than those required of the reform program. Additionally, the authors suggested that implementation fidelity suffers when the practitioners perceive the new program as contrary to their goals, interests, or prior agendas.

There are also specific characteristics of program design and dissemination that can influence teachers' fidelity of implementation. One study that described the implementation of a new reading program revealed the benefits of providing highly structured plans for the teachers and having an extra follow-up workshop (Stein et al., 2008). In a review of research, O'Donnell (2008) found that there was strong fidelity of implementation when the program was explained with "clarity and specificity" (p.51) rather than in general terms. In a qualitative study specifically about Modeling Instruction, researchers identified key influences that affected teachers' ability to effectively implement and disseminate the method (Lee et al., 2012). They found it was important to provide teachers with the physical space and resources required for the innovation, as well as supporting their empowerment through a sense of ownership. In Modeling Instruction this is done by encouraging teachers' to add to and adapt the curriculum while developing and participating in a supportive community.

Methodology

Research Context

This research occurred in the context of an externally funded project titled *Transforming Instruction through Modeling Experiences* or *Project TIME*. The primary goal of Project TIME was to increase secondary science teachers' content knowledge through the dissemination of the Modeling Instruction professional development. Project activities included three concurrent two-week summer institutes, each focusing on a different content area (physics, biology, and chemistry) and led by highly experienced members of the Modeling Instruction community. A total of 59 teachers attended the summer institutes with the majority of these from the partner districts associated with Project TIME. Other teachers traveled from distant states to attend the institute.

Sample

From the group of teachers participating in Project TIME, nine teachers were purposefully selected to participate in this research study. The choice to use nine participants was appropriate given the qualitative nature of the study (Creswell, 2013). Two factors influenced the selection of the participants. First, we aimed to choose two or three participants from each of the disciplines addressed in the Modeling Instruction workshop: biology, chemistry, and physics. Second, we elected to choose teachers from a single school district, thus supporting our desire to have a homogeneous group of

participants. The group of participants was homogeneous in regard to the context within which they worked. In doing so, we aimed to support the transferability of the findings.

The school district was located near a large metropolitan area within a southeastern state. The district included six high schools and served over 38,000 students. Table 1 provides participants' background information. Note that participants' names have been replaced with pseudonyms. Of the nine participants, only one was male. To protect this participant's anonymity, all participants will be referred to as females.

Instruments

RTOP. The Reformed Teaching Observation Protocol (RTOP) (Arizona Board of Regents, 2002) is an observation instrument that aims to measure reformed teaching in mathematics and science classrooms. Unlike many observation instruments, the RTOP has a high reliability rating. Evidence has demonstrated that teachers with improved RTOP scores in turn have improved student achievement (Sawada, n.d.). For these reasons, we elected to use the RTOP.

The RTOP includes five categories: Lesson Design and Implementation; Content: Propositional Knowledge; Content: Procedural Knowledge; Classroom Culture: Communicative Interaction; and Classroom Culture: Student/Teacher Relationships. Within each category, the RTOP includes five statements to which the evaluator assigns a score ranging from 0 (never occurred) to 4 (very descriptive). RTOP observations are conducted in pairs, with each observer completing the RTOP individually. Afterwards, the observers meet to compare ratings and develop a "combined" RTOP that represents the agreed upon scores on each of the statements on the instrument.

Observational checklist. Based on a review of the literature, Project TIME researchers created an observational checklist (see Appendix A) to support findings from the RTOP. The observational checklist consisted of 11 statements that identified key instructional practices specific to Modeling Instruction. Using the observational checklist, the classroom observers recorded evidence taken from the lesson that aligned with the statements.

Interview protocols. To gain deep insight into the teachers' perceptions of instructional practices, the Project TIME research team created an interview protocol (see Appendix B), which consisted of a series of open-ended questions to which the teacher responded. The protocol was not rigid, however, in the sense that follow-up questions and additional questions could be asked by the interviewer as appropriate.

Procedures

In March 2012, Project TIME personnel selected the teachers that would participate in the two-week summer institutes. From this collection of individuals, we purposefully selected nine teachers to invite to participate in the research component of the project. During the month of April, we observed each of the participants teaching a single lesson within a class period selected by the participant. Observations were conducted in pairs and served to provide baseline data regarding instructional practices prior to participating in the summer institute. Observers completed the RTOP and Observational Checklist at this time.

In June 2012, participants attended the two-week summer institute that engaged them in the Modeling Instruction professional development designed for their particular content area (biology, chemistry, or physics). The institute classes were led by experts in Modeling Instruction and included more than 60 contact hours. Participants engaged as learners in the modeling curriculum, actively developing and employing models. Participants completed homework problems nearly every night.

During September 2012, we observed the participants teaching a single lesson within a class period selected by the participant. As before, observations were conducted in pairs and included the completion of the RTOP and the Observational Checklist. The purpose of these observations was to document any changes in instructional practices that occurred potentially as a result of attending the summer institute. In addition, we interviewed each participant immediately following the observation using the interview protocol. These interviews provided insight into participants' perceptions of their implementation of the modeling curriculum.

Data Analysis

RTOP. Participants received scores on 25 items across five categories on the RTOP. Within each category, we summed the scores to produce a score for each category for each participant. Next, we examined the RTOP scores for all participants, noting patterns and trends that arose between the pre-and post-observations.

Interview Protocol. After transcribing the interviews, we analyzed interview data using open coding (Creswell, 2013). Following a grounded theory approach (Strauss & Corbin, 1990), we developed our phenomena, categories, and codes. An initial read of the transcripts revealed two major phenomenon related to participants' fidelity of implementation of Modeling Instruction, as well as factors

Table 1: Participant information

Participant	Race	Subject	Years Teaching	School
Ms. Moore	W	Biology	3	A
Ms. Williams	W	Physics	16	A
Ms. Jones	W	Biology	18	B
Ms. Wilson	W	Biology	1	B
Ms. Johnson	W	Chemistry	3	B
Ms. Brown	W	Chemistry	18	C
Ms. Davis	W	Biology	20	C
Ms. Taylor	W	Chemistry	19	C
Ms. Miller	W	Chemistry	13	D

that contributed to the fidelity of implementation. Independently, we utilized the categories we had constructed using the guidelines set forth by Merriam (1988). Throughout the investigation into each phenomenon, four main categories emerged. Each researcher analyzed two of the transcripts and then met to confer on our application of the categories in analyzing the two transcripts. Once we developed agreed upon code descriptions, we individually read all of the transcripts, coding statements that related to the identified codes. Afterwards, we collaboratively reviewed the transcripts, marking those statements with which there was agreement or disagreement. For those statements for which there was disagreement, we discussed the statement and its assigned code until a consensus was reached. Afterwards, we analyzed these codes for both descriptive findings (i.e., patterns) and categories (i.e., themes) (Patton, 2002).

Observational checklist. Through the analysis of the interview data, we were able to note the components of Modeling Instruction that participants stated were utilized in their instruction. Based on this, we analyzed the observation checklists, looking for evidence regarding the fidelity of implementation of the identified Modeling Instruction components.

Results

RTOP

Table 2 presents participants' pre- and post-observation scores for each of the five RTOP categories and the total RTOP score. Among the RTOP's five categories, participants consistently demonstrated growth in the Content: Propositional Knowledge category. Within the remaining four categories, participants' scores did not reveal consistent patterns. For example, within category 5 – Classroom culture: Student/teacher relationships, six participants had an increase in scores while two participants demonstrated a decrease and one remained unchanged.

All participants demonstrated increases in their total RTOP scores, with the exception of Ms. Johnson. Six participants (Ms. Williams, Ms. Jones, Ms. Brown, Ms. Davis, Ms. Taylor, and Ms. Miller) had increased or unchanged scores across all five categories. In contrast, two participants (Ms. Wilson and Ms. Johnson) demonstrated no change or decreased scores in four of the categories, with the exception being Content: Propositional Knowledge.

Table 2: Participants' RTOP Scores

Participant	Observation	RTOP Category 1	2	3	4	5	Total
Ms. Moore	Pre	10	8	3	8	8	37
	Post	9	15	7	7	10	48
Ms. Williams	Pre	1	4	0	0	2	7
	Post	8	12	6	8	7	41
Ms. Jones	Pre	0	6	0	1	0	7
	Post	11	15	8	15	15	64
Ms. Wilson	Pre	0	6	0	0	2	8
	Post	0	9	0	0	1	10
Ms. Johnson	Pre	6	12	4	4	4	30
	Post	1	15	1	2	2	21
Ms. Brown	Pre	0	5	1	0	0	6
	Post	2	11	1	3	4	21
Ms. Davis	Pre	6	10	2	4	6	28
	Post	6	16	9	7	6	44
Ms. Taylor	Pre	1	6	1	1	4	13
	Post	2	12	2	2	5	23
Ms. Miller	Pre	10	12	6	12	16	56
	Post	18	18	14	17	18	85

Category 1 – Lesson design and implementation; Category 2 – Content: Propositional knowledge; Category 3 – Content: Procedural Knowledge; Category 4 – Classroom culture: Communicative Interaction; Category 5 – Classroom culture: Student/Teacher Relationships

Interviews

The interview analysis revealed four themes: implemented modeling practices, aspects supporting the desire to implement, challenges to implementation, and perceptions of changes in practice. Each of these themes will be presented in the following paragraphs.

Implemented modeling practices. During the interview, participants were asked to identify the modeling techniques utilized in their instruction. With the exception of Ms. Taylor, the remaining eight participants reported the use of whiteboards in their lessons. Whiteboards are large, group-sized whiteboards used within the modeling instruction approach to facilitate student presentations during "board meetings." Participants received class sets of whiteboards as a part of the Modeling Instruction professional development.

Beyond whiteboards, five participants (Ms. Moore, Ms. Brown, Ms. Johnson, Ms. Davis, and Ms. Williams) described their use of the modeling curriculum in their classrooms. In some instances, the participant alluded to a general use of the curriculum materials that were received during the summer workshop. For example, Ms. Brown said, "I have that notebook on my desk and I'm flipping through it." In other instances, the participant provided a specific example of a lab that she had implemented. For example, Ms. Davis said, "With the characteristics of life, I did use some of the modeling activities. I just [taught it] right from the book." In addition to white boards and the curriculum, participants mentioned increased use of student discussions (Ms. Moore and Ms. Johnson), teacher questioning (Ms. Wilson, Ms. Johnson, and Ms. Williams), class consensus (Ms. Davis and Ms. Miller), collaborative groups (Ms. Jones and Ms. Davis), and discovery learning (Ms. Jones and Ms. Taylor).

Aspects supporting the desire to implement. As participants described their implementation of Modeling Instruction, they often made statements regarding aspects of teaching that seemed to support their desire to implement Modeling Instruction. Specifically, seven participants

described student benefits of Modeling Instruction. Focusing on student enjoyment, Ms. Johnson said, “The students respond to it. They like it because they’re not having to do as much bookwork. It’s a lot of discussion.” In contrast, Ms. Williams focused her thoughts on student learning. She said:

> Teaching uniform motion from a graphical perspective as opposed to a just purely visual and algebraic perspective I think has helped. I think that my kids understand distance time graphs significantly better than they have. . . . They were able to see it and maybe understand it a little bit better, which I think is different from years past.

Here, Ms. Williams described a specific instance in which she felt Modeling Instruction supported student learning better than her previous instructional methods. Unlike Ms. Williams who described her perception of student learning, Ms. Moore referred specifically to test scores as evidence of student learning. She said, “Their test scores are definitely better than my peers who aren’t using the method.”

In addition, two participants spoke of student self-efficacy. Ms. Jones described students developing a belief in their abilities to succeed as a result of her implementation of Modeling Instruction. Ms. Jones said, “I think they were shocked that they could do it. . . . Once they figured it out – that’s the impressive part. That they’re like, ‘Oh yeah, I can do this. I don’t have to have her tell me what to do.’ So that’s my favorite part.”

In contrast, seven participants described aspects of Modeling Instruction that appealed to them as the teachers. For example, Ms. Brown said, “I like the more student-oriented thing instead of me standing there doing it and them copying it down. I like them being more accountable for what they’re learning.” Similarly, Ms. Wilson stated, “The questioning. I love the questioning. The more questions I can ask to make them think deeper, that’s what I really like about it. Just something to make them think.” Both Ms. Brown and Ms. Wilson have described aspects they like about Modeling Instruction. Furthermore, two participants stated that they enjoyed implementing Modeling Instruction without providing specific examples.

Beyond an affinity for the techniques, two participants identified the benefit of informal assessment that resulted from the use of Modeling Instruction. Ms. Miller said, “It helps me to have a better understanding of what they know . . . and to identify misconceptions.” Similarly, Ms. Williams said, “I understand why you [the student] don’t get it, because you are thinking this instead of this.”

In a completely different vein, Ms. Moore said, “I was really excited because I have an honors class. I can do a little bit more with them.” From this statement, Ms. Moore seemed to indicate a belief that because her students were in an honors class they were better suited for participating in Modeling Instruction. Although other participants did not speak directly to this belief that higher achieving students may be better suited for participating in Modeling Instruction, some participants mentioned the achievement level of students as a challenge to implementation, which will be highlighted in the following section.

Challenges to implementation. In addition to describing instructional aspects that supported the desire to implement Modeling Instruction, participants readily identified challenges that they faced with implementation. We characterized these challenges as either internal or external.

Internal challenges were those obstacles presented by the participants that seemed to lie within the control of the participants. These internal challenges are provided below along with exemplar quotes.

1. Not fully understanding the modeling methods – Ms. Moore said, “I don’t understand enough about it. . . . I still need help understanding the method.”
2. Battling the desire to return to former instructional practices – Ms. Brown stated, “It’s hard if it’s not what you’ve been doing. I mean it’s hard not to pull open that filing cabinet when I know I’ve got 14 years of stuff in that filing cabinet. And 14 years worked out pretty good. Now I’m starting all over. It’s hard.”
3. Misalignment between personal beliefs and Modeling Instruction – Ms. Jones explained, “I believe that for me the best instruction is the most variety that I can do. You know? So I like a little bit of that and a little bit of this.”

In contrast, external challenges were those obstacles identified by the participants that were outside of the participant’s control. Challenges classified as external were often based on participants’ beliefs or perceptions. The key to their classification as external, however, was the participants’ view of the challenge as being something they could not change. Many of the participants’ statements coded as external challenges were related to the students. In some instances, participants felt that implementing Modeling Instruction was difficult due to the achievement level of the students. For example, Ms. Brown said, “I don’t know that I could have gone any faster with the level of student that I have. I think that the level of student you have makes a huge difference. . . . I feel like I’ve had to go at a much slower rate than people who have even a mixed class.” Here, Ms. Brown referred to low achieving students, questioning the appropriateness of Modeling Instruction. Similarly, Ms. Taylor described the inappropriateness of Modeling Instruction for both her high-achieving and low-achieving students. She stated:

> I think I have a fairly big discrepancy in student skill. And I think that I am losing the upper end because they are getting bored. And I think that I am losing the really, really lower end because – no fault of the modeling – I just think that I am losing the lower end. I think chemistry is just beyond their scope.

Not all participants attributed the student challenges to achievement levels. Instead, participants spoke of students’ struggles with the learning processes

associated with Modeling Instruction. For example, Ms. Brown said, "It's also very frustrating because they're not used to that. . . . It's frustrating for them because they want me to tell them what to do." Similarly, Ms. Johnson stated, "They're not used to thinking. They're not used to being held accountable for their own original thought." Furthermore, participants spoke of a disbelief in the methods of Modeling Instruction. Ms. Williams said:

> Kids aren't just going to come up with variables on their own. I mean they just don't necessarily inherently understand all those relationships . . . . They are not going to get there if I leave it all up to them. Not by me just having guiding questions.

In addition to challenges related to students, participants identified the pacing of the curriculum and the misalignment of the Modeling Instruction curriculum with the district's scope and sequence as external challenges. According to Ms. Johnson,

> The modeling curriculum does not 100% align with all of my standards. Which is why I am using it in partiality, I mean I am not able to implement it 100%. And I can't go in the same sequence as the modeling scope and sequence is because I am held by my district's scope and sequence.

Participants also described concerns regarding students' preparation for the end-of-course (EOC) test as well as preparation for college level courses. Ms. Davis stated, "[If] I didn't have the EOC looming, then I would be more willing to take a gamble. But right now, I'm still pretty concerned with full implementation [of Modeling Instruction]." With regard to college, Ms. Taylor said, "I think you have to make that decision [of whether to implement Modeling Instruction on] what are professors in universities teaching. What style of teaching are professors in universities using?" Both Ms. Davis and Ms. Taylor appear to be concerned regarding the preparation that Modeling Instruction provides for their students.

Finally, participants expressed concern related to the teacher evaluation system. Ms. Jones reported:

> Because number one, we're not required [to implement modeling] . . . . If I got evaluated on a day that I'm doing just modeling, a standard evaluation technique would not get me [the best score of] 5. . . . It's not necessarily the everyday norm of what people do and I think our evaluation systems are set up on a norm.

Given the accountability system currently in place, Ms. Jones was concerned with the perceived misalignment between Modeling Instruction and the district's evaluation system.

Perceptions of changes in practice. As participants described implementing Modeling Instruction, they provided insights into their perceptions of the resulting changes in their instructional practices. We categorized the changes described by participants as additive or transformative (Thompson & Zeuli, 1999). These are described in the following paragraphs.

Participants categorized as additive viewed the process of implementation of Modeling Instruction as adding elements of Modeling Instruction into their existing instructional practices. Six of the participants described their instructional changes in this additive way. For example, Ms. Jones conveyed:

> I've incorporated whiteboards since the modeling thing this summer. But I've always done group work and things like that. But I didn't think about whiteboards. I think they're a fabulous addition. . . . I try to incorporate it all so I don't do a modeling type outline every lesson but I certainly try to include it in every unit.

Similarly, Ms. Johnson said:

> I certainly use it as a teaching strategy through every unit. . . . For a teacher who's not using modeling 100% of the day, any time I see a trend that occurs in my lesson, like when we were talking about frequency versus wavelength, I can bring modeling in and have them draw me scenarios.

In contrast, participants who perceived their changes in practice as transformative described the process of completely changing the way they approached teaching. Six of the participants spoke of transformative changes to their instructional practices. For example, Ms. Moore said, "I re-thought a lot of things. . . . It really has changed how I think about teaching because this is the teacher I wanted to be but didn't know how to be." Similarly, Ms. Taylor reported, "Completely. I'm going in a completely different order. Before, I would have told the kids what to do and now I try very, very hard to let them figure it out."

Three participants (Ms. Williams, Ms. Jones, and Ms. Miller) provided both additive statements and transformative statements. In reviewing these participants' transcripts holistically, we aimed to identify whether the person's perceptions of her changes in instructional practices were predominantly additive or predominantly transformative. This holistic analysis of Ms. Williams's transcript revealed that Ms. Williams held a predominantly additive view. She spoke of incorporating a graphical approach but in reference to whiteboards felt like "too much of one thing for too long" was not appropriate. She said, "I'm trying to use [whiteboards] as an introduction or to kind of conclude an activity instead of using it as my primary instructional tool for an entire period." Similarly, Ms. Jones's transcript revealed a predominantly additive view. Ms. Jones spoke of having "always done group work" along with the adding of whiteboards and student presentations to her units. Finally, Ms. Miller's transcript revealed a predominantly additive view as well. Ms. Miller perceived herself as having been an inquiry-based teacher prior to attending the workshop. After attending the workshop, she noted that she was trying to blend in the Modeling Instruction with her other instructional approaches.

Observational Checklist

During interviews, participants identified components of Modeling Instruction implemented within their classrooms. Components included whiteboards, student discussions, teacher questioning, class consensus, and discovery learning. For each component, we examined the observational checklist for evidence of fidelity of implementation. The results follow.

Whiteboards. Eight of the nine participants mentioned their use of whiteboards during instruction. Of these eight participants, only four utilized whiteboards during the observed lesson, with only one of these implementing the whiteboards with fidelity. In this case, Ms. Miller's students engaged in drawing models of data from their experiments on the whiteboards and presented and discussed their results with the class. During these presentations, Ms. Miller tried to get the students to question each other and to agree or disagree with the ideas presented. In this way, Ms. Miller appeared to be implementing the whiteboards with fidelity.

In contrast, students in both Ms. Jones's class and Ms. Davis's class were engaged in presenting their ideas on whiteboards. The students had not used data, however, to draw conclusions or build models to be represented on the whiteboards. Instead, the whiteboards served as a means for students summarizing their ideas for the lesson. Like students in these two classes, Ms. Moore's students recorded their ideas on whiteboards without having previously worked with data to generate a model. The difference in Ms. Moore's classroom, however, was that rather than students presenting the information to the class, Ms. Moore reviewed the whiteboards asking for clarifications as needed. Based on these descriptions, it appears that Ms. Jones, Ms. Davis, and Ms. Moore implemented the whiteboards with low fidelity.

Student discussions. Ms. Moore and Ms. Johnson indicated the increased use of student discussions as a component of Modeling Instruction they had implemented in their instruction. Based on notes from the observational checklist, however, neither Ms. Moore nor Ms. Johnson generated student discussion during the observed lesson. While both attempted to encourage student thinking through teacher questioning, neither encouraged student dialogue afterwards. As a result, student discussions appeared to have been implemented with low fidelity.

Teacher questioning. Ms. Wilson, Ms. Johnson, and Ms. Williams mentioned teacher questioning as a modeling component implemented in their classrooms. During the observed lesson, Ms. Wilson asked predominantly lower-order thinking questions, failing to question with a goal of deeper understanding. At times, her questions appeared to create misconceptions that went unaddressed. Similarly, Ms. Johnson asked students if they were sure about their answers, yet never followed through to have them truly explain their thinking. Although she questioned students to think of real world examples, she only asked other higher-order questions periodically during the lesson. Ms. Williams also attempted to question students regarding their thinking. She often would say, "I don't understand how you did this," in an effort to get students to explain. Although she attempted to guide students' development of ideas, however, she often utilized closed-ended questions. It appears that all three participants were attempting to improve their questioning techniques, although one cannot argue that their current questioning patterns engaged students in the depth of thinking characteristic of Modeling Instruction.

Class consensus. During the interview, Ms. Davis and Ms. Miller spoke of using the class consensus during their instruction. During Ms. Davis' observed lesson, there was no use of a class consensus to manage dissent or bring students to resolution regarding the concept under investigation. Therefore, no statements can be made about the fidelity of her use of this technique. In contrast, Ms. Miller encouraged her students to comment, question, and agree/disagree with the presenting group's ideas. When there was dissent, she allowed the time to reach a class consensus regarding the concept at hand. It would appear that Ms. Miller has implemented the practice of gaining a class consensus with high fidelity.

Discovery learning. Both Ms. Taylor and Ms. Jones described their use of discovery learning as a component of Modeling Instruction utilized in their classroom. For Ms. Taylor, the practices displayed during the observed lesson did not appear to facilitate discovery learning. She asked closed questions and often answered her own questions before giving students a chance to answer. In addition, although they gathered data and performed calculations, Ms. Taylor did not support the students in drawing conclusions or building ideas based on this data.

In contrast, Ms. Jones appeared to implement practices that aimed to support students' engagement in discovery learning. She required the students to provide evidence and logic to support their statements. On occasion, Ms. Jones provided the necessary scaffolding through her questions to support students in moving towards the correct conclusion. She asked a number of probing questions to support students' development of understanding. During the whiteboard meeting, however, she dominated the conversation, making comments and questioning the presenters, but leaving little room for student discourse to develop. It would appear that Ms. Jones has implemented discovery learning into her classroom, but not with complete fidelity.

Limitations

Prior to discussing these results, it is important to note the limitations of the work. First, given the qualitative nature of this research and the small number of participants, these results may not generalize to the larger population. Qualitative studies, however, are not intended to produce generalizable results. Instead, the intent is to produce transferable results. We have aimed to support the transferability of these results through the detailed descriptions of the methods. Second, the Modeling Instruction professional development consists of multiple two-week workshops. The participants in this study participated in only one two-week workshop; thus findings may not extend to teachers participating in multiple years of the professional development. Finally, observations for each teacher were limited to a single observation before the workshop and a single observation afterwards. Although these observations were announced,

it is not clear if observed lessons were representative of typical instruction.

Discussion

The purpose of this research was to examine the impact of Modeling Instruction professional development on instructional practices and identify factors that affect fidelity of implementation. As evidenced by the RTOP scores, all participants demonstrated improvement in their content knowledge with respect to propositional knowledge (category 2). Beyond this, however, the impact of the professional development varied across the participants. All participants identified aspects supporting their desire to implement Modeling Instruction. An analysis of these aspects did not reveal insights regarding varying levels of impact. In order to understand the varied impact, we discuss the remaining results across three groups: no impact, medium impact, and high impact.

No Impact

For two participants, the change in pre- to post-observation total RTOP scores revealed little to no impact of the professional development on their instructional practices. These two participants, Ms. Wilson and Ms. Johnson, had either decreased or unchanged scores across the remaining four RTOP categories. Both Ms. Wilson and Ms. Johnson viewed the implementation of Modeling Instruction as additive, meaning the Modeling Instruction consisted of a menu of techniques which they could selectively incorporate into their instructional practices. While both Ms. Wilson and Ms. Johnson described components of Modeling Instruction that they had implemented in their classrooms, these components were implemented with low fidelity, which may serve to explain the lack of growth in their RTOP scores.

When describing the challenges for implementing Modeling Instruction, both participants described external challenges that were not within their control. For Ms. Johnson, these external challenges revolved around a perceived mismatch between the modeling curriculum and her district's scope and sequence. For Ms. Wilson, the external challenges involved the preparation of students for the end-of-course tests and the low achieving students that populated her classes.

For participants classified as no impact, it appears that the participants viewed the new program as contrary to their goals, interests, and prior agendas, thus supporting the hypothesis offered by Spillane and colleagues (2002). This perception of the new program likely led to the low fidelity of implementation as well as minimal instructional changes exhibited in practice.

Medium Impact

For four participants, the change in total RTOP scores from pre- to post-observation was between 10 and 20, inclusive, which resulted in their classification within the group for which the professional development had a medium impact on their instructional practices. Three of these participants (Ms. Moore, Ms. Brown, and Ms. Taylor) expressed a belief in the transformative nature of the professional development. This transformative nature resulted in internal challenges preventing implementation. For Ms. Moore, the internal challenge was a lack of confidence and understanding regarding the methods behind Modeling Instruction. For Ms. Brown, the internal challenge rested within her struggle to not return to her "filing cabinet" and use the instructional materials that she felt had been effective for many years. Alternatively, Ms. Taylor's internal challenge involved the pacing of the curriculum. Specifically, she was concerned that she might not be able to cover all of the required material in her course given the slow pace with which she was moving within the modeling curriculum.

With regard to external challenges, Ms. Moore's idea was closely related to her internal challenge. In reference to the summer workshop, she stated, "I feel like we were doing a lot of learning about the material, but not a whole lot of learning about the method." She perceived that the methods associated with Modeling Instruction were not adequately addressed in the summer workshop, which led to her internal challenge of not understanding the methods. This lack of understanding of the methods likely influenced Ms. Moore's low fidelity of implementation.

Similarly, Ms. Brown's external challenges which centered on the students and pacing were related to her internal challenge. She felt like the students were frustrated because of the change in instructional methods. She indicated that students were not accustomed to the new instructional strategies and, in some instances, were not academically prepared for them. In addition, Ms. Brown perceived that her students were falling behind because she was not able to move at the pace she would have preferred. As was the case with Ms. Moore, these external challenges likely supported the development of Ms. Brown's internal challenge. Despite Ms. Brown's discussion of the transformative nature of the professional development and her attempt to utilize the modeling curriculum in her classroom, her observation did not provide an opportunity to ascertain the fidelity of implementation within her practices.

Finally, Ms. Taylor's external challenges involved preparing students for success in college and students' abilities in general. With regard to college preparation, Ms. Taylor stated that university instructors utilize lectures and therefore she felt students should experience lecture-style instruction at the high school level. Related to the students' abilities, Ms. Taylor identified the low academic ability of her students as a challenge that resulted in the need to slow the pace of instruction as well as provide additional instructions or directions. These external challenges led to her internal struggle involving the concern that all material would be covered. The need to provide additional directions combined with her pacing concerns likely led to her low fidelity of implementation.

In contrast, Ms. Davis viewed the inclusion of Modeling Instruction within her instructional practices as additive in nature. Her internal and external challenges were very similar, however, to those of Ms. Moore, Ms. Brown, and Ms. Taylor. Ms. Davis expressed that

she was uncomfortable with the methods (internal) and presented the level of her students and the end-of-course test as obstacles to implementation (external). As before, it is likely that these external challenges led to her internal challenge. Furthermore, her feelings of discomfort likely led to the low level of fidelity in implementation.

Unlike the participants categorized as no impact, medium impact participants expressed both additive and transformative views of the professional development as well as external and internal challenges to implementing Modeling Instruction. Given the mixture of additive and transformative views, it is not clear how these views resulted in the medium impact of the professional development on their instructional practices. With regard to the challenges, across these three participants the identified external challenges appeared to lead to internal challenges that in turn impacted the fidelity of implementation. The medium impact participants possessed knowledge structures that were likely different from those required for Modeling Instruction. This misalignment, in turn, led to the cognitive dissonance expressed as internal challenges, which according to Spillane et al. (2002) would result in low fidelity of implementation.

High Impact

Three participants demonstrated increased scores across all categories of the RTOP, which led to large increases (greater than 20) in total RTOP scores from pre- to post-observations. These results indicated that the professional development had a high impact on their instructional practices. All three participants (Ms. Williams, Ms. Jones, and Ms. Miller) provided statements indicating a transformative view of the professional development as well as statements indicating an additive view. In addition, a holistic review of their interview transcripts indicated that they held a predominantly additive view. This seemingly contradicting view of the professional development can perhaps be explained by the participants' perception that they were implementing modeling methods in their classroom prior to attending the workshop. That is, they made statements such as, "I've always done group work," or, "I'm still very much an inquiry-based teacher." One can hypothesize that these teachers recognized the transformative nature of the professional development but believed that they had experienced the transformation prior to attending the professional development. The result would then be the perceived need to add the unfamiliar components of Modeling Instruction into the practices.

In reflecting on the challenges for implementation, Ms. Jones and Ms. Williams expressed both internal and external challenges. For Ms. Jones, the internal challenge centered on her belief that it was best for her to use a variety of instructional approaches, as opposed to solely utilizing Modeling Instruction. This internal challenge was possibly influenced by her identified external challenge, which involved her concern regarding the teacher evaluation system. Ms. Jones believed that her instruction would be rated poorly within the evaluation system if she were observed teaching with Modeling Instruction. Thus, she developed the internal challenge associated with needing to utilize multiple instructional strategies. This may in part explain Ms. Jones's fidelity of implementation that was a mixture of low and medium.

Similarly, Ms. Williams's internal challenge involved her belief that it was impractical to teach science without lecturing—a stance she felt was established during the summer workshop. Her external challenges involved her concerns for students who might become discouraged as they learned the materials as well as students' inability to develop the relationships represented in the concepts without being told what the relationships were. Ms. Williams's belief in the external challenge of students' ability to develop the concepts is clearly related to her internal challenge of the impracticality of not lecturing. This need to lecture combined with expectations regarding students' abilities may help to explain Ms. Williams's low level of fidelity that occurred despite her being in the high impact group.

Unlike Ms. Jones and Ms. Williams, Ms. Miller revealed no internal challenges to implementing Modeling Instruction. Rather, her challenges were limited to external factors, including the scope and sequence of the topics along with the absence of particular topics from the curriculum. In regards to Ms. Miller's lack of internal challenges, it is interesting to note that she was the only participant who implemented the Modeling Instruction with high fidelity.

Given the high impact participants' tendency to believe they were already implementing many of the components of Modeling Instruction, one might hypothesize that their knowledge, beliefs, and attitudes upon entering the summer workshop positively influenced their willingness to utilize Modeling Instruction in their classrooms. This willingness was perhaps manifested in their general instructional practices, which resulted in improved RTOP scores. For Ms. Jones and Ms. Williams, their RTOP scores were extremely low prior to entering the project, indicating a general lack of reform-oriented practices being in place. Yet, they held the belief that they were already implementing modeling components prior to the summer workshop. This belief perhaps led to the low fidelity of implementation as Ms. Williams and Ms. Jones failed to make the distinction between their current practices and the Modeling Instruction. In contrast, Ms. Miller entered the program with high RTOP scores, indicating more reform-oriented practices when compared to Ms. Jones and Ms. Williams. The professional development served to strengthen her practices, leading to high fidelity of implementation.

Conclusion

The importance of supporting teachers with transforming their instructional practices becomes paramount (Lumpe et al., 2012), when considering science achievement in the U.S. (Machi, 2009). When implemented with fidelity, Modeling Instruction is a curriculum that represents the transformative change in instructional practices that is needed to support student achievement (Dye et al.,

2013; Hestenes, 2000). Despite the success of this method, little is known regarding the impact of Modeling Instruction professional development on teachers' instructional practices nor the factors that influence the fidelity of implementation.

Results from classroom observations indicated that participants attending the professional development fell into three broad categories: no impact, medium impact, and high impact. Participants' interviews revealed a complicated relationship between internal and external challenges that impacted the fidelity of implementation. In addition, participants' perceptions of their own instructional practices as reform oriented prior to entering the professional development appeared to play a significant role in the impact of the professional development.

Individuals preparing to lead professional development on Modeling Instruction would be wise to listen to the voices of these participants. Participants provided valuable insights to be considered in future workshops, including, but not limited to:

- the need to make the pedagogical methods associated with the Modeling Instruction more explicit within the professional development;
- the need to support participants in understanding the transformative nature of professional development;
- the need to help participants to develop an alignment between the modeling curriculum and the particular district's scope and sequence; and
- the need to aid participants in understanding how to use Modeling Instruction with students of varying academic abilities.

Addressing these ideas would serve to strengthen the professional development and perhaps support a greater impact on instructional practices.

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Angela T. Barlow, Ph.D., is a professor of mathematics education, Middle Tennessee State University. Correspondence concerning this article should be sent to: Angela T. Barlow, MTSU Box 83, Murfreesboro, TN 37132. Email: angela.barlow@mtsu.edu

Tasha M. Frick is a doctoral student in the chemical education concentration of the Mathematics and Science Education Ph.D. program, Middle Tennessee State University.

Heather L. Barker is a doctoral student in the interdisciplinary science education concentration of the Mathematics and Science Education Ph.D. program, Middle Tennessee State University.

Amy J. Phelps, Ph.D., is a professor of chemical education, Middle Tennessee State University.

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Appendix A

Observational Checklist

Observation	Explanation
Did the teacher ask students to explain their thinking?	
Did the teacher use questioning to guide students' development of ideas?	
Did the teacher use questioning to point out misconceptions?	
Did the teacher manage classroom dissent to bring students to resolution regarding the concept under investigation?	
Did the teacher use students' ideas about a concept to generalize or extend the model to a broader application?	
Did the teacher ask probing questions to keep the dialog going?	
Did the students work with data to draw conclusions and build ideas (or models)?	
Were the students presenting their ideas?	
Were the students working collaboratively to develop understanding?	
Did students question each other's ideas?	
Did the students summarize results on whiteboards?	
Other Comments:	

Appendix B

Interview Protocol

1. Would you describe today as an atypical instructional day?
2. How has the developmental class on problem-based modeling impacted your instructional practices?
3. How are the modeling techniques working in your classroom? (discuss any difficulties with probing questions)
4. In regards to modeling techniques, what strengths did you find once implemented in the classroom? And what weaknesses?
5. Have you had any feedback from your administration?
6. Have you shared any of the modeling techniques with your coworkers? Their thoughts?
7. In a follow up workshop what topics would support you to successfully implement modeling in your classroom?