NC Modeling Project Mathematics and Science Partnership Final External Evaluation Report

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Introduction

The second iteration of the NC Modeling Project began its operation under NC DPI Math/Science Partnership funding in spring, 2011. This final external evaluation report summarizes evidence gathered and results of evaluation activities through the end of the project period, May 31, 2014. In keeping with the evaluation plan for the project, formative and summative evaluation activities focused on documenting the quality and outcomes of the project's professional development and support activities, and gathering evidence of the degree to which the project attained its goals and objectives. Specific evaluation questions addressed the following areas:

1. To what extent did the project develop and deliver effective programs of professional development and support aligned with project goals?

2. To what extent did participating teachers improve their knowledge of disciplinary content and instructional strategies, leading to effective, standards-based instruction?

3. To what extent did science performance improve for students of participating teachers?

4. To what extent did the project developing quality partnerships to support and sustain ongoing improvements in science teaching and learning?

In accordance with the evaluation plan, evaluation activities conducted during the three-year project collected a variety of data through a mixture of quantitative and qualitative methods:

- <u>Pre/post participant content assessments</u> to gather information on participants' content knowledge in science. These are "concept inventory" assessments developed by the national Modeling Project and aligned with the content of the respective institutes.
- <u>Student assessments</u> to monitor changes in student performance. Course-specific pre/post student assessments track student performance in the specific content targeted by the project; North Carolina EOC scores track overall student performance in the relevant science courses (however, changes in state assessment system make these less useful in the evaluation).
- <u>Pre/post participant questionnaires</u> to gather information on attitudes, perceptions, and practices relative to teaching.
- <u>Participant feedback forms</u> to document participant perceptions of the quality and effectiveness of project activities (summer institutes, followups, coaching, etc.).
- <u>Observations</u> of a sample of classrooms, professional development sessions, and other project activities to provide additional data on implementation.

- Focus group and individual interviews to gather feedback from a participants, project personnel, and project partners regarding project activities and impact.
- Examination of project-collected data and artifacts, including participant products, course materials, staff activity log summaries and other records of project work.

The project evaluation plan specifies a non-matched quasi-experimental design, in which outcomes for project participants are compared with outcomes reported in national research on the Modeling Project. The national research has established the effectiveness of the Modeling Project design; the evaluation is to gauge the extent to which this project's implementation yields comparable results. Statistical analysis compares the nature and magnitude of pre/post changes in the participant group to those reported in the national literature. This report summarizes the data collected and analyzed for the three cohorts of participants, discussing the short-term outcomes observed. Additional information is reported about classroom implementation and results noted by early participants who have continued to use Modeling in their instructional practice.

The evaluation findings are summarized beginning on the next page, and are discussed in more detail in the following sections of this report:

I. Overview of Results

Summary of Evaluation Findings

Modeling Project Professional Development and Support

1) The project's professional development activities – Modeling institutes and follow-up sessions – were well designed and implemented.

2) The project was successful in connecting participating teachers with knowledgeable facilitators and other Modeling teachers.

3) In-school support by the Project Coaches was valued by participating teachers, who felt that it positively influenced their practice.

4) Overall, participants reported that their professional development experiences in the Modeling Project were effective in enhancing their knowledge, skills, and teaching practice.

Impact on Participating Teachers

5) Eight out of nine groups of participating teachers significantly enhanced their knowledge of the science content targeted in their respective institutes. Magnitude of the changes is comparable those found in the previous iteration of the project.

6) Participating teachers feel more comfortable with their understanding of the instructional strategies promoted by the Modeling project.

7) Participating teachers began the project typically using "traditional" instructional strategies in their science teaching, with some use of "standards-based" strategies. They report significant changes as a result of Modeling professional development and support.

8) Participating teachers vary in their implementation of the Modeling Approach. Nature and degree of implementation are related to participants' time in the project and their comfort with the strategies. The majority of participants intend to continue their implementation in the coming school year.

Impact on Student Performance

9) Results of pre/post student testing show significant growth in student understanding of the targeted concepts. Three fourths of students in targeted courses demonstrated significant pre/post gains on the assessments.

Other Impacts

10) The Modeling Project has enhanced capacity in the state to support continued implementation of Modeling instruction.

Operation of the Modeling Project Partnership

11) Project partners worked well together and carried out their roles effectively.

Summary of Closing Observations

A. Summary Observations about the Modeling Project

Overall, the Modeling Project's professional development and support activities over its three-year period were effective in contributing to progress toward the project goals. The majority of participating teachers were positive about their experiences in the project. One third of the participants returned to take a second (or even third) Modeling institute. Several of the teachers are continuing their direct participation in Modeling professional development by enrolling in another Modeling summer institute in 2014 through a newly-funded Title IIB project.

Participants have demonstrably grown in their knowledge and skills, and are putting their learning into practice (to varying degrees). As noted earlier, the great majority of teachers expressed their intention to continue implementing the Modeling Approach in their teaching in the coming school year. While they may not yet have reached the level of fluent implementation desired by the project, nevertheless they have made progress and are confident that they will continue to do so.

In summary, the evidence gathered in the Modeling Project external evaluation indicates that:

- Project activities were well-designed and implemented, and participants valued their experiences.
- Teacher participants demonstrated significant growth in their knowledge of the targeted science content.
- Teacher participants report enhancing their pedagogical knowledge and skills, and have begun to implement the Modeling Approach in their science teaching in significant ways.
- Student assessment results and anecdotal evidence indicate a positive contribution of the Modeling Project to student learning of the targeted content.

The design and implementation of the Modeling Project showed numerous strengths that contributed to the effects observed, including:

- The project was based on a well-researched and documented national program, with strategic adaptations to fit the current North Carolina context. The use of Project Coaches to provide ongoing implementation support is a particular enhancement to the original model.
- Participants were deeply immersed in Modeling from the outset, with support provided as participants' learning built over time. The project structure also fostered strong relationships among participants and between participants and facilitators.
- The experienced Modeling teachers who designed and facilitated the institute, follow-up, and coaching sessions were knowledgeable about the science content, research-based pedagogy, and effective professional learning, and had great credibility with the teacher participants.
- The facilitators showed flexibility in planning project activities, while still adhering to the overall goals of the project.
- The project's management at The Science House provided leadership that made it function as a partnership, rather than simply a provider/client project.

That said, some concerns were identified in the evaluation, including:

- The bulk of project contact with participants was limited to a one-year period. Given the demands of shifting instructional practice to the Modeling Approach, support for multiple years would likely produce more consistent and fluent implementation.

- Principals committed to do this as part of the teacher application to participate, but were uneven in their follow-through.

- The MSP program's emphasis on involving higher education science faculty made finding an appropriate role for university content experts a persistent issue for the project.

B. Evaluation Successes

The greatest success with respect to the Modeling Project evaluation is the quality of the data gathered, and this is due in large measure to the support of the project staff. Project personnel were committed to ensuring the maximum possible response rate on the various instruments and protocols used in the evaluation, and were of great assistance in prompting participants to respond. The result was an 86% response rate overall. In addition, project personnel encouraged participants to take the evaluation seriously as an assessment of the project, resulting in more thoughtful (and, we assume, more accurate) responses.

C. Evaluation Caveats and Constraints

There were no major challenges in carrying out the evaluation of the Modeling Project. However, the evaluation's ability to report project outcomes and impacts confidently was constrained by several issues. For the most part, these were known from the outset of the project; while they did not impact conducting the evaluation, they must be considered in interpreting the results and forming conclusions.

1) Relatively small number of participants

2) Changes in participants' teaching assignments

3) Determining a useable comparison group.

4) Determining degree of implementation.

5) Attributing student performance changes.

6) Relating project impact to state assessment results.

II. Program Overview

This section provides a brief description of the Modeling Project strategies and activities, highlighting key components of the project. Note that this is not intended as a complete treatment of the project design and implementation, but rather to give background important for examining results of the evaluation. The project focused on providing content and pedagogy enhancement to grade 9-12 teachers of Biology, Chemistry, and Physics. It followed essentially the same approach as the previous MSP-supported project that operated from 2008 until 2011, with the major change being the addition of an institute for Biology teachers, developed by experienced Modeling facilitators, with support and input from a biology content expert at the partner IHE.

The Modeling Project included the following components:

- Three-week summer institutes. The 14-day institutes were designed by experienced Modeling facilitators based on materials from the national project based at Arizona State University (with the exception of the new Biology institute, which was developed by personnel in this project). The institutes focused on deepening teachers' understanding of the targeted content (physics, chemistry, or biology) as well as introducing them to the Modeling Approach for designing and implementing instruction. Teachers applied for one of the three subject area institutes.

- Academic year follow-up workshops. Three two-day follow-up workshops, led by project facilitators, provided assistance and reinforcement for implementing Modeling strategies addressed in the summer institute, as well as attention to additional content not addressed in the summer.

- Project Coaches. The project contracted with two experienced Modeling teachers to serve as project coaches. They provided school-based support to assist participating teachers in translating their new knowledge and skills into practice. The coaches scheduled times to visit participants' schools and worked with the teachers during school hours. They also provided support to facilitators and participants during the summer institutes and follow-up sessions.

- Modeling teachers community. Participants received access to information, resources, and professional interaction through the web-based portal of the American Modeling Teachers Association (AMTA). This site provides a place from which teachers can find additional materials and receive support from other teachers implementing the Modeling Approach. The AMTA site is now the official site for Modeling nationwide, and contains the resources formerly housed at Arizona State University, the original developers of Modeling. Project personnel are leaders in AMTA – one institute facilitator is a past president, and one of the project coaches is currently the president.

Participating teachers received numerous materials through their project activities, including curricular resources. They also were compensated for time attending project activities outside of normal working hours.

III. Evaluation Findings: Modeling Project Professional Development and Support

1) The project's professional development activities – Modeling institutes and follow-up sessions – were well designed and implemented.

As described in the Project Overview, the Modeling project professional development consists of a three-week summer institute, with three follow-up sessions during the academic year. Review of institute materials and observation of institute and follow-up sessions by the external evaluator indicate that the project's professional development reflected characteristics of effective adult learning. Participant responses on feedback forms also support the quality of the professional development design and implementation. The participants' positive perceptions are similar across all three years, indicating consistency in the implementation of project activities.

	2011-12		2012-13		2013-14	
From participant feedback forms:	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)
The sessions involved participants in an active manner.	3.7	75%	3.8	83%	3.7	78%
Session facilitators were knowledgeable about the content addressed.	3.9	91%	3.9	90%	3.9	92%
Session facilitators made the topics interesting and understandable.	3.8	82%	3.8	76%	3.7	81%
Session facilitators answered questions in ways that were relevant to classroom situations.	3.7	79%	3.8	79%	3.6	71%
Session facilitators modeled effective strategies that I can use in teaching my students.	3.8	86%	3.8	79%	3.7	70%
Session facilitators worked well together as a team in conducting the institute activities and discussions.	3.9	86%	3.8	78%	3.7	78%
The content addressed was relevant to the topics I'm supposed to cover in the courses I teach.	3.8	88%	3.7	72%	3.5	62%
The sessions built from participants' existing knowledge of the topics addressed.	3.7	73%	3.6	72%	3.5	65%
The sessions provided opportunities to reflect on how the information learned applies to my own situation.	3.5	66%	3.5	64%	3.4	54%
The sessions provided opportunities to share ideas with and learn from other participants as well as from the facilitators.	3.8	84%	3.8	78%	3.7	75%

Participants had few concerns about the institute design. The concerns that were voiced typically involved addressing all the topics specified in the NC Essential Standards and having a clear understanding of how the institute content aligns with the NCES.

The participating teachers were very positive about the structure and components of the summer institutes, as seen in the following table. Again, their ratings were consistent from year to year.

	2011-12		2012-13		2013-14	
(From participant feedback forms) How much did each component listed below contribute to the overall effectiveness of the Summer Institute?	Mean (4 pt scale)	Major contribution	Mean (4 pt scale)	Major contribution	Mean (4 pt scale)	Major contribution
Activities/discussion focused on deepening your understanding of the biology/chemistry/physics content addressed.	3.3	62%	3.2	50%	3.5	60%
Discussion focused on building your understanding of the Modeling approach for teaching and learning science.	3.8	84%	3.9	86%	3.7	81%
Modeling of instructional strategies by session facilitators to illustrate their use.	3.8	80%	3.8	86%	3.8	80%
Having participants lead Modeling activities with the group and receive feedback from session facilitators and other participants.	3.4	55%	3.3	56%	3.4	56%
Materials and resources received at the institute.	3.7	80%	3.7	74%	3.6	67%
Interacting with session facilitators.	3.7	71%	3.8	83%	3.7	79%
Interacting with and sharing ideas with other institute participants	3.7	69%	3.7	71%	3.7	73%

According to participants' responses, the institutes were successful in meeting their stated objectives. More specific outcome measures relative to the teachers' content knowledge and instructional practice are discussed in subsequent sections in this report. Overall, participants felt that the institutes had impacted their knowledge and skills in ways pertinent to their teaching, and valued their participation in the project.

From participant feedback forms:

	There was little or no change in my understanding of the content addressed.	I received a good refresher on the content addressed, but little new understanding.	I learned some new things about the content addressed; my understanding is now a little deeper.	I learned a lot of new things about the content addressed; my understanding is much deeper than before.
2011-12	7%	18%	38%	36%
2012-13	3%	16%	36%	45%
2013-14	2%	3%	48%	48%

	2011-12		2012-13		2013-14	
From participant feedback forms:	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)
I am now more knowledgeable about the content addressed in the institute.	3.3	54%	3.1	50%	3.4	57%
I am now more knowledgeable about the Modeling approach for teaching science.	3.7	70%	3.9	86%	3.8	80%
I received valuable curricular materials and resources in this institute.	3.8	84%	3.7	74%	3.7	77%

I expect that my science teaching will be more effective as a result of what I learned in this institute.	3.9	86%	3.8	81%	3.8	79%
This Modeling Project Summer Institute was well organized.	3.8	82%	3.9	88%	3.9	87%
I would recommend this institute to other science teachers.	3.9	93%	4.0	98%	3.8	87%

	2011-12		2012-13		2013-14	
From end-of-year feedback forms:	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)
I am using things I learned at the summer institute as a regular part of my science teaching.	3.5	67%	3.4	54%	3.7	74%
The summer institute had a significant influence on my science teaching.	3.6	71%	3.6	66%	3.7	77%
Overall, I feel my time was well spent in the summer institute.	3.8	87%	3.8	81%	3.9	90%
I received valuable teaching ideas from the follow-up sessions.	3.4	57%	3.5	58%	3.6	67%
I regularly use things I learned at the follow-up sessions.	3.2	47%	3.3	47%	3.4	52%
Participating in the follow-up sessions enhanced the effectiveness of my teaching.	3.3	51%	3.3	49%	3.5	58%
Overall, I feel my time in the follow-up sessions was well spent.	3.4	63%	3.5	64%	3.5	64%

The following are illustrative comments from participants about the institutes and follow-up sessions:

> *Workshops and weekend retreats offered a wealth of information on the modeling pedagogy that was "modeled" by us (the teachers) acting as students under the guides of several excellent/experienced teachers. We experienced it from the students' perspective… which was a great learning experience. The support by the staff after the workshop and throughout the academic year was supreme as well.*

> *The Modeling Workshop is an awesome summer workshop honestly without which I wouldn't have had the confidence to teach the modeling curriculum. I love how the course was run. It felt like I was a physics student again in a classroom and I was really able to experience the positive effects of modeling. I liked how the instructors modeled the Modeling approach. We got to see first hand how the concepts should be taught and why it is so successful in the classroom.*

> *This sort of professional development is in-depth and it takes time to let the topics be absorbed. I appreciate having time to let the content be absorbed by myself. I was always treated like a valuable member of a team. My questions were taken seriously and I was provided with all the help I needed to understand the Modeling approach. To be honest it was fun. I enjoy doing labs, either as a student or a teacher.*

> *I was given a tremendous number of tools and resources through this experience. I have a curriculum I believe in and a network of teachers who I can lean on for support. I feel that the*

instruction was highly effective this summer and the follow-up weekends were especially helpful in maintaining an entirely new way of teaching. It is nice to step away from the teacher role for a weekend, and step into student role. It forces me to remember what it's like to be a student. It helped me to stay connected with other science teachers who use modeling. The sessions were imperative for getting through the curriculum materials.

The best thing about the modeling project is the support I received after the summer sessions. Often attend workshops but receive no support after. So when I would try to implement the new strategies, I would often have a lot of difficulty doing it correctly. However, with the modeling project, I had support after the workshop that would allow me to get help when needed. The followup sessions reinvigorated me and also enabled me to discuss challenges that I encountered along the way. I discovered that my challenges were not unique.

The followups were incredibly important because we had put into practice the information and strategies presented at the 3 week workshop. As we completed each of the sessions, confidence was increased, quirks were ironed out and vetted, and participants shared their experiences. These were all very valuable. Part of the value of the sessions, was the timing. They were spaced appropriately to provide us with the feedback we needed at the "right" time.

From the perspective of the participants, as well as from observations by the external evaluator, the Modeling project summer institutes and follow-up sessions were well-designed and implemented. The project demonstrated consistent quality in implementing its activities across the three years. Specific outcomes of the activities are discussed in the section on participant impact later in this report.

2) The project was successful in connecting participating teachers with knowledgeable facilitators and other Modeling teachers.

A key feature of the Math Science Partnership program is developing closer relationships among content experts and classroom teachers. Experienced Modeling teachers designed and facilitated the Modeling institutes and led the sessions. Participants were very positive about their instructors:

	2011-12		2012-13		2013-14	
From participant feedback forms:	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)
Session facilitators were knowledgeable about the content addressed.	3.9	91%	3.9	90%	3.9	92%
Session facilitators made the topics interesting and understandable.	3.8	82%	3.8	76%	3.7	81%
Session facilitators answered questions in ways that were relevant to classroom situations.	3.7	79%	3.8	79%	3.6	71%
Session facilitators modeled effective strategies that I can use in teaching my students.	3.8	86%	3.8	79%	3.7	70%
Session facilitators worked well together as a team in conducting the institute activities and discussions.	3.9	86%	3.8	78%	3.7	78%

Participating teachers report greater familiarity with resource persons after their experience in the Modeling project. The project activities were also valuable opportunities for teachers from across the state to get to know each other as sources of lesson ideas, resources and implementation support. According to their responses on the participant feedback forms, both objectives were achieved. The teachers were asked to use a 1 (low) – 5 (high) scale to describe their status prior to the project and their current status. The table below contains mean responses:

	2011-12		2012-13		2013-14	
From participant feedback forms: The following items list the Modeling Project's objectives for its participating teachers. For each objective, indicate 1) your status before you started with the project; and 2) your status as a result of your participation in the project.	Prior status mean (5 pt scale)	Current status mean (5 pt scale)	Prior status mean (5 pt scale)	Current status mean (5 pt scale)	Prior status mean (5 pt scale)	Current status mean (5 pt scale)
Your familiarity with experienced Modeling teachers who can serve as resources for your science teaching.	2.7	4.1^	2.4	4.1*	2.3	4.2*
Your familiarity with biology/chemistry/physics teachers at other districts and schools in the state.	2.7	3.8^	2.4	3.9*	2.4	4.1*

*^ Difference significant at p<0.01   * Difference significant at p<0.0001*

Participating teachers valued working with both the facilitators and their fellow participants. The project activities provided opportunities for teachers from across the state to get to know each other as sources of lesson ideas, resources and implementation support.

	2011-12		2012-13		2013-14	
From participant feedback forms: Please share your opinion of the value of the following components to the quality of your overall experience in the project this year:	Mean (4 pt scale)	Great value (4)	Mean (4 pt scale)	Great value (4)	Mean (4 pt scale)	Great value (4)
Working with experienced Modeling teachers who led project activities	3.7	71%	3.7	68%	3.7	70%
Working and sharing ideas with other participating teachers in the project	3.7	69%	3.7	77%	3.7	77%

	2011-12		2012-13		2013-14	
From participant feedback forms: Please give your opinion of the following statements about your overall experience in the Modeling Project:	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)
Overall, the Modeling Project has fostered a valuable relationship with experienced resource persons that I can continue to use to help my teaching.	3.3	52%	3.6	62%	3.5	62%
Overall, the Modeling Project has fostered a valuable relationship with other biology/chemistry/ physics science teachers that I can continue to use to help my teaching.	3.2	42%	3.6	70%	3.4	58%

Furthermore, responses to a survey of prior participants indicate that a significant proportion have maintained some level of contact with facilitators, coaches, and teachers they met through the project.

From prior participant feedback forms: Please give your opinion of the following statements about your overall experience in the Modeling Project:	Mean (4 pt scale)	Mostly True (3)	Very True (4)
I am still in touch with Modeling Project facilitators and coaches, and contact them if I have questions or need assistance.	2.3	24%	18%
I am still in touch with other Modeling teachers I met through the project, and contact them if I have questions or need assistance.	2.7	33%	25%

Narrative comments from participants include the following:

> *The way ____ and ____ walked us through the material and the labs day in and day out was phenomenal. They were very good about answering any and all questions that we had and were very open about sharing their materials that they have used in their own classrooms., and bouncing ideas off other teachers and hearing about their successes and failures just enhanced the experience.*
>
> *My instructors were both very knowledgeable about the content and the conceptual problems students have. They were very capable of helping to foresee challenges we would have and providing insight on how they handled it.*
>
> *The instructors for our summer and follow-up sessions were DYNAMIC in providing us with an overview of the modeling process; encouraging us to experience the training in "student mode" in order to fully appreciate what we would be delivering to students; transparently shared their own experiences (both +/-) as modeling instructors; and, were available to answer questions and provided rich information via our Dropbox.*
>
> *Not only have the leaders of this project been very supportive, but the other participants that I have come to know are excellent resources. I can email/call/text any of the leaders or fellow participants with questions or with problems and I know I will receive the help I need.*
>
> *Teaching is a pretty isolated profession, at least in part because we don't take time to go be with other teachers. Without a doubt this is the most helpful aspect. I really benefited from talking to other teachers about their experiences teaching using the modeling approach. I was able to share my first time modeling experience with teachers who have been modeling for years and with other new modelers.*

The project was successful in connecting participants to other persons who could serve as resources – facilitators and other teacher participants. For some individuals, these connections have continued to provide benefits.

It should be noted that there was a lack of substantive involvement of higher education science faculty in the project. Normally, an MSP project focuses on connecting participating teachers with such IHE faculty as resources for subject area expertise. In this particular case, however, the expertise in Modeling lies not with IHE faculty in NC, but with experienced teachers in the state who have undergone extensive development through the national project at Arizona State University. These individuals are highly qualified, so their use in leadership roles was appropriate and the quality of project activities and outcomes did not appear to be impacted.

3) In-school support by the Project Coaches was valued by participating teachers, who felt that it positively influenced their practice.

The Project Coaches were a critical component of this Modeling project, one which has typically not been included in other Modeling professional development sites. The coaches provided regularly scheduled in-school support to the participating teachers during each academic year. The project plan was for the coaches to visit all participants at some level, concentrating on those requesting or needing their assistance and support. This plan was subsequently modified to enable to coaches to focus on visiting teachers as needed, rather than on a schedule. On-site coaching was only available during the year of institute participation (although when visiting a current participant, the coach might also check in with a prior participant teaching at the school). Coaches were available to all current and prior participants by phone or email.

On the end-of-year feedback survey, most participants indicated that they saw their coach an appropriate amount.

From participant feedback forms: Mark the statement below that best describes your opinion about the frequency of meeting with the project coach:

	Not enough – I wish we could have worked together more often	About right – we met often enough to do what was needed	More than enough – we could have had fewer meetings
2011-12	16%	82%	2%
2012-13	16%	84%	0%
2013-14	22%	74%	3%

The coaches worked on a variety of issues with the teachers, according to their interests or needs. As seen in the table below, the nature of the coaches' interactions was fairly consistent across the years. With a (mostly) new group of participants each year, this would be expected.

	2011-12		2012-13		2013-14	
From participant feedback forms: Different teachers worked on different things with the project coach. How much time and attention did you and the coach give to each of the following areas during your work together?	Mean (3 pt scale)	A lot (3)	Mean (3 pt scale)	A lot (3)	Mean (3 pt scale)	A lot (3)
Learning more about the Modeling Approach	2.0	22%	2.0	20%	1.8	19%
Working on particular teaching strategies (inquiry, questioning, grouping, whiteboards, etc.)	2.1	27%	2.3	41%	2.1	30%
Using technology during instruction	2.0	26%	1.7	11%	1.6	16%
Planning units or lessons that use the Modeling Approach	1.6	8%	1.6	13%	1.6	12%
General assistance with science teaching issues and questions	2.3	38%	2.2	40%	2.0	25%

Overall, participants valued their work with their project coach, as seen in the following table and narrative comments:

	2011-12		2012-13		2013-14	
From participant feedback forms	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)
I received valuable teaching ideas from the project coach.	3.3	51%	3.6	62%	3.3	48%
I regularly use things I learned in working with the project coach.	3.0	37%	3.4	56%	3.2	41%
The support from the project coach enhanced the effectiveness of my teaching.	3.3	59%	3.5	62%	3.3	48%
Overall, I feel my time working with the project coach has been well spent.	3.4	60%	3.6	69%	3.4	50%

> *______ is PHENOMENAL! I cannot say enough for her wealth of experience; natural ability to teach both students and teachers, including constructive feedback; and, promptness in responding to the few email and phone communications I initiated!*
>
> *______ was always ready to come by and observe my class, give me feedback, make suggestions and bring the necessary materials if I didn't have them. She was very supportive with new technology that we purchased as a result of my modeling experience. Also, she was very supportive in content review and lesson planning. Excellent guide.*
>
> *The project coach was particularly helpful in actually participating in the class. As an active participant, the coach modeled for both teacher and students important aspects of the Modeling approach - questioning strategies, whiteboarding, use of technology, etc. Also helpful was discussion and feedback after the class. Very encouraging and nurturing.*
>
> *______ observed my lessons and had helpful feedback to give. She was an extra set of eyes that were able to objectively identify areas for improvement. She had experience with modeling and she could relate to difficulties I was having. She was also experienced in teaching physics, which was wonderful. She jumped in during a whiteboard discussion and led it for me, which was great for me to see. It was helpful for me to see how she got kids involved, what types of questions she asked, how she responded to kids, etc.*
>
> *My project coach came to my classes and helped me evaluate my techniques according to the modeling approach. It was tailored to my needs and situation and I found it extremely valuable. Without a follow-up visit, there can often be a tendency to let that "summer workshop" simmer on the back burner without actually being implemented.*

Teachers were appreciative of the coaches' knowledge and experience, indicating that giving implementation support, sharing good advice and ideas, and serving as a "sounding board" and "supportive ear" were especially helpful.

4) Overall, participants reported that their professional development experiences in the Modeling Project were effective in enhancing their knowledge, skills, and teaching practice.

The project's institutes, follow-up sessions, and school-based coaching were designed to address multiple objectives, including enhancement of content and pedagogy, familiarity with resources, and ability to design and implement effective science lessons using the Modeling Approach. Responses on the participant feedback questionnaire indicate that participating teachers valued their experiences in the project and felt the project had an impact in each of its targeted areas.

	2011-12		2012-13		2013-14	
From end-of-year participant feedback forms:	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)	Mean (4 pt scale)	Very True (4)
Overall, the Modeling Project has had a significant influence on my science teaching.	3.7	73%	3.6	66%	3.7	75%
Overall, the Modeling Project has had a significant influence on my understanding of science content.	3.2	46%	2.9	36%	3.2	50%
Overall, the Modeling Project has had a significant influence on my use of technology in my science teaching.	3.0	31%	2.7	19%	3.0	25%
Overall, the Modeling Project has had a significant influence on my ability to plan and implement effective science units and lessons.	3.3	49%	3.3	49%	3.4	52%
Overall, the Modeling Project has had a significant influence on my awareness of quality curricular resources to use in my science teaching.	3.3	52%	3.4	53%	3.4	47%
Overall, the Modeling Project has fostered a valuable relationship with experienced resource persons that I can continue to use to help my teaching.	3.3	52%	3.6	62%	3.5	62%
Overall, the Modeling Project has fostered a valuable relationship with other biology/chemistry/ physics teachers that I can continue to use to help my teaching.	3.2	42%	3.6	70%	3.4	58%

Perceived influence on teachers' use of technology was the lowest-rated outcome in the table above. This is consistent with the evaluator's observation that the institutes varied in their emphasis on using technology in the lessons, with physics having the greatest emphasis. The lower rating seen in the table is in accord with the lower overall emphasis across the institutes, in comparison with the other intended outcomes listed.

Overall, teachers were very positive about the value of their experience in the Modeling project overall, as well as its various components. The consistency of their ratings across the three years supports the consistent quality of project leaders' work.

From end-of-year participant feedback forms: Overall, how satisfied are you with the professional development and support you received during your participation in the Modeling Project?

	Very satisfied	Satisfied	Mixed feelings	Dissatisfied	Very dissatisfied
2011-12	67%	29%	4%	0%	0%
2012-13	68%	30%	2%	0%	0%
2013-14	67%	31%	2%	0%	0%

From end-of-year participant feedback forms: Please share your opinion of the value of the following components to the quality of your overall experience in the project this year:	2011-12 Mean (4 pt scale)	2011-12 Great value (4)	2012-13 Mean (4 pt scale)	2012-13 Great value (4)	2013-14 Mean (4 pt scale)	2013-14 Great value (4)
3-week Summer Institute	3.8	87%	4.0	98%	4.0	97%
Two-day follow-up workshops during the school year	3.5	59%	3.6	65%	3.6	63%
In-school work with the project coach	3.3	49%	3.5	63%	3.1	41%
Materials and resources received through the project	3.6	67%	3.7	79%	3.9	89%
Using the project website and online resources to interact with others and gather ideas	3.1	39%	3.0	30%	2.9	33%

From end-of-year participant feedback forms:	2011-12 Mean (4 pt scale)	2011-12 Very True (4)	2012-13 Mean (4 pt scale)	2012-13 Very True (4)	2013-14 Mean (4 pt scale)	2013-14 Very True (4)
I feel my time has been well spent as a Modeling Project participant.	3.7	80%	3.8	81%	3.8	83%
I would recommend the Modeling Project to other science teachers.	3.8	88%	3.9	91%	3.9	90%

Participants' narrative comments elaborate their positive view of their Modeling Project experience, as seen in the following illustrative examples:

This project really is the best professional development I've experienced. Excellent, well thought-out Institute. Not only have I learned valuable pedagogical tools that greatly enhance student learning, but I have also learned a LOT of physics myself. I love the modeling materials, and appreciate the time taken to do labs myself during the program.

I cannot say enough about the professional development given me at the Physics Modeling Institutes these past 2 years. Not only were the instructors outstanding and approachable, but the other participants were focused and willing to share and be vulnerable. Being able to collaborate and share ideas with other science educators was great experience. I knew that I had help and support if I needed it. The pedagogical approaches that we not only learned but experienced have been so helpful to me in the three different levels of physics that I'm presently teaching. It was very helpful actually performing the labs and taking and analyzing my own data. Also, the followup by ______ has been extremely valuable. When I needed help, I knew who I could turn to. Thank you!

I would love to be able to attend another Modeling Workshop. I would (and have) recommended these workshops to all of my colleagues. Out of all the professional development I have participated in during my 11 years of teaching, this workshop has had the greatest impact on my teaching.

The Modeling Professional Development Institute is one of the best professional development experiences I have had as a teacher. The Modeling staff and coaches are terrific and have always been extremely supportive. Their guidance and encouragement throughout have been essential elements to the program's success. The Modeling approach really has re-energized my teaching.

IV. Evaluation Findings: Impact on Participating Teachers

5) Eight out of nine groups of participating teachers significantly enhanced their knowledge of the science content targeted in their respective institutes. Magnitude of the changes is comparable those found in the previous iteration of the project.

Participants' growth in understanding of the targeted science content was measured using nationally developed and validated "concept inventories," developed by the national Modeling Project at Arizona State University and American Chemical Society – the Force Concept Inventory (physics), Conceptual Survey of Electricity and Magnetism (physics II), and Assessment of Basic Chemistry Concepts (chemistry). Biology participants were assessed using the Biology Concept Inventory, developed and validated by the biology institute designers and the external evaluator. All assessments are aligned with the content of their respective institutes. A pre-assessment was administered on the first day of each summer institute. The post-assessment was administered during the final follow-up session the following spring. The tables below show the results of the pre/post assessments across the three years of the project:

Biology (Biology Concept Inventory)

	# (%) with both pre and post data	pre mean % correct (sd)	post mean % correct (sd)	mean pre-post gain	p value (paired t-test)	Effect size	normalized average gain <g>	# (%) of teachers with significant pre/post gain (> 1/3 sd)
2011-2012	18 of 18 (100%)	75.5% (0.10)	81.5% (0.13)	6.0%	0.0177	0.50	0.25	56% (10 of 18)
2012-2013	19 of 22 (86%)	78.9% (0.12)	81.4% (0.12)	2.5%	0.1385	0.21	0.11	47% (9 of 19)
2013-2014	19 of 23 (83%)	72.3% (0.11)	76.8% (0.13)	4.5%	0.0089	.38	0.16	47% (9 of 19)

Chemistry (Assessment of Basic Chemistry Concepts)

	# (%) with both pre and post data	pre mean % correct (sd)	post mean % correct (sd)	mean pre-post gain	p value (paired t-test)	Effect size	normalized average gain <g>	# (%) of teachers with significant pre/post gain (> 1/3 sd)
2011-2012	19 of 22 (86%)	71.8% (0.18)	80.3% (0.20)	8.5%	0.0011	0.43	0.30	47% (9 of 19)
2012-2013	15 of 18 (83%)	77.4% (0.16)	77.9% (0.15)	0.5%	0.8123	0.003	0.02	27% (4 of 15)
2013-2014	20 of 23 (87%)	68.3% (0.14)	82.9% (0.12)	14.6%	0.001	0.68	0.42	70% (14 of 20)

Physics (Force Concept Inventory)

	# (%) with both pre and post data	pre mean % correct (sd)	post mean % correct (sd)	mean pre-post gain	p value (paired t-test)	Effect size	normalized average gain <g>	# (%) of teachers with significant pre/post gain (> 1/3 sd)
2011-2012	15 of 20 (80%)	68.7% (0.30)	84.2% (0.22)	15.5%	0.0021	0.58	0.50	53% (8 of 15)
2012-2013	16 of 18 (89%)	66.9% (0.29)	77.3% (0.27)	10.4%	0.0266	0.37	0.31	38% (6 of 16)

Physics II (Conceptual Survey of Electricity and Magnetism)

	# (%) with both pre and post data	pre mean % correct (sd)	post mean % correct (sd)	mean pre-post gain	p value (paired t-test)	Effect size	normalized average gain <g>	# (%) of teachers with significant pre/post gain (> 1/3 sd)
2013-2014	16 of 18 (89%)	57.1% (.30)	66.6% (.19)	9.5%	0.0027	0.54	.28	75% (12 of 16)

Overall, the pre/post results above support the following conclusions:

- Using the USDE standard for significance – paired t-test $p<0.15$ – eight of the nine groups of teachers demonstrated statistically significant pre/post mean gains. Moreover, the effect sizes – ranging from 0.37 to 0.68 – indicate the pre/post gains reflect meaningful learning in those institutes.

- Over the three years of the project, complete pre/post assessment data were collected for 86.3% of the total participants (157 of 182). Using the USDE standard for individual gains – gain greater than one-third standard deviation – 51.6% of these teachers (81 out of 157) posted a significant increase in their performance. It should also be noted that the pre-test performance of 25 of the 157 teachers (16%) was high enough to make it impossible to meet the criterion for significant gain, even with a perfect score on the post-test. Taking this factor into account, the proportion of teachers making significant individual gains rises to 61.4% (81 out of 132).

- The normalized average gain is considered by developers of the Modeling program as a more valid calculation than a raw pre/post difference. National research on the Modeling Physics program showed typical normalized gains in the range of .3 to .6. The normalized gains shown by most of the chemistry and physics groups fall into this range, and are therefore consistent with other sites. As the biology institute and assessment are new, there is no comparable national data to which to compare.

Another way to examine the effectiveness of the project's content enhancement is to compare the assessment results to those of the previous 3-year iteration of the Modeling Project, which operated from 2008-2011. The tables below show that the current results are comparable to the results seen in the previous project. (Note: The previous project did not include the Biology institute.)

Chemistry (Assessment of Basic Chemistry Concepts)

	# (%) with both pre and post data	pre mean % correct	post mean % correct	mean pre-post gain	normalized average gain <g>	# (%) of teachers with significant pre/post gain (> 1/3 sd)
2008-11	41 of 52 (79%)	75.0%	86.5%	11.5%	0.46	22 of 41 (54%)
2011-14	54 of 63 (86%)	72.1%	80.6%	8.5%	0.30	27 of 54 (50%)

Physics (Force Concept Inventory)

	# (%) with both pre and post data	pre mean % correct	post mean % correct	mean pre-post gain	normalized average gain <g>	# (%) of teachers with significant pre/post gain (> 1/3 sd)
2008-11	33 of 39 (85%)	70.0%	79.7%	9.7%	0.32	16 of 33 (48%)
2011-14	31 of 38 (82%)	67.8%	80.6%	12.8%	0.40	14 of 31 (45%)

Physics II (Conceptual Survey of Electricity and Magnetism)

	# (%) with both pre and post data	pre mean % correct	post mean % correct	mean pre-post gain	normalized average gain <g>	# (%) of teachers with significant pre/post gain (> 1/3 sd)
2008-11	20 of 23 (87%)	58.8%	70.0%	11.2%	0.27	11 of 20 (55%)
2011-14	16 of 18 (89%)	57.1%	66.6%	9.5%	0.28	12 of 16 (75%)

The objective pre/post assessment results show that the project was effective in enhancing the content understanding of its participants, even though as high school teachers they generally were confident of their content background. Each year, the majority of teachers participating in the project perceived that their content knowledge had grown as a result, as indicated by their responses on the end-of-year feedback survey:

	2011-12		2012-13		2013-14	
From end-of-year participant feedback forms: Project objective: Understand key biology/ chemistry/physics concepts at a depth needed to effectively teach the content specified in the Standard Course of Study.	Mean (5 pt scale)	% 4-5	Mean (5 pt scale)	% 4-5	Mean (5 pt scale)	% 4-5
Status before participating in the Modeling project	3.8	65%	4.1	72%	3.8	59%
Status as a result of participating in the Modeling project	4.3*	88%	4.5*	98%	4.6*	97%

** Difference significant at p<0.01*

	2011-12			2012-13			2013-14		
From end-of-year participant feedback forms:	Mean (4 pt scale)	Mostly True (4)	Very True (4)	Mean (4 pt scale)	Mostly True (4)	Very True (4)	Mean (4 pt scale)	Mostly True (4)	Very True (4)
Overall, the Modeling Project has had a significant influence on my understanding of science content.	3.2	29%	46%	2.9	34%	36%	3.2	25%	50%

Teachers who have participated in the project for multiple years (institutes in different subjects) perceived an even greater impact on their content knowledge:

	1 year partic.			2+ years partic.	
From end-of-year participant feedback forms:	Mean (4 pt. scale)	Very true (4)		Mean (4 pt. scale)	Very true (4)
Overall, the Modeling Project has had a significant influence on my understanding of science content.	2.9	36%		3.4*	59%

* *Difference significant at $p<0.002$*

Participant comments also indicate that most feel their content knowledge was enhanced by their participation in the project, although in different ways for different participants:

> *I did not have a deep understanding of electricity, despite having taken many courses and even teaching it at the AP level. It was made quite clear in the workshop that I did not know as much as I thought I did and I enjoyed expanding my content base. After 3 weeks in the modeling institute I felt excited to teach it a second time. I was more confident and more interested in the content because I had a better understanding of it.*

> *Modeling has provided more of a connection between ideas. The empirical nature of how the models develop in the curriculum is a key component. As such, content knowledge is not as compartmentalized for myself as the teacher. While I believe I had a fair grasp of chemistry content prior to the institute, there are deeper connections between the various content components. Understanding where the content comes from and how it fits together makes that content more flexible and useful in various settings. It's a question of not only knowing content, but understanding why and how we know the content.*

> *It has been over 30 years since I graduated from college and 17 years since I taught Biology. A lot has happened in those years in Biology, namely advances in DNA. Participation in the Modeling Project has refreshed and updated my content in Biology. Through the modeling workshop many of my misconceptions were identified and corrected. The workshop also gave me a deeper understanding, well beyond just memorization.*

> *Modeling has given me a greater depth of understanding of the content I teach. There have been at least 3 occasions while teaching this material that I have suddenly understood why things work the way they do. I knew the math and the general concept but didn't have a good grasp it. I am actually able to reason my way to a sound answer. Now it's easier to explain to the students. Instead of passing on individual pieces of knowledge to my students, I can give them a way to think.*

I came to the Modeling Institute knowing nothing to very little about the chemistry content. It's clear to me that I held many of the misconceptions regarding energy that are described as being held by students. I was more fuzzy about the way I viewed energy transfers than I am now. Without the Institute I would not have been effective at teaching chemistry. I left feeling like I had a good understanding of what my students needed to know to be successful.

Since I am a veteran biology teacher, who has made a habit of staying current with my science content knowledge, I cannot say that my content knowledge changed as a result of the Modeling Project. I feel the modeling has helped me to deepen my understanding of content in regards to how it should be presented. For some topics, it gave me a new way of thinking about it. I feel that I've gained more insight on how to structure the content in my biology courses.

Overall, the evidence indicates that the Modeling project has been successful in enhancing the content knowledge of the majority of its participating teachers.

6) Participating teachers feel more comfortable with their understanding of the instructional strategies promoted by the Modeling project.

Implementation of the instructional strategies that comprise the Modeling approach is dependent, in part, on teachers' perceptions of being well prepared to use the desired strategies. The results from the teacher pre/post questionnaires indicate that – other than strategies generally associated with process skills in laboratory activities – most participants did not feel particularly well prepared to do so prior to beginning their participation in the Modeling project. Their perceived preparation had improved significantly at the end of the project year. The table below gives values of "composite" indicators, derived from aggregating groups of questionnaire items. Mean values are on a 100-point scale; a value of at least 70 is generally seen as a desirable level. Significant improvement – with moderate to large effect size – is seen in all four composite indicators. In addition, linear regression modeling revealed that, controlling for the pre-questionnaire value, participating in the project for more than one year made a significant contribution to the post-value of three composite indicators. That is, participating for multiple years added from 4.8 to 6.8 points to the indicator's predicted post-value, compared to 1-year participants.

	Pre-Questionnaire			Post-Questionnaire					
From pre/post questionnaires: Composite indicators	Mean (sd)	% at or above 70		Mean (sd)	% at or above 70		p*	Effect size	Multiple institute contrib.
Perceived preparation to support development of science process skills	69.91 (16.15)	50%		82.03 (13.96)	86%		< 0.0001	0.75	4.83
Perceived preparation to plan effective lessons aligned with Modeling approach	55.83 (16.51)	16%		75.93 (13.88)	73%		< 0.0001	1.10	6.83
Perceived preparation to use a variety of standards-based instructional strategies	61.36 (14.57)	30%		77.18 (12.48)	75%		< 0.0001	1.01	5.04
Confidence regarding aspects of investigative science instruction	56.98 (13.40)	18%		66.66 (17.20)	48%		< 0.0001	0.60	n.s.

** p values computed by paired sample t-test (two-tailed), with n=146*
"Multiple institute contribution" = increase in post-score (controlling for pre-score) for participating in the project for more than one year; computed by linear regression.

The table below gives pre/post results for the teachers' perceived preparation for the particular items listed in the questionnaire. For each of the items, their perceived preparation significantly improved after their project participation.

	Pre-Questionnaire			Post-Questionnaire	
From pre/post questionnaires: Many teachers feel better prepared to guide and help students develop and apply some science processes than others. How well prepared do you feel to provide guidance to students in learning to do the following things?	Mean (4 pt scale)	% "well prepared" (4-5)		Mean (4 pt scale)	% "well prepared" (4-5)
Generate testable hypotheses and design appropriate scientific experiments to investigate them	3.77	64%		4.18*	88%
Organize, describe, graph, and interpret data	4.10	81%		4.40*	93%
Analyze & evaluate information using scientific reasoning	3.99	76%		4.37*	94%
Using empirical data to validate models or test hypotheses	3.60	54%		4.22*	88%
Represent scientific ideas or relationships in multiple formats (mathematical, graphical, diagrams, etc.)	3.90	71%		4.31*	90%
Explain and defend their ideas orally and in writing	3.71	57%		4.20*	87%
From pre/post questionnaires: Many science teachers feel better prepared to engage in some planning/preparation activities than others. How well prepared do you feel to do each of the following things?					
Develop science units & lessons around key "big ideas" rather than traditional topics	3.46	52%		3.94*	78%
Identify misconceptions that students are likely to have about a science concept.	3.56	52%		4.06*	83%
Design effective science lessons that guide students in investigating a science concept idea (guided inquiry)	3.46	45%		4.17*	88%
Design effective science lessons that engage students in exploring or investigating a science concept in an open-ended fashion (open inquiry)	3.22	33%		3.98*	78%
Adapt science lessons from existing resources to make them more inquiry-based.	3.39	47%		4.08*	84%
Identify and select specific formative assessment strategies to build into appropriate places in a science lesson to probe student thinking and guide instructional decisions.	3.35	43%		3.99*	78%
Design individual or group tasks that prompt students to demonstrate and explain their understanding of the targeted concepts.	3.42	43%		3.99*	80%
From pre/post questionnaires: Many science teachers feel better prepared to use some teaching strategies than others. How well-prepared do you feel to do each of the following things?					
Lead a class of students using investigative, inquiry-oriented activities.	3.52	52%		4.18*	88%
Manage students and materials to create an orderly	3.97	78%		4.21*	91%

environment for lab activities					
Have students work effectively in cooperative learning groups.	3.71	63%		4.13*	85%
Use questioning to elicit students' thinking or probe for misconceptions.	3.74	62%		4.13*	85%
Use questioning to assess students' conceptual understanding.	3.80	66%		4.19*	88%
Use writing tasks as a tool to foster students' scientific thinking.	3.33	38%		3.88*	72%
Use student presentations as a means to monitor what they are learning.	3.50	47%		4.08*	85%
Use performance tasks for assessment purposes.	3.33	45%		3.89*	72%
Use Internet resources to teach science concepts.	3.87	75%		4.15*	85%
Display & analyze data using computers or graphing calculators.	3.41	44%		4.06*	78%
Collect data using scientific probes connected to computers or calculators.	3.12	40%		3.98*	75%

* *Difference significant at $p<0.0001$, paired sample t-test (two-tailed), with $n=146$*

The questionnaire results suggest that the teachers needed and received additional knowledge about and experience with the strategies underlying the Modeling Approach. Furthermore, responses to the end-of-year feedback survey indicate that participants feel their pedagogical repertoire has grown as a result of their project experiences thus far. The teachers were asked to use a 1 (low) – 5 (high) scale to describe their status prior to the project and their current status. The table below contains mean responses for participants with one year and two or more years participation in the project.

	1 year partic.			2+ years partic.	
From participant feedback forms: The following items list the Modeling Project's objectives for its participating teachers. For each objective, indicate 1) your status before you started with the project; and 2) your status as a result of your participation in the project.	Mean Prior	Mean Current		Mean Prior	Mean Current
Your understanding of characteristics of the Modeling approach, including how it is similar to and different from "inquiry" science teaching.	2.4	4.1*		3.5	4.4*
Your understanding of current research on student thinking and student learning of science concepts, and the implications of the research for effective science instruction.	3.0	4.0*		3.1	4.0*
Your familiarity and comfort with instructional strategies used in the Modeling approach, including how teacher and student roles change at different parts of the Modeling Cycle.	2.4	4.1*		3.3	4.2*
Your familiarity and comfort with the implications of the Modeling approach for how science units and lessons should be designed.	2.3	4.1*		3.2	4.1*
Your familiarity and comfort with using technology to collect, organize, display, and analyze data in laboratory activities.	3.4	4.3*		3.4	4.2*
Your familiarity and comfort with using appropriate computer software and the Internet to illustrate, explore, and apply science concepts.	3.6	4.3*		3.3	4.2*
Your knowledge of common student misconceptions about physics/physical science/chemistry content and how to identify them in my students.	3.1	4.2*		3.1	4.0*

Your knowledge of strategies to promote student discourse that probes their thinking and monitors their understanding.	2.9	4.2*		3.1	4.0*
Your knowledge of strategies to foster collaborative student work and to assess student learning in collaborative groups.	3.1	4.2*		3.0	4.0*

* *Pre/post difference significant at p<0.0001, paired t-test (two-tailed)*

As might be expected, the prior status ratings on items related to the Modeling Approach were higher for "veteran" participants. Both groups reported significant mean growth on all items.

Overall, participants left the project activities with greater perceived understanding of the strategies utilized, and greater confidence that they can apply them effectively in their teaching. Thus, they would be expected to be more likely to try implementing the strategies with their students. As discussed in the next section, this was indeed the case.

7) Participating teachers began the project typically using "traditional" instructional strategies in their science teaching, with some use of "standards-based" strategies. They report significant changes as a result of Modeling professional development and support.

The pre/post teacher questionnaires asked participants about their teaching practices. They reported their frequency of using a variety of instructional strategies – some associated with a "traditional" approach to instruction, some associated with a "standards-based" approach – as well as frequency of using various assessment and technology strategies. As seen in the table below, the composite indicators show a greater frequency of using "traditional" teaching strategies, with infrequent use of standards-based strategies or technology. (A level of 70 is indicative of regular use.) There was significant change on the post-questionnaire. Teachers significantly decreased their frequency of using traditional strategies and significantly increased their frequency of using more investigative, assessment and technology-based strategies. In addition, linear regression modeling revealed that, controlling for the pre-questionnaire value, participating in the project for more than one year made a significant contribution to the post-value of two composite indicators – further decreasing use of traditional strategies and increasing use of standards-based ones.

	Pre-Questionnaire			Post-Questionnaire					
From pre/post questionnaires: Composite indicators	Mean (sd)	% at or above 70		Mean (sd)	% at or above 70		p*	Effect size	Multiple institute contrib.
Frequency of using "traditional" teaching strategies	64.38 (11.01)	32%		59.70 (11.37)	17%		< 0.0001	0.41	-4.54
Frequency of using standards-based teaching strategies	55.28 (13.20)	17%		73.14 (12.55)	66%		< 0.0001	1.14	2.22
Frequency of using strategies for formative assessment during instruction	59.78 (12.75)	21%		70.67 (12.95)	53%		< 0.0001	0.78	n.s.
Frequency of using technology in science teaching	51.70 (19.30)	18%		62.77 (18.04)	32%		< 0.0001	0.57	n.s.

** p values computed by paired sample t-test (two-tailed), with n=146*
"Multiple institute contribution" = increase in post-score (controlling for pre-score) for participating in the project for more than one year; computed by linear regression.

Examining pre/post results for individual questionnaire items associated with "traditional" instruction reveals that participants primarily report significant reduction in their use of lecture:

"TRADITIONAL" STRATEGIES

From pre/post questionnaires: In your classes, how often do you . . .	Pre-Questionnaire Mean (5 pt scale)	Pre-Questionnaire Weekly basis (4-5)		Post-Questionnaire Mean (5 pt scale)	Post-Questionnaire Weekly basis (4-5)
Introduce content through formal presentations.	3.61	62%		3.01*	29%
Demonstrate a science-related principle or procedure.	3.65	62%		3.56	57%
Use short answer tests (multiple choice, fill in the blank, problem sets, etc.).	3.76	63%		3.74	60%
From pre/post questionnaires: In your classes, how often do students . . .					
Read from the textbook or other informational materials in class.	2.84	31%		2.70	25%
Answer questions or problems from the textbook or a worksheet.	3.44	55%		3.41	51%
Review or check homework or worksheet assignments in class.	3.53	60%		3.50	54%
Engage in a laboratory activity after a teacher presentation or class discussion, to illustrate or apply the concept being studied.	3.46	53%		3.32	49%

* *Difference significant at $p<0.0001$, paired sample t-test (two-tailed), with $n=146$*

Teachers initially reported fairly regular use of cooperative grouping, real-world connections, requiring evidence, and working with data, but less frequent use of strategies more deeply associated with standards-based instruction and the Modeling approach. All items showed significant pre/post change in reported frequency:

"STANDARDS-BASED" STRATEGIES

From pre/post questionnaires: In your classes, how often do you . . .	Pre-Questionnaire Mean (5 pt scale)	Pre-Questionnaire Weekly basis (4-5)		Post-Questionnaire Mean (5 pt scale)	Post-Questionnaire Weekly basis (4-5)
Organize students into collaborative groups to discuss ideas or to work on an activity or assignment.	3.99	76%		4.46*	96%
Pose questions to students that are open-ended, allowing multiple responses.	3.71	63%		4.35*	93%
Use real-world contexts to introduce/develop science concepts.	3.81	69%		4.23*	87%
Require students to supply evidence to support their claims.	3.66	58%		4.39*	91%
Encourage students to explain concepts to one another.	3.83	66%		4.46*	90%
Encourage students to come up with alternative explanations.	3.32	46%		4.10*	83%

From pre/post questionnaires: In your classes, how often do students . . .					
Engage in a laboratory activity to explore a concept before discussing it in a formal manner.	2.99	28%		3.81*	72%
Design their own scientific investigation to answer a question or solve a problem.	2.44	11%		3.14*	34%
Record, represent, and/or analyze data.	3.63	59%		4.13*	85%
Make a presentation or demonstration for the class.	3.14	33%		3.73*	65%
Prepare a written lab report or other description of what they found in a science investigation.	2.85	23%		3.10^	31%
Write reflections about their science learning in a notebook or journal	2.35	21%		3.28*	41%

** Difference significant at p<0.0001 ^ p<0.004, paired sample t-test (two-tailed), with n=146*

Similarly, participants showed significant pre/post change on their reported use of strategies associated with assessment and use of technology:

ASSESSMENT STRATEGIES	Pre-Questionnaire			Post-Questionnaire	
From pre/post questionnaires: In your classes, how often do you . . .	Mean (5 pt scale)	Weekly basis (4-5)		Mean (5 pt scale)	Weekly basis (4-5)
Use informal questioning to find out what students know before a unit.	3.65	61%		4.04*	79%
Use pre-planned questions or formative assessment tasks to identify student misconceptions prior to addressing a concept.	3.00	32%		3.47*	53%
Use informal questioning to check student understanding during a lesson.	4.26	90%		4.55*	94%
Use pre-planned questions to check student understanding during a lesson.	3.59	62%		3.90^	72%
Use specific tasks or assignments in a lesson as "check points" to monitor student understanding during the lesson.	3.65	63%		3.99*	76%
Embed assessment into regular class activities.	3.61	60%		3.99*	73%
Use tests requiring open-ended responses (description, justification, etc.).	3.18	37%		3.87*	70%
Use a performance task or laboratory activity as a formal assessment.	2.82	26%		3.32*	45%
Use student notebooks or journals to assess student learning.	2.71	29%		3.32*	46%

** Difference significant at p<0.0001 ^ p<0.0006, paired sample t-test (two-tailed), with n=146*

TECHNOLOGY STRATEGIES	Pre-Questionnaire			Post-Questionnaire	
From pre/post questionnaires: In your classes, how often do students . . .	Mean (5 pt scale)	Weekly basis (4-5)		Mean (5 pt scale)	Weekly basis (4-5)
Use a calculator to assist with computations.	3.71	66%		3.90^	71%
Use a computer or graphing calculator to display or analyze data.	2.81	30%		3.42*	52%
Gather data using scientific probes attached to a computer or graphing calculator.	2.20	16%		2.99*	33%
Access Internet resources for information, activities, simulations, etc. about a science concept.	3.54	52%		3.79^	66%

** Difference significant at p<0.0001 ^ p<0.002, paired sample t-test (two-tailed), with n=146*

Furthermore, when asked on the questionnaires about their use of various types of lesson designs, the results indicate an initial inclination toward using activities that confirm a previously presented idea. Reported baseline use of the most inquiry-oriented kinds of lessons was infrequent. On the post-questionnaire, there was significant decrease in reported use of confirmatory lessons and increase in use of inquiry-oriented lessons.

From pre/post questionnaires: For each description below, indicate the extent to which it is similar to the kinds of science lessons you typically use in your classroom (the lesson activities described may extend over more than one class session).	% responding "My lessons are rarely if ever like this"			% responding "My lessons are frequently similar to this"	
	Pre	Post		Pre	Post
(*Textbook-centered*) Students read a section of the text, then work individually or together on a set of assigned questions or problems. The teacher goes over the questions, either explaining the correct answers or calling on students to explain.	61%	69%		3%	1%
*(*Confirming activity*) The teacher presents information on a concept. Students then do an activity that illustrates the concept, followed by work on questions to reinforce their learning. The teacher goes over the questions, either explaining the correct answers or calling on students to explain.	9%	20%		43%	18%
^(*Teacher-guided activity*) Students do an activity, following directions in the text or other given material. The teacher then leads a discussion of the activity, highlighting the important science concepts to be learned. Students apply the concepts, either in written questions or following directions for a related activity.	16%	30%		21%	14%
*(*Inquiry-oriented activity*) The teacher introduces a problem or question to the class. Students work in groups to explore the question and make conjectures about how to investigate it. After trying out their ideas, students present their findings in a class discussion. The teacher uses data collected by the students to further clarify the concepts. Students write in a journal to explain what they found and to reflect on their learning.	27%	7%		21%	52%

** Distribution difference significant at p<0.0001, ^ p<0.003*

The data consistently indicate that prior to the project, inquiry-oriented teaching was being attempted by some participants, but was not yet frequent or consistent in its implementation. The post-questionnaire data indicate significant increases in use of the desired strategies. On feedback forms the majority of participants attribute their changes to participating in the Modeling Project. Teachers with multiple years in the project gave significantly higher ratings to the project's influence on their instructional practice.

	1 year partic.			2+ years partic.	
From end-of-year participant feedback forms:	Mean (4 pt. scale)	Very true (4)		Mean (4 pt. scale)	Very true (4)
Overall, the Modeling Project has had a significant influence on my science teaching.	3.6	63%		3.8*	80%
Overall, the Modeling Project has had a significant influence on my use of technology in my science teaching.	2.8	22%		3.1*	33%
Overall, the Modeling Project has had a significant influence on my ability to plan and implement effective science units and lessons.	3.2	47%		3.5*	59%
Overall, the Modeling Project has had a significant influence on my awareness of quality curricular resources to use in my science teaching.	3.3	46%		3.5*	59%

* *Difference significant at $p<0.05$*

When asked to describe the changes they have made in their teaching, participant responses included the following illustrative examples:

I want to start by saying that this workshop provides such a valuable insight to teaching. I am simply going to list how my science teaching has changed. 1. I spend more time facilitating learning rather than lecturing. 2. I do more collaborative group work with assigned roles. 3. Students are asking their peers questions rather than asking me questions. 4. The way the curriculum is designed helps me to review old models as we learn new information. 5. I spend a lot more time asking questions rather than answering questions. 6. I do more activities, and more importantly I do activities that truly test for misconceptions. These activities are meaningful and force students to truly understand concepts. 7. I now have students explain their lab results, observation, and conclusions in class. I also force students to argue and defend their perspective. 8. Students read, write, analyze, and explain scientific concepts almost every day. I honestly am having more fun teaching, and I feel like students are having more fun too.

Modeling has totally changed the way I teach Biology. Prior to the workshop, I would say that about 80% of my class was lecture based, with a few labs added throughout the course. Now, I incorporate lecture for about 20% of the course. I am more aware of the connections between units of study, and make a more conscious effort to instill this awareness in my students. This gives them a deeper and more thorough understanding of Biology as a science. The students are doing more hands-on activities, more group work, allowing students to discuss activities and concepts among themselves to come to a deeper understanding, and then share that understanding through white-boarding. I can definitely see an increase in the rigor of the course. They are more engaged in the classroom and their overall understanding of the concepts has improved.

I LOVE modeling...and so do my students! I feel much less like the disseminator of information and now serve as the facilitator of knowledge acquisition. My students enjoy the many hands-on *activities and labs that springboard them into knowledge; and, on several occasions I have thrilled in watching students have those "ah-ha" moments that bridges and solidifies their understanding. In particular, at the beginning of the year I noted that I have 3 students with "accommodations" within my modeling class, yet modeling has made it difficult to remember just who those students are. The multimodality approach is conducive to ALL learners and although I have a wide-spectrum of abilities in my class modeling seems to be meeting everyone's needs. I am extremely grateful to have been trained in modeling and have also incorporated aspects of it in my AP class, as well!*

I am doing more whiteboarding, and that reveals to me where my students misconceptions lie. I am definitely making more connections to the student's real-life, which seems to help them connect more. I have done many more lab and inquiry-based activities this year than I did in my first two years teaching. I am much more careful about how I question my students. My goal is now to elicit clear and logical conclusions based on evidence rather than correct responses based on memorized facts. My students come to class expecting to leave with more questions than answers. They joke that I never actually answer their questions, except with more questions. I have noticed that I am doing less worksheets and I have barely used the book or power points at all this year.

My teaching has changed in the following ways: I am more thoughtful in my lesson planning. Modeling has a very specific method of explaining concepts and it requires that I give new thought to my presentation of material in class. Because I have reordered the presentation of material, I have had to rethink the concepts. I use whiteboarding to greater advantage. We used to use it to go over homework math problems. Now students provide explanations of their work and other students interact more with the students who are presenting. My questioning is better because I am deliberate in using socratic questioning methods. I have given students question stems to use when they are questioning and their questions are better. I have never done heavy lecture but now students are taking more responsibility for the class and the learning that takes place.

I have completely changed the way that I teach as a result of the three modeling workshops that I have attended. I used to think that I was a good physics teacher but after teaching with Modeling, I realized that I just taught my physics students to be better algebra students, not better thinkers or problem solvers. The same is true for chemistry. My students could solve problems that I had showed them how to solve but had no real idea of what was happening in terms of the types and behaviors of the particles involved. Now, the class is not all about me but all about all of us in the room. I now have them do the labs first, and develop the models from experimental data. I also do lab practicums and whiteboarding, and we have whiteboard discussions, all as a result of the modeling workshop. I strongly believe kids learn how to think like real scientists using this new approach to teaching. I will never go back to my old ways.

8) Participating teachers vary in their implementation of the Modeling Approach. Nature and degree of implementation are related to participants' time in the project and their comfort with the strategies. The majority of participants intend to continue their implementation in the coming school year.

Data gathered from participating teachers – both in the current cohorts and previous participants – indicate that most are attempting to use what they learned in the Modeling Project in their classrooms.

About 10% of the 115 current and former participants responding to the end-of-year implementation survey indicated that they did not use the Modeling Approach at all in their teaching during the 2013-14 school year. The typical reasons were: lacking needed equipment; not being assigned to teach the course corresponding to the Modeling institute they attended (a factor outside the control of both the teacher and the project); or moving to a non-teaching position (administrator, instructional coach, etc.). For these teachers, failure to use Modeling was due to lack of opportunity, not of intent. Only three respondents indicated that they were not using Modeling because they had reservations about the approach.

Of the 90% of respondents reporting that they currently use Modeling in their teaching, teachers vary in the degree to which they have adopted the full Modeling approach, as well as their comfort with their implementation to-date. As seen in the following tables from the end-of-year implementation survey, results differ for teachers who were only in the project for one year and those who elected to participate for multiple years. About half in both groups are using Modeling as their main approach at least some of the time, but those with greater project participation use the Approach more frequently in their overall teaching.

From end-of-year participant feedback forms: Mark the statement below that most closely represents how you currently use the Modeling Approach.

1 year	2+ years	
40%	46%	The Modeling Approach is the core of my instructional approach; I use it in lessons wherever possible.
30%	38%	I use the Modeling Approach as my main approach when teaching lessons supplied through the project and sometimes when teaching other lessons as well.
0%	5%	I use the Modeling Approach as my main approach, but only when teaching lessons supplied through the project (not when teaching other lessons).
25%	10%	I use the Modeling Approach as a supplement to my regular teaching, to enhance or enrich some lessons.
5%	0%	I do not use the full Modeling Approach in my teaching, but I incorporate particular strategies from the Approach into my typical teaching.

Distribution difference is significant at $p<0.0038$ (chi sq = 15.46, df=4)

Interestingly, one-year participants report feeling more effective in their implementation than those working with the project for two or more years. It is our thought – supported by the project coaches – that the more experienced teachers have greater understanding of the Modeling approach and greater expectations for how it should look in their classrooms.

From end-of-year participant feedback forms: Mark the statement below that most closely represents how you feel about your implementation of the Modeling Approach this year.

1 year	2+ years	
33%	25%	I am comfortable using the Modeling Approach and feel I do an effective job with the lessons.
43%	63%	I am comfortable using the Modeling Approach, but feel I can do a better job implementing the lessons.
20%	13%	I don't feel I am very effective using the Modeling Approach sometimes, but I feel good about the attempts I am making and know I will do better with more experience.
3%	0%	I feel very mechanical when using the Modeling Approach; I'm not comfortable with it yet.
0%	0%	I am very frustrated with the Modeling Approach; I don't feel good about how things have gone so far.

Distribution difference is significant at $p<0.0352$ (chi sq = 10.33, df=4)

Participants were asked for their perceptions of aspects of their science instruction on the pre/post teacher questionnaires. They assessed the degree to which particular factors represented an issue or barrier to their use of the desired strategies. They also reported the degree of success or challenge they felt with their implementation of particular strategies. As seen in the table below, the composite indicators show that participants perceived relatively few barriers to using the Modeling Approach, and felt moderately successful in using the indicated strategies. (A level of 70 is typically the target level.) There were significant changes in both indicators on the post-questionnaire. Teachers significantly decreased their perception of barriers and significantly increased their perceived success with the strategies, both with moderate effect sizes. In addition, linear regression modeling revealed that, controlling for the pre-questionnaire value, participating in the project for more than one year made a small but significant contribution to the post-value of both composite indicators.

	Pre-Questionnaire			Post-Questionnaire					
From pre/post questionnaires: Composite indicators	Mean (sd)	% at or above 70		Mean (sd)	% at or above 70		p*	Effect size	Multiple institute contrib.
Frequency of reporting a variety of factors as issues limiting use of the Modeling Approach.	33.01 (17.97)	1%		21.24 (13.99)	0%		< 0.0001	0.75	-3.21
Frequency of reporting success with strategies associated with implementing the Modeling Approach.	55.98 (14.56)	17%		74.00 (15.33)	64%		< 0.0001	1.03	2.94

** p values computed by paired sample t-test (two-tailed), with n=146*
"Multiple institute contribution" = increase in post-score (controlling for pre-score) for participating in the project for more than one year; computed by linear regression.

In general, the most common challenges to implementation on the pre-questionnaire involved time, materials, comfort with the strategies, and preparing students for high-stakes assessments. Most of the larger concerns showed a significant decrease on the post-questionnaire. The concern over pacing, however, did not change.

From pre/post questionnaires: The items listed below are factors that other teachers have cited as challenges to using more investigative or inquiry-based strategies in their science teaching. For each one, please rate the extent to which it is an issue for you.	Pre-Questionnaire Mean (3 pt scale)	Pre-Questionnaire This is not an issue for me (1)		Post-Questionnaire Mean (3 pt scale)	Post-Questionnaire This is not an issue for me (1)
I do not feel well enough prepared with the strategies; I don't feel comfortable using them.	2.01	16%		1.36*	65%
I do not have appropriate curriculum materials that follow an inquiry approach.	2.03	28%		1.37*	68%
I do not have the proper equipment and materials needed for the activities.	2.17	21%		1.73*	39%
Too much preparation time is needed to get materials ready.	1.85	31%		1.44*	58%
My class periods are not long enough to use an inquiry approach effectively.	1.22	79%		1.24	81%
It takes too long to address the topics; I need to cover material more quickly to keep up with the pacing guide.	1.98	25%		2.04	27%
I am not convinced that an inquiry approach is better than what I currently do.	1.22	80%		1.23	80%
I am concerned that I won't be able to answer all the questions that students might ask when using this approach.	1.51	56%		1.32^	70%
It is too difficult to assess learning or assign grades using this approach.	1.59	48%		1.32*	71%
I am concerned that students won't be adequately prepared for assessments given by the district and/or state.	1.87	31%		1.59*	54%
My students don't have the kind of background to be successful with this kind of teaching; it's too challenging for them.	1.73	39%		1.61	51%
My students' behavior won't allow me to use this kind of approach.	1.59	52%		1.50	58%
My school administration discourages using this kind of approach to teaching.	1.07	93%		1.09	92%
My district administration discourages using this kind of approach to teaching.	1.07	93%		1.13	89%

* *Difference significant at $p<0.0001$ ^ $p<0.004$, paired sample t-test (two-tailed), with n=146*

When asked about their degree of success in using particular strategies associated with Modeling instruction, participants reported a mixture of success and challenges. Initially, they felt successful with use of groups, questioning, multiple representations, whiteboards, and using technology themselves; the greatest challenges were presented by shifting away from more "traditional" strategies – allowing students to design their own approach, stepping back from a "telling" role, delaying introduction of formal vocabulary, and using writing for student explanations. The table below shows significant increases in perceived success with all the listed strategies:

From pre/post questionnaires: Listed below are instructional elements that are particularly emphasized in inquiry-based instruction. For each one that you currently do in your science teaching, indicate the degree to which you feel you are successful or find it challenging to do.	Pre-Questionnaire Mean (5 pt scale)	Pre-Questionnaire % responding "success" (4-5)		Post-Questionnaire Mean (5 pt scale)	Post-Questionnaire % responding "success" (4-5)
Having students work effectively in collaborative groups.	3.74	67%		4.26*	88%
Having students design their own approach to investigate a question or hypothesis.	3.02	34%		3.59*	59%
Prompting students to justify their ideas or solutions, whether correct or incorrect.	3.46	57%		4.10*	77%
Stepping back from a "telling" or "explaining" role.	3.08	39%		3.75*	66%
Using effective questions to probe deeper for student understanding beyond their initial response.	3.54	59%		3.97*	74%
Having students represent ideas or relationships in mathematical, graphic, and pictoral forms.	3.52	54%		4.09*	77%
Having students explain their ideas, results, or explanations orally.	3.48	49%		4.07*	74%
Having students explain their ideas, results, or explanations in writing.	3.17	34%		3.85*	65%
Using whiteboards as a tool for students or groups to display their thinking for others to see.	3.81	70%		4.36*	90%
Testing ideas (or models) using data from lab activities.	3.14	39%		3.97*	79%
Helping students learn to question each other and to critique each others' ideas in a positive manner.	2.94	36%		3.48*	50%
Using tasks, projects, presentations, and other different ways of assessing student understanding	3.45	51%		4.00*	73%
Delaying introduction of formal vocabulary or terminology until needed for effective classroom discourse.	3.13	43%		3.79*	68%
Using technology myself to collect, analyze, and display data from lesson activities.	3.69	65%		3.99^	74%
Having students use technology to collect, analyze, and display data from lesson activities.	3.36	43%		3.99*	73%

* *Difference significant at $p<0.0001$ ^ $p<0.0004$, paired sample t-test (two-tailed), with n=146*

Participants were asked to elaborate about challenges they were facing in using the Modeling Approach. Examples of their responses include the following:

Time is the most significant factor. The modeling approach has a specific pacing that is not the norm. Our county has benchmarks and we are graded on the tests. With modeling, there were some tests that my students were very ill-prepared for!

The single greatest challenge is the amount of time that it takes to implement modeling. I would use modeling 100 % of the time if it were not for the constraints of the State's testing protocol. I believe that modeling is a very good way to teach and learn science. However, modeling takes more time than more traditional ways of teaching and given the testing environment in the state, I had to "come off the modeling grid" in order to "cover" all of the material that would be tested on the NC *final exam. Towards the end of the semester, I had to switch to a more traditional teaching method simply to finish teaching the curriculum before the state final exam.*

My department does not allow me to follow the pacing guide from modeling which makes it more difficult. My students also are intimidated by questioning because they feel it means they have done something wrong, or because they are afraid they will not be able to answer questions. Many get frustrated with this approach. Some feel that I am not helping them as much as I should. Students and parents complained that I was not teaching and the grades were unsatisfactory. My administration requested me to return to a more traditional method while still trying to use modeling where possible.

I really want to make the Modeling approach work in my classroom. My administration does not fully support it, though. I don't think they all understand why it is important. One AP said she wishes I would just tell the students what they need to know. I think I will get better at it next year, I just hope the administration will not get in the way. I think it will take some time before I am good at it.

My main challenge has been with discipline and student absences. Modeling does not seem to work as well for students with chronic absences, yet those students are the exception. A minor issue was the benchmark assessments did not line up with the course plan.

Overall, the great majority of participants – particularly those taking part for multiple years – expressed their intention to continue their implementation efforts in the next school year.

From participant feedback forms: Do you plan to continue trying to implement the Modeling Approach in your science teaching next school year?

	Definitely yes	Probably yes	Not sure	Probably no	Definitely no
1 year	66%	24%	6%	3%	1%
2+ years	79%	14%	7%	0%	0%

Participant comments illustrate their generally positive view of Modeling as they continue to work on their implementation:

I think about next year and I am excited about starting over and hopefully not making the same mistakes. From what I have observed, even my mistakes sometimes lead to great discussions and better understanding of the information. I feel that every time I use this approach, I will be more successful. I think this is a great approach to teaching biology. I simply need more practice!

I have worked this year to learn the basics of the material and methods in the modeling curriculum. Even though I am not comfortable yet, I know that this method of teaching will help my students become critical thinkers. I have been searching for a method of teaching that will really bring that skill to the forefront and I think this is it. It isn't easy - I am often tired, under-prepared, behind and frustrated. It is more difficult because I have to break habits that I have formed over my years of teaching. Becoming a good modeling teacher is not simple but it provides a challenge that I can see will improve my effectiveness as a teacher. I will definitely continue to use this approach, and I know that it will be better next year and so I am fine with this.

This is my second year using Modeling instruction; I feel like I'm doing a much better job this year *than last year. I think the Modeling approach is the best instructional approach for the physics classes I teach. I still need to practice because it takes a long time to become good at this. The more times I go through the curriculum, the more I find to improve upon and get better at. I am, as ever, crunched for time to cover all the objectives in the standard course of study. I find it difficult to cover the breadth necessary at the depth that Modeling reaches.*

I have been implementing the Modeling Approach in Physics and Chemistry since I first participated in the Modeling Project in 2010. I feel very confident implementing the Physics curriculum and achieve superior results from my students as compared to my prior method. This is the first year I have taught a Physical Science course since I participated, and know that I need to work on both delivery and materials for that course. Students in Physical Science need a lot more scaffolding and some of the units are pretty sparse when compared to the NC Essential Standards requirements. I have been working on that this year, but know there is a lot that I need to improve upon for next year.

After only one year, I am beginning to see the benefits of the Modeling approach both for the teacher and the student. For the teacher, the benefit comes from gaining a much more accurate picture of what students know and understand. It also provides a more coherent and comprehensive framework for planning purposes. For students, the approach is more engaging and thought provoking. Students gain confidence in their ability to actually think and work through problems rather than resorting to "I don't get it - you didn't teach us". While this cultural shift associated with Modeling is uncomfortable at first for both teacher and students, the benefits far outweigh the inconvenience and discomfort.

The Modeling Approach was scary last fall, the first time I implemented it. I worked extremely hard to reorganize the sequence of topics I teach. I really needed to do this anyway, but modeling gave me a framework to operate in and a reason to do it right now. I have been teaching for a number of years, so realigning everything felt like I was a first year teacher again. This semester, I am tweaking stuff still to make it better, but I have so much more confidence in what I am doing. Now, I can't envision teaching without it.

V. Evaluation Findings: Impact on Student Performance

9) Results of pre/post student testing show significant growth in student understanding of the targeted concepts. Three fourths of students in targeted courses demonstrated significant pre/post gains on the assessments.

Ultimately, The Modeling project's success will be gauged by its impact on student learning. The project's evaluation plan calls for administration of a pre/post assessment to students that is aligned to the focus of the project's professional development. The same assessments that teachers completed (Force Concept Inventory, Assessment of Basic Chemistry Concepts, and Biology Concept Inventory) were given to students of those teachers at the beginning and end of the pertinent course. Results for each assessment over the three project years are shown in the tables that follow:

Biology Pre/post Student Assessment Results

	# teachers reporting class data	# students tested	Mean pre-test score (sd)	Mean post-test score (sd)	Signif. level – paired t-test	Eff. size	Mean <g>	Students with signif. gain	Teachers with signif. class gain
Proj. Yr. 1 2011-12	14 of 15 (93%)	614	32.6% (.113)	43.6% (.158)	<0.0001	.81	.314	438 (71%)	11 (79%)
Proj. Yr. 2 2012-13	14 of 22 (63%)	752	28.0% (.098)	39.3% (.151)	<0.0001	.91	.157	542 (72%)	10 (71%)
Proj. Yr. 3 2013-14	16 of 22 (73%)	939	28.3% (.103)	41.5% (.155)	<0.0001	1.02	.139	752 (80%)	15 (94%)
TOTAL	44 of 59 (75%)	2,305	29.3% (.106)	41.3% (.155)	<0.0001	.92	.170	1,732 (75%)	36 (82%)

Chemistry Pre/post Student Assessment Results

	# (%) teachers reporting class data	# students tested	Mean pre-test score (sd)	Mean post-test score (sd)	Signif. level – paired t-test	Eff. size	Mean <g>	Students with signif. gain	Teachers with signif. class gain
Proj. Yr. 1 2011-12	13 of 17 (76%)	990	31.5% (.140)	45.0% (.189)	<0.0001	.82	.197	669 (68%)	11 (85%)
Proj. Yr. 2 2012-13	9 of 12 (75%)	613	31.0% (.135)	42.8% (.181)	<0.0001	.75	.171	410 (67%)	8 (89%)
Proj. Yr. 3 2013-14	20 of 22 (91%)	1,116	32.0% (.140)	43.8% (.176)	<0.0001	.96	.173	705 (63%)	20 (100%)
TOTAL	42 of 51 (82%)	2,719	31.6% (.139)	44.0% (.182)	<0.0001	.77	.181	1,784 (66%)	39 (93%)

Physics Pre/post Student Assessment Results

	# (%) teachers reporting class data	# students tested	Mean pre-test score (sd)	Mean post-test score (sd)	Signif. level – paired t-test	Eff. size	Mean <g>	Students with signif. gain	Teachers with signif. class gain
Proj. Yr. 1 2011-12	11 of 14 (79%)	491	23.2% (.103)	46.9% (.225)	<0.0001	1.05	.309	418 (85%)	11 (100%)
Proj. Yr. 2 2012-13	8 of 12 (66%)	400	25.3% (.123)	47.1% (.226)	<0.0001	1.14	.292	337 (84%)	8 (100%)
Proj. Yr. 3 2013-14	13 of 17 (76%)	444	25.4% (.105)	53.2% (.205)	<0.0001	1.79	.372	378 (92%)	13 (100%)
TOTAL	32 of 43 (74%)	1,335	24.6% (.111)	49.1% (.222)	<0.0001	1.47	.325	1,133 (85%)	32 (100%)

Noteworthy results contained in the tables include:

- Overall, the students' mean scores on the biology and chemistry assessments increased about 12%, with the physics increase about double that figure. Each pre/post assessment difference is significant at $p<0.0001$ with moderate to large effect size, indicating meaningful growth in student understanding.

- 107 of the 118 teachers (91%) providing data demonstrated significant gains in pre/post class means. This includes all the physics teachers, all but three chemistry teachers, and all but 8 biology teachers

- The average normalized gains <g>, a measure used by the National Modeling Project, were 0.181 and 0.325 for chemistry and physics, respectively. This is within the range reported for Modeling classes in the national literature (national data are not available for the biology assessment).

- Almost three fourths of the students (73%) posted a significant pre/post gain, defined by USDE as a gain of at least one-third standard deviation from their pre-assessment score.

The results indicate that students in these Modeling classes did make significant gains in their learning.

From a more qualitative perspective, participating teachers are positive in their reports of a variety of desirable student outcomes that they attribute to using the Modeling approach (these data were not collected in 2011-12):

	2012-13			2013-14		
From end-of-year participant feedback forms: In your estimation, to what extent has your use of the Modeling approach impacted the following outcomes for your students?	mean (4 pt scale)	Moderate impact (3)	Great impact (4)	mean (4 pt scale)	Moderate impact (3)	Great impact (4)
Solid understanding of the important science concepts.	3.2	44%	40%	3.3	38%	45%
Basic science process skills (communicating, measuring, graphing, inferring, etc.)	3.4	38%	52%	3.4	37%	52%
Higher-order process or thinking skills (analyzing data, making conjectures or hypotheses, designing investigations, evaluating ideas, etc.)	3.4	42%	48%	3.5	42%	53%

Ability to explain their thinking/reasoning for an idea or answer orally	3.3	28%	52%	3.5	38%	55%
Ability to explain their thinking/reasoning for an idea or answer in writing	3.0	42%	32%	3.1	38%	38%
Ability to represent concepts in multiple ways (pictures, graphs, equations, narrative)	3.3	48%	40%	3.4	43%	48%
Willingness to consider alternative ideas, explanations or solutions	3.1	40%	34%	3.2	40%	40%
Interest in learning about topics or ideas in science	2.9	36%	32%	3.0	45%	28%
Active engagement in learning activities	3.4	32%	54%	3.5	32%	58%

Teachers' anecdotal reflections, for the most part, are strongly positive, as seen in this sample of comments:

> *Students are not only much more engaged in activities, but they are also more participatory and/or skilled at pulling their groupmates in. I think students understand the concepts not just at their base levels, but in a more holistic sense; always having their eye on the "connection" - either to previous topics OR to real life.*

> *The students really learn more with modeling because they have to be able to explain their answers and sometimes draw what they know. Students can't hide or not participate. They have to be engaged everyday. That is what teaching and learning is all about!*

> *Students were hesitant at first but now retain more when I focus on "why' something happens they way that we see it versus just "here is the information". They seem to get the "big picture" ideas which leads to a better understanding of the overall concepts.*

> *My students scored much higher than the teachers who have more experience than me and use the traditional teaching method. My students seem to understand and know the concepts in biology throughout the course. They remembered everything from the beginning of the semester.*

> *The curriculum has great activities to encourage collaborative learning, literacy skills, and implementing stable mathematical skills. I have also seen a greater involvement in my class from students that might traditionally not interact. Lastly, I saw a huge improvement in my EOC scores. In 2012-2013 school year, I only had eight students perform at the highest achievement level, level 4. This year I had seventeen students that performed at the highest achievement level, level 5. Overall, 42/49 of my students were proficient. I know that Modeling Project was instrumental in this improvement.*

> *My students are thinking! They know that if they cannot explain their answer either through a visual (writing) or verbally that we will not be able to move forward. Students are challenged and most like it. Students must think critically and are more active and engaged when using the Modeling approach. They do fairly well on standardized testing, but that is not my purpose. I use it because it prepares them better for college science course or the workplace whichever they choose. The collaboration and thinking skills gained through the processes in Modeling are valuable tools for either college classes or the workplace.*

The state End-of-Course (EOC) assessments are another measure of student learning important to teachers and administrators, and are required for reporting in the project's Annual Performance Report. In high school science, the state administers an EOC assessment only for the Biology course. The table below contains the results of the Biology EOC for the three years of the project, along with the state-level rate for rough comparison purposes. It is important to note that the Biology EOC assessment was changed in 2013, including a new scoring scheme, so results in 2012 are not comparable to subsequent years.

	# (%) of teachers reporting results	# of students tested	# (%) of students scoring proficient or above	State-level proficiency rate
Project Year 1 2011-12	14 of 15* (93%)	642	556 (86.6%)	83.0%
Project Year 2 2012-13	17 of 19* (89%)	1,148	541 (47.1%)	46.5%
Project Year 3 2013-14	14 of 19* (74%)	922	469 (50.9%)	data not yet available

** This number excludes participants from private schools, whose students do not take the state assessment.*

Results for the Modeling Biology teachers are slightly higher than statewide results. However, this is too rough a comparison to support any claim regarding performance in participants' classrooms.

Moreover, seeking to use the state assessments for evaluating the impact of the overall Modeling Project on students is problematic for the following reasons:

- The state does not give EOC assessments in chemistry and physics. This means that EOC data are only available for biology participants, who make up only 38% of the participant group.
- No "EOC"-equivalent pretest is administered at the beginning of the biology course, so actual change in student learning cannot be determined. Comparing the each year's results to the prior year for the participating teachers would involve tenuous assumptions about the comparability of the student groups involved.

The project collects EOC data for the biology participants for inclusion in its Annual Performance Reports, but EOC results are not included as part of the project evaluation.

VI. Evaluation Findings: Other Impacts

10) The Modeling Project has enhanced capacity in the state to support continued implementation of Modeling instruction.

The Modeling Project was successful in building capacity to support continued implementation of the Modeling approach in several ways:

- 52 of the 155 participants (34%) participated in two or more Modeling institutes (13 of these were in three institutes, 3 had taken four institutes). This ongoing participation enables these teachers to directly apply the Modeling approach and instructional materials to multiple courses they teach, as well as giving them additional support from the project as they continue to refine their Modeling implementation.

- The project continued to build a "critical mass" of Modeling teachers at schools across the state. Twenty-eight schools have two teachers who have participated in the project since it began in 2008; another 12 schools have three participants; and 6 schools have four or more, totaling 44 schools with more than one Modeling teacher. In all, 118 participants have at least one Modeling colleague at their school, including 74 participants in the current project. Thus, *almost half the participants in the current project this year (74 of 155) had at least one colleague at their school who also has Modeling experience*. Having multiple teachers at a school who have had Modeling professional development and are engaged with implementing the Modeling approach presents opportunities for collegial support and encouragement, which can help teachers address questions or frustrations, and enhance the likelihood of continued implementation.

- The AMTA website is featured prominently in the project's professional development as a community for sharing tested resources and for ongoing collegial interaction. On the end-of-year feedback survey, 34% of the participants reported "great value" in their use of the website; another 37% reported "moderate value." Not all participants used the site regularly, but those who did found it to be a good source of implementation support.

- The project worked actively to expand the leadership capacity to support Modeling in North Carolina. The project took advantage of existing leadership to serve as institute facilitators and project coaches, but project leaders recognized the need to expand the pool of experienced leaders to support future efforts. To that end, they identified Modeling teachers who demonstrated effective classroom use of Modeling and who showed interest and promise as potential leaders of Modeling professional development. These teachers were given opportunities to "intern" with the project, assisting the facilitators during follow-up sessions and as co-facilitators of the summer institutes. They are being prepared to lead institute sessions in subsequent years. In this way, the project is looking ahead to meet what is expected to be a growing interest in Modeling in the state and a concurrently growing need for experienced persons to lead the effort.

VII. Evaluation Findings: Operation of the Modeling Project Partnership

The Modeling project was a partnership of five county school districts (Bertie, Buncombe, Duplin, Durham, and Guilford), the Science House at North Carolina State University, and the New Schools Project. The national Modeling program at Arizona State University and the American Modeling Teachers Association are also linked to the partnership, providing access to expert personnel and quality resources. The project recruited participants statewide, with priority given to qualified applicants from the partner districts. Its formative evaluation component included providing feedback on the operation of the partnership, for use in planning and decision-making.

11) Project partners worked well together and carried out their roles effectively.

Because it was funded as a "mathematics and science partnership", it was important that the entities involved in the Modeling project – five school districts, one IHE, and the New Schools Project – actually acted as partners, collaborating toward achievement of mutually-held goals. Several indications suggest that this was the case:

- Project partners carried out their defined roles in operating the project. NCSU provided the Project Director, as well as facilities on campus for holding summer institutes and follow-up sessions. Duplin Co. served as fiscal agent for the project and provided key individuals who served as the project coach and an institute facilitator. All five district partners assisted in recruiting eligible teachers, who comprised 36 of the 155 (23%) participants over the three project years. The New Schools Project provided funds to expand project offerings, as well as recruiting a total of 59 teachers from member schools (38% of the total participants).

- Project planners had a good working relationship and engaged in collaborative planning and decision-making regarding project activities. Concerns or disagreements were handled professionally and in a spirit of seeking consensus on the best course of action. In large measure, this was likely due to the pre-existing relationship among the planners, which enabled them to work together effectively from the earliest stages of the project.

- The partnership demonstrated a commitment to gather and use formative feedback to make improvements in the nature and quality of its activities. Project staff gathered feedback from the project experiences and addressed the concerns identified in planning for subsequent activities. In particular, the developers of the new biology institute worked closely with the project evaluator to make adjustments to the institute design and the pre/post content assessment based on formative data collected.

- The partnership made effective use of existing capacity in the state to lead the institutes. Pairs of experienced Modeling teachers from the state served as the facilitators of each institute. Ties to the national Modeling Project ensure access to expert advice and support for the facilitators. The project identified additional outstanding Modeling teachers and included them as "facilitators-in-training" at the institutes, further developing capacity in the state to lead institutes in future years.

The Modeling project involved the appropriate partners for its purpose, and operated effectively in pursuit of its goals.

VIII. Closing Observations

A. Summary Observations about the Modeling Project

Overall, the Modeling Project's professional development and support activities over its three-year period were effective in contributing to progress toward the project goals. The majority of participating teachers were positive about their experiences in the project. One third of the participants returned to take a second (or even third) Modeling institute. Several of the teachers are continuing their direct participation in Modeling professional development by enrolling in another Modeling summer institute in 2014 through a newly-funded Title IIB project.

Participants have demonstrably grown in their knowledge and skills, and are putting their learning into practice (to varying degrees). As noted earlier, the great majority of teachers expressed their intention to continue implementing the Modeling Approach in their teaching in the coming school year. While they may not yet have reached the level of fluent implementation desired by the project, nevertheless they have made progress and are confident that they will continue to do so.

In summary, the evidence gathered in the Modeling Project external evaluation indicates that:

- Project activities were well-designed and implemented, and participants valued their experiences.
- Teacher participants demonstrated significant growth in their knowledge of the targeted science content.
- Teacher participants report enhancing their pedagogical knowledge and skills, and have begun to implement the Modeling Approach in their science teaching in significant ways.
- Student assessment results and anecdotal evidence indicate a positive contribution of the Modeling Project to student learning of the targeted content.

The following samples of participant reflections describe their view of their experiences in the project:

> *The Modeling Project has been an invaluable experience for me as a teacher. I see the content I teach in a completely different light, and I can see that my students (whether they want to admit it or not) have a much greater depth of understanding of the content than they ever did when I taught using more traditional methods (direct instruction, guided and independent practice). I know that my students will take what they have learned in my class with them always. I appreciate that the Modeling approach requires higher order thinking from my students, and I know that they are learning more than simply the chemistry content - they are learning how to think and problem-solve. I have thoroughly enjoyed and greatly benefited from studying together with like-minded colleagues during both years I have been involved in the institutes. Thank you very much for making this possible!*

> *This program is one of the most productive and useful professional development workshops that I have ever attended. Modeling has definitely opened my eyes to a new approach to teaching biology. This experience has empowered me with a method of teaching that I truly believe will make learning science more engaging and enjoyable. More knowledge means better teaching. I am better able to answer questions b/c I know the mistakes and misconceptions students will have and where their breaks in understanding occur. Introducing concepts by extracting students' misconceptions gets*

them vested in the topic. Working through activities and experimental data allows them to come up with a consensus that they all have a vest interest in. It allows them the discovery and they seem much more involved in the process. When I try to lecture now I just can't. I just realize how much of a waste of time it is. When I watch other teachers lecture, I cringe knowing how little the students are actually getting from that class.

My teaching style has changed completely as a result of my participation in the Modeling Project. I taught Chemistry one year what I would consider "the traditional way". Now with implementing modeling into my class my students are much more engaged and seem to truly enjoy being in my class. It was a little scary to me at first, but now I would not consider teaching Chemistry any other way. I am extremely pleased with everything dealing with the project. I am very grateful that I was able to participate and hope that I'm able to do the biology institute this summer.

When I actually realized that the Modeling would not follow typical pacing, I was reluctant. I admit not being too thrilled to start something completely from scratch (compared to the curricula I was previously using). I thought Modeling was a strategy you could adapt to any curricula. Now, I can see I did not understand the concept at all. However, after participating and using Modeling in my classroom, I am pleasantly surprised how effective it has been. I decided that I was going to commit to the "whole" program, not just bits and pieces. I am glad I made that commitment. Otherwise, I would not have had the confidence to say that it worked. The PD was very effective. Although at first as mentioned, I was skeptical. As we progressed, I became much more comfortable with the entire process. Now I can see that Modeling can be adapted to other curricula, but since this product is complete and proven successful there is basically no need to do so. However, if it becomes necessary for new units or lessons to be created, I will feel confident that I can create them in the "modeling" method.

The design and implementation of the Modeling Project showed numerous strengths that contributed to the effects observed, including:

- The project was based on the well-researched and documented program developed at Arizona State University. The instructional materials used in the institutes were developed and vetted through the national program, and thus provided a strong framework to support classroom implementation (participants did not have to try to "adapt" materials to the Modeling Approach). The current project was not a "cookie cutter" replication of the original project, however. Project leaders made strategic adaptations to the professional development design to fit the current North Carolina context, making it more meaningful and relevant to participants. In particular, their use of Project Coaches to provide ongoing implementation support is a particular enhancement to the original professional development model.

- Participants were deeply immersed in Modeling from the beginning of their three-week summer institute experience. This extended experience enabled the teachers to engage with the Modeling Approach, experience it as a student, reexamine their own content understanding, and reflect on the implications for their teaching. The follow-up sessions and coaching visits during the academic year extended the in-depth work on content and pedagogy, providing support as participants' learning built over time. The project structure also fostered strong relationships among participants and between participants and facilitators, which in turn created a supportive context to push participants' thinking and learning.

- The experienced Modeling teachers who designed and facilitated the institute, follow-up, and coaching sessions were knowledgeable about the science content, research-based pedagogy, and effective professional learning. The facilitators each brought individual strengths that complemented each other well. As current or former classroom teachers with extensive practical experience using Modeling, they had great credibility with the teacher participants.

- The facilitators showed flexibility in planning project activities, while still adhering to the overall goals of the project. The project's willingness to adjust its activities showed responsiveness to changing conditions and enhanced its credibility with the participants and the partner districts.

- The project's management at The Science House provided leadership that made it easier for issues to be resolved and needed tasks to be completed in a timely manner. The relationships enabled the Modeling Project to function as a partnership, rather than simply a provider/client project.

That said, some issues and concerns were identified in the evaluation, including:

- The bulk of project contact with participants was limited to a one-year period (summer and the following academic year). The next summer, project activities focused on a fresh group of participants and implementation support for previous participants was limited to phone/email contact with facilitators and interactions through the AMTA website. To a large measure, this was a consequence of the project budget and project planners' desire to involve as many teachers as possible. As a result, there was variability in continued implementation after the "participation year." Project coaches made an effort to stay in touch with previous participants and to provide support where possible; and the online resources remained available for previous participants to access information and interact with others. Given the demands of shifting instructional practice to the Modeling Approach, however, implementation support for multiple years would likely produce more consistent use of the Approach as envisioned by the project. Participants recognized this, as seen in some of their comments, and in the fact that one third of them have participated for multiple years. This enabled them to extend their Modeling into other subject areas, but also provided additional professional development and support for their implementation of Modeling pedagogy in general. Finding the appropriate balance between breadth of participation and depth of involvement is a persistent issue for any project of this type.

- Several participants noted the important role that local administrators play in supporting implementation of the Modeling Approach. Principals committed to do this as part of the teacher application to participate, but were uneven in their follow-through. Attempts were made to engage principals, to help them learn about Modeling, but this was not a major effort of the project.

- The project had a strong rationale for its choice of facilitators to lead the institutes and follow-ups. However, the MSP program's emphasis on involving higher education science faculty made finding an appropriate role for university content experts a persistent issue.

B. Evaluation Successes

The greatest success with respect to the Modeling Project evaluation is the quality of the data gathered, and this is due in large measure to the support of the project staff. Project personnel were committed to ensuring the maximum possible response rate on the various instruments and protocols used in the evaluation, and were of great assistance in prompting participants to respond. The result was an overall completion rate of 86% for the pre/post data most critical for the evaluation. In addition, project personnel encouraged participants to take the evaluation seriously as an assessment of the project, resulting in more thoughtful (and, we assume, more accurate) responses.

C. Evaluation Caveats and Constraints

There were no major challenges in carrying out the evaluation of the Modeling Project. However, the evaluation's ability to report project outcomes and impacts confidently was constrained by several issues. For the most part, these were known from the outset of the project. While they did not impact conducting the evaluation, they must be considered in interpreting the results and forming conclusions.

1) Relatively small number of participants
The nine cohorts of teachers over the three years of the Modeling Project reflect the numbers proposed by the partners and supportable by the level of funding provided. Aggregating the data from the cohorts yielded 155 total participants (unduplicated count), which is an acceptable number for analysis. Finer-grained examination of the data – by subject area or participation level – involved subgroups with smaller numbers, limiting the power of the analysis. This could not be avoided, but the limitation must be recognized in reporting results of the project.

2) Changes in participants' teaching assignments
Overall, 28 out of 182 total participants (15%) did not teach any classes of their targeted course during the school year of their participation. In most cases, their teaching assignment was changed to accommodate changes in student enrollment and scheduling at their schools, a factor beyond the control of the project. The effect, however, was that teachers were unable to apply their learning in the course context intended, making their initial implementation of the Modeling strategies more challenging. Furthermore, they were unable to take part in pre/post student testing, which was designed for the targeted courses only, thereby limiting the availability of data on changes in student learning.

3) Determining a useable comparison group.
The quasi-experimental design for the summative evaluation entailed having a suitable comparison group available against which to compare the pre and post performance of participating teachers. The original intent was to use reported results for Modeling teachers in the national Modeling Project literature as the comparison set. To a limited extent, appropriate data were available for physics and chemistry, but not to the depth expected. Because the biology institute is new with this project, no comparable data are available.

4) Determining degree of implementation.
The evaluation design contained multiple ways to examine participants' implementation of the Modeling Approach – observations, surveys, narrative reflections, coaches' assessments. Of these, classroom observations using the RTOP protocol would provide the most objective and quantifiable data. The project intended for coaches to use the RTOP when visiting participants, to collect data over time about their instructional characteristics. However, it became apparent that coaches needed to be more actively involved in participants' classrooms during their visits, so opportunities to gather data using the RTOP were sporadic and generated insufficient data for analysis. The remaining implementation data were perceptual and self-reported. While participants were generally quite frank in acknowledging their implementation challenges and successes, reliance on their self-reports alone introduced some uncertainty into any assignment of implementation level.

5) Attributing student performance changes.
While the long-term goal of the Modeling Project is to impact students' achievement in their science courses, documenting attributable changes is a significant challenge in the evaluation. The project gathered pre and post concept inventory data (FCI, ABCC, or BCI) for the students of participating

teachers. However, questions about fidelity of implementation and opportunity-to-learn in the teachers' first attempts to use the Modeling approach made issues of attribution of pre/post changes problematic.

6) Relating project impact to state assessment results.
The Annual Performance Report called for the project to report performance on the pertinent state assessment for students of participating teachers. This was problematic for the Modeling Project for multiple reasons, including: a) The state no longer administers End-of-Course assessments in physics and chemistry, so the data called for in the APR do not exist in these subjects; b) The Biology EOC assessment changed during the project, making year-to-year comparisons difficult; and c) Attributing student performance changes during a teacher's first year of implementing a challenging new approach is a difficult proposition.