Modeling Instruction for Physical Science and Chemistry in Ohio 2013-2014

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Annual Report

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INTRODUCTION

Modeling Instruction for Physical Science and Chemistry in Ohio, developed and implemented by faculty at the Ohio State University (OSU), is designed to demonstrate techniques and strategies that high school physics, physical science, and chemistry teachers can utilize in their classrooms that will result in more inquiry-based learning experiences for their students. This marks the ninth year that the Ohio Board of Regents (OBR) has funded this initiative. Three modeling programs were offered during the three-week period from June 10-28, 2013. They included two Year 1 course offerings and an advanced Year 2 experience. These three courses have been offered consecutively since 2007-08. The abbreviations below will be used throughout this report to denote the respective workshops:

- PHYS1 = Year 1 – Physics/Physical Science Modeling Workshop (previously offered in 2004-05, 2006-07, 2007-08, 2008-09, 2009-10, 2010-11, 2011-12, and 2012-13).

- CHEM1 = Year 1 – Chemistry Modeling Workshop (also taught in 2007-08, 2008-09, 2009-10, 2010-11, 2011-12, and 2012-13).

- YEAR2 = Year 2 – Advanced Workshop (previously taught in 2005-06, 2007-08, 2009-10, 2010-11, 2011-12, and 2012-13). This course is designed to help teachers who took one of the first year courses (Physics/Physical Science or Chemistry Modeling) modify their curriculum and lessons so that they are consistent with their efforts to use modeling and inquiry-based instruction.

Instructional Team

Positions and responsibilities of the instructional team members are outlined in Table 1.

Table 1: Instructional Team by OSU Position/District and Modeling Responsibilities

OSU Position	University Staff	Modeling Responsibilities
Lecturer in Engineering Education Innovation Center	Dr. Kathy Harper	Admin./YEAR2 and PHYS1 Contributor
Assistant Professor in Chemistry	Dr. Ted Clark	Admin./YEAR2 and CHEM1 Contributor
Assistant Professor in Education	Dr. Lin Ding	Educational Consultant
Undergraduate Student	Audrey Nguyen	Support and logistics
District	**Teacher-Instructors and Site Support**	**Modeling Responsibilities**
Avon Lake HS, retired	Liz Emmer	CHEM1 Instructor
Amherst Steele HS	Chas Deremer	PHYS1 instructor
Dublin Coffman HS	Heidi Kresge	YEAR2 Instructor
Laurel School	Brian Carpenter	PHYS1 Instructor
New Albany HS	Jessica Nettler Stacey Raymond	Site support/logistics CHEM1 Instructor
Ontario HS	Rick Jacox	YEAR2 Instructor

Dr. Kathleen A. Harper is the Project Director. Dr. Harper has been one of the co-Principal Investigators (PI) since the program was first funded in 2004-05. Dr. Ted Clark is the other co-PI. In addition, the university instructional team included Dr. Lin Ding, an Assistant Professor in Education, and an undergraduate student, Audrey Nguyen, who provided administrative support. As in previous years, experienced high school teachers who had completed the Modeling Workshops were the primary workshop instructors. During the 2013-14 implementation, six teachers from six different Ohio districts served as the teacher-instructors.

This was the second year in a row that New Albany High School, northeast of Columbus, was the host school. Dr. Harper again confirmed that the facilities met their needs and the support was exceptional. The leadership designated a stipend for a New Albany teacher, Jessica Nettler, to assist with logistics, which helped to ensure effective use of the location. Moreover, since many of their chemistry and physics faculty had attended previous workshops, they were well aware of participants' needs.

Evaluation Activities

Institutional Research Consultants, Ltd. (IRC), the external evaluator, prepared three sets (Pre-survey, End of Workshop, and Post-survey) that the instructional team administered. There were two Pre-surveys: the one required by OBR and one developed by IRC. These surveys covered participants' opinions about science teaching, instructional practices, and demographics. IRC combined the two preliminary surveys, and this report provides analysis of selected OBR questions and all the IRC items. IRC also developed an End of Workshop Survey that the instructional team administered at the end of the summer session.

Fifty-four participants completed the three-week summer course and everyone completed the Pre-survey and End of Workshop Survey (Table 2). The response rate on the Post-survey ranged from 78 percent for CHEM1 to 88 percent for PHYS1, resulting in an 83 percent response rate overall. Table 2 presents the participant and response counts for the workshops.

Table 2: Survey Response Rates by Workshop

Workshop	Total in Program	OBR/IRC Pre-survey		End of Workshop		OBR/IRC Post-survey	
		Surveys	Return Rate	Surveys	Return Rate	Surveys	Return Rate
PHYS1	24	24	100.0	24	100.0	21	87.5
CHEM1	23	23	100.0	23	100.0	18	78.3
YEAR2	7	7	100.0	7	100.0	6	85.7
TOTAL	**54**	**54**	**100.0**	**54**	**100.0**	**45**	**83.3**

The Pre-survey and End of Workshop survey results were covered extensively in an interim evaluation report.[1] Parts of that report are updated here. The focus in this document is on participants' opinions about and use of modeling toward the end of the project year, including analysis and discuss of the differences between their pre- and post-survey responses.

We also invited the instructional team to have input into this report. We administered an online survey to the six teacher-instructors, interviewed Dr. Harper, and received a written response from Dr. Clark. They confirmed the impacts on the teachers and provided additional examples of school and district benefits. Finally, their feedback enhances our awareness and understanding of program changes that they have made each year.

[1] IRC submitted a report to Dr. Harper on the results from the Pre-survey and End of Workshop Survey on January 9, 2014.

PARTICIPANT DESCRIPTION

Current Position, Reasons for Choosing the Program, and Credit Received

Table 3 shows that almost all of the Pre-survey respondents were regular teachers (93%). Two (4%) taught special education (one each from the PHYS1 and CHEM1 courses). Two (4%), a pre-service teacher and a graduate student, both of whom were in CHEM1, marked the "Other" option. By year-end, this distribution was generally maintained. On the Post-survey, only one participant specified the "Other" category—the pre-service teacher from the initial survey was working as a long-term substitute. Appendix 1 provides additional detail on participants' characteristics.

Table 3: Current Position in Pre-survey and Post-survey

	Pre-survey *N=54*		Post-survey *N=45*	
	N	%	N	%
Teacher	50	92.6	42	93.3
Special Education, Resource or Inclusion Teacher	2	3.7	2	4.4
Other (Pre-survey: Graduate Student and Pre-service Teacher; Post-survey: Long-term Substitute)	2	3.7	1	2.2

Table 4 presents reasons for participants' decision to take part in one of the workshops. Nearly three-fifths (59%) said a former participant encouraged them to enroll in the course, which was especially true for CHEM1 (70%). Half (50%) chose to take part based on their own initiative. Only two (4%) said encouragement from the project director was a factor. One (2%) respectively (all three individuals were in the CHEM1 group) attributed their attendance to a school district requirement, district incentives, and school staff agreement that the program was needed.

Table 4: OBR Pre-survey – Reasons for Choosing Program[1]

	PHYS1 *N=24*	CHEM1 *N=23*	YEAR2 *N=7*	TOTAL *N=54*
a. Applied on my own initiative	45.8	52.2	57.1	50.0
b. Participation was required by the school district	0.0	4.3	0.0	1.9
c. School district provided incentives to participate	0.0	4.3	0.0	1.9
d. Encouraged to participate by the project director	4.2	0.0	14.3	3.7
e. School staff agreed that the program was needed	0.0	4.3	0.0	1.9
f. Encouraged to attend by a former participant	54.2	69.6	42.9	59.3
g. Other reason	12.5	4.3	14.3	9.3

[1]Total can add to more than 100 percent, as respondent could give more than one response.

From the nine percent who gave "other reasons" were the desire to "*take Year 2"* and receive *"graduate credit"* as well as the following additional responses:

> *Coworker encouraged me to attend.*
>
> *Full inclusion in Physical Science co-teaching in 2013-14 SY.*
>
> *Shadowed program during my master's program and wanted to have the full experience.*

Eighty-nine percent indicated that they are receiving graduate credit (Table 5). More than a quarter will receive credit respectively toward continuing education (30%) and certification/licensure (28%). Nineteen percent expected to earn credit toward a salary increase. Three participants (6%) did not expect to be awarded any credit, while the one who gave an "other" response was uncertain, "*I will try to get graduate credit but am not sure I qualify.*"

Table 5: OBR Pre-survey – Types of Credit Participant Will Receive[1]

	PHYS1 *N=24*	CHEM1 *N=23*	YEAR2 *N=7*	TOTAL *N=54*
a. Graduate credit	91.7	87.0	85.7	88.9
b. Undergraduate credit	0.0	0.0	0.0	0.0
c. Credit toward salary increase	16.7	21.7	14.3	18.5
d. Credit toward continuing education	25.0	30.4	42.9	29.6
e. Credit toward certification/licensure	25.0	30.4	28.6	27.8
f. No credit given	8.3	4.3	0.0	5.6
g. Other	0.0	4.3	0.0	1.9

[1]Total can add to more than 100 percent, as respondent could give more than one response.

Background of Participants

Appendix 1 provides teachers' demographics on all available items. The overall distribution was nearly even on gender (male=52% and female=48%); however, CHEM1 was nearly two-thirds female (65%) and PHYS1 had more males (58%). All were white. About three-fifths (59%) of this year's participants were under age 41, which makes this the youngest cohort to date. More than a quarter (28%) were under 30, suggesting that the project is attracting newer teachers. Of the remaining age categories, about a quarter were 41-50 years old (24%) while those 51-60 (18%) composed the smallest single age group; older participants were concentrated in YEAR2.

Consistent with their relative youth, more than two-fifths (43%) had five years or less of teaching experience, with PHYS1 (54%) having the largest contingent of newer teachers. In contrast, the majority in the other workshops (YEAR2=72% and CHEM1=65%) had more who had spent more than five years as teachers. A little over a third (36%) had been at the same school for more than five years; there was only modest variation on this item for each group.

Two-thirds (67%) had master's degrees, 28 percent reported a bachelor's degree, and three (6%) had a doctorate. The most frequently mentioned degree areas were Science Education (59%), Chemistry/Biochemistry (41%), Biology or Life Science (28%), and Physics/Physical Science (24%). Nearly a fifth (19%) listed "other" degree areas. These included additional science areas (animal sciences, medical sciences, comprehensive high school science), other education-related degrees (education, instructional design, and special education), and one had a background in vocal performance.

Grades Taught and Coverage of Physics, Physical Science, and Chemistry Classes

Most (93%) taught high school (Appendix 1). However, three (6%) middle school teachers and a one primary (grades K-3) level teacher (2%) were part of the 2013-14 cohort. Nearly all taught science only (94%); however, one high school teacher taught math only (2%). The elementary teacher was the only participant with a self-contained classroom (2%).

The extent to which the teachers are responsible for one or more sections of physics, physical science, or chemistry provides a general idea of the need for modeling instruction in schools.

We reviewed the course loads for all the teachers (see Appendix 3). During the 2012-13 and 2013-14 school years, a third to more than half taught each of the target courses—physics (36-39%), physical science (56% on both surveys), and chemistry (47-52%). All of the YEAR2 teachers taught one of these courses each academic year as did all but five participants from the first year sessions (91% on the Pre-survey and 89% on the Post-survey). Respondents' reports of responsibility for physics, physical science, and chemistry classes at their schools verified that modeling is applicable to the courses they teach and their students will potentially benefit from the changes in instructional practices.

Districts Represented

Twenty-six districts were represented (see Appendix 2A). Most participants (89%) taught in public schools, two (4%) were from the same charter school, and four (7%) worked at private schools. Columbus City Schools again contributed the largest single group with ten participants (19%) and South-Western was next with three representatives (6%). Eight schools respectively had two teachers (4%) in attendance. Seventeen (31%) of participants were from counties more than an hour's drive from the training site, demonstrating the statewide relevance of the training. The PIs once again requested funding which allowed them to offer local temporary housing to teachers whose residence was outside the central Ohio service area. Appendix 2B has the district and school ratings; eight participants (15%) were from schools with a Continuous Improvement rating and one (2%) was located at a school in Academic Emergency.

OPINIONS ABOUT THE SUMMER WORKSHOPS AND THEIR IMPACTS

All 54 teachers who took part in a summer workshop completed an End of Workshop Survey. Appendices 4-7 provide participants' responses to questions about the impact of the session and the extent to which their understanding increased because of their experience. Selected open-ended responses are integrated into the report and additional comments were included only in the preliminary report (see footnote 1 on page 2).

Summer Workshop Highlights

Appendix 4 presents participants' opinions about the workshop at the end of the summer session. All respondents confirmed that they gained skills in how to use inquiry in the classroom and that the workshop was a successful professional development overall. In addition, everyone in Year 2 viewed the amount of guidance/structure as appropriate. High proportions (83-100%) of each group affirmed the following[2]:

- Participants would recommend this workshop to other teachers (98%).
- Participants' questions and concerns were addressed effectively (98%).
- They improved their content knowledge (96%).
- The workshop contributed positively to their attitude about science (96%).
- The workshop helped them become a more effective teacher (94%).
- They gained skills in complex thinking and reasoning (89%).
- They increased their ability to see connections between science and mathematics (87%).

[2] The overall average for each item is presented in parentheses.

There was substantial variation in the response by workshop type on several items this year. On three of the items, CHEM1 and YEAR2 gave similarly high ratings, but the PHYS1 group had a lower level of agreement. Specifically, at the end of the summer course, both CHEM1 and YEAR2 (100% each) agreed that adequate time was allowed for participants to reflect and relate materials to their experience; however, only three-quarters (75%) of the PHYS1 teachers felt they had the time needed to do this. Although all of YEAR 2 and all but one in CHEM1 (96%) confirmed that the workshop enhanced their confidence in teaching science, fewer in PHYS1 (71%) attested to this impact. In addition, fewer PHYS1 participants (79%) reported that their session prepared them to encourage science activities in their building compared to everyone in YEAR2 and most in CHEM1 (91%). The greatest variation between the three groups occurred in their response to whether teachers had a better understanding of how to apply science standards; YEAR2 (86%) was more confident than both PHYS1 (46%) and CHEM1 (74%). Of interest is the fact that the overall response to this item (63%) was noticeably less than the prior cohort (85%). A similar pattern appeared with their preparedness to provide professional development to their peers on specific workshop activities (PHYS1=46%, CHEM1=70%, and YEAR2=100%).

Table 6 covered additional areas of science instruction on which the workshops were designed to strengthen participants' understanding. Appendix 12 has these items in the order of their appearance on the survey.

Table 6: Increased Understanding from the Workshops[1]
—Questions Ordered by High to Low Total Response—

	PHYS1 *N=24*	CHEM1 *N=23*	YEAR2 *N=7*	TOTAL *N=54*
Effective applications of inquiry-based instruction in classrooms.	100.0	100.0	100.0	100.0
Strategies that can be used to improve students' science performance.	100.0	100.0	100.0	100.0
Awareness of current research in science education.	100.0	91.3	85.7	94.4
Effective uses of alternative assessment.	87.5	91.3	100.0	90.7
The technology required for effective instruction in science.	87.5	73.9	100.0	83.3
Ability to utilize current research in science education in my classes.	79.2	78.3	85.7	79.6
Strategies for facilitating change in science instruction in my building.	87.5	60.9	100.0	77.8
Application of Ohio's science standards.	33.3	65.2	100.0	55.6

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.

All participants said they increased their understanding of effective applications of inquiry-based instruction in their classrooms and that they learned strategies that they can use to improve students' science performance. All PHYS1 teachers agreed that they increased their awareness of current research in science education, while slightly fewer in the other two groups reported this impact (CHEM1=91% and YEAR2=86%). Overall, most participants (91%) felt that their understanding of effective uses of alternative assessment had increased (PHYS1=88%, CHEM1=91%, and YEAR2=100%). YEAR2 also unanimously agreed that their understanding of the technology needed for effective instruction had improved, though PHYS1 (86%) and CHEM1 (74%) agreed to a lesser extent. In addition, participants confirmed increases in their ability to use current science education research in the classroom (78-86%). However, there was wide variation in the groups on the two remaining items. Although the seven YEAR2 participants agreed that they had increased understanding of strategies for facilitating change in science instruction in their buildings and most of PHYS1 (88%) echoed this sentiment, only 61 percent of CHEM1 attributed growth in their ability in this area to the workshop. Finally, YEAR2 also expressed full agreement that their session had improved their understanding of how to apply Ohio's science standards, but the first year groups were much less convinced (PHYS1=33% and CHEM1=65%).

The teachers were also asked to rate the value of specific workshop activities (Table 7 and Appendix 6). Everyone confirmed the worth of interacting with other participants and workshop facilitators. Moreover, there was unanimous recognition of the value of modeling inquiry. YEAR2 wholly agreed that the large blocks of "free" time spent working on curriculum were an asset. The majority of participants described the introduction to various sources of curriculum materials (96%), the purchase of the educational/classroom materials (93%), and the discussion of reading assignments as worthwhile (87%). All of YEAR2 and most of CHEM1 (87%) thought the research article reading assignments were worth their time, while PHYS1 (71%) was less enthusiastic about this aspect. Participants in each group felt the examples on how to apply district standards were the least worthwhile activity, ranging from a high for YEAR2 (71%) to a low reported by PHYS1 (42%).

Table 7: Workshop Activities Rated Worthwhile[1]
—Questions Ordered by High to Low Total Response—

	PHYS1 *N=24*	CHEM1 *N=23*	YEAR2 *N=7*	TOTAL *N=54*
Overall interaction with the other participants.	100.0	100.0	100.0	100.0
Overall interaction with workshop facilitators.	100.0	100.0	100.0	100.0
Modeling of inquiry.	100.0	100.0	100.0	100.0
Year 2 Workshop Only: Large blocks of "free" time spent working on curriculum.	NA	NA	100.0	100.0
Introduction to various sources of curriculum materials (books, websites, etc.).	100.0	90.9	100.0	96.2
Purchase of educational/classroom materials.	87.5	95.5	100.0	92.5
Discussion of reading assignments.	75.0	95.7	100.0	87.0
Reading assignments (research articles).	70.8	87.0	100.0	81.5
Examples on how to apply district standards.	42.1	57.1	71.4	53.2

[1]Percent of participants who indicated that the activity was "Very Worthwhile" or "Somewhat Worthwhile." Percentages are based on those with valid response to item.

Teachers in the first year sessions responded very positively to the training. Almost everyone described "*student mode*" as the most useful aspect. For example, a PHYS1 participant shared, "*I really felt that student mode will help me be successful.*" They emphasized the value of observing and applying effective practices such as, "*hands-on labs, modeling in class, lab materials, lesson plan, and playing part of student and teacher*." Participants also found the collaboration, discussions, and networking with other teachers to be very useful, including one PHYS1 teacher who emphasized that the discussions with other colleagues created a "*very supportive environment*." The CHEM2 group stressed the value of the demo and whiteboard tools; they especially seemed to appreciate the time to practice the techniques they learned. In answer to, "What aspects of this workshop were most useful to you?" teachers gave the following responses.

PHYS1

It was important to see the whole process of modeling, from procedure lab to white boarding, to worksheets, and finally deployment lab. The modeling method is a complete package and that is what makes it successful.

Being in student mode and navigating the course through what my students will experience. This was further enhanced with constant reflection in teacher mode. Also, the emphasis of having us do questioning exercises was useful.

The questioning paradigm and deployment labs and how it all works together.

Developing relationships among teachers. Seeing another "take" on pre-survey year one (differences between experiment/successful modeling teachers).

I really felt that student mode will help me to be successful. Also, my chance to question other "students" with suggestions was very successful.

Discovered the structure of modeling to implement it properly.

Development/deployment labs. White boarding questioning. Group discussion. Free materials.

Ability to interact with the instructors as real people teaching in real schools. Not a college professor leading the course that is not teaching in a public or private school.

CHEM1

The chance to experience effective modeling techniques and questions, and then the chance to practice using those techniques.

The networking was great. Experiencing firsthand the activities and how the teachers worked with the students was really fantastic. The freebies were much appreciated.

The student modeling and whiteboard sessions. Discussion of demos, labs, etc. Lab experiences and resulting discussion.

Watching our instructors model their classroom discourse. Getting to practice questioning techniques. Ted's talks. Demo and lab ideas.

Keeping a compilation book with student and teacher notes. Playing "student," white boarding, asking questions, and practicing questioning.

Participating in white boarding. Observing modeling questioning. Exposure to chemistry content.

Dialogue with colleagues. Examples of modeling from a teacher and student perspective. Great lab ideas and classroom management strategies. Nice purchases.

Doing the labs and white boarding and reviewing the materials with other participants (both controlled and when able to just "mingle").

The more veteran teachers in YEAR2 particularly enjoyed the collaborative discussions, "*sharing with participants,"* opportunity to develop models and materials, and the overall interaction with other instructors. Their comments underscored their enthusiasm about their improved understanding of modeling.

I greatly enjoyed the discussions after lunch about the readings and especially with Kathy and Ted's input as well. This is where I think I gained the greatest leaps into my understanding about what modeling is all about.

Learning development and deployment. How students "uncover" the model and test. Difference between causal and descriptive model.

Interactions with other participants and instructors. Learning about "new" educational research on modeling.

Learning about the types of questions and problems to write and the unit we developed.

Very helpful. I now can develop my own models.

Model development. I will be much better prepared to adjust materials to my specific needs. Understand how to "stay within the model."

Discussion about content with classmates and instructors.

Although the comments above underscored the YEAR2 group's growing confidence with being able to adapt models to their own needs, some still felt apprehensive about implementation, which may indicate the need for additional support.

I am more confident about developing a model cycle that is working with the learning targets I have to meet. Strengths: Very inquiry, NOS oriented.[3] *Weakness: Time—it takes a lot.*

I feel great. The most useful/helpful things for me were the discussions at the readings. I love that Heidi and Rick were "rocks" that we could fall back on when we were stuck.

Strength: I loved doing this. It really helped me see what the "how" and "why" of a model and a modeling unit. Weakness: The "jump in with both feet" approach works best if all group members have actually done some modeling.

Strengths: The building up of "tools" through the weeks. Weaknesses: Not entirely sure how I will do on my own creating models without guidance.

This was great! Developing my own unit materials forced me to really think about how to develop it. Why would we sequence things the way we did, how does each part support the model, how does it help the students better develop their models?

[3] NOS = Nature of Science.

> *Very positive. Much more confident in my ability to "tweak" existing units or create my own. Definitely learning by doing works best for me. I would like more materials if they exist on how to develop a unit.*

Compared to the first year participants, those in YEAR2 expressed a deeper understanding of modeling practices and application in their classrooms. One person summed up the experience with, "*Well, in first year I learned what to do. This year I learned how to do it*." Another described how the workshop reinforced existing instructional knowledge, *"Further ingrained my 'modeling mindset' about unit planning.*" Moreover, everyone acknowledged that the additional coverage met expectations. The majority of participants enjoyed the workshop instructors, who were "*very helpful when asked, but hands off so we could 'struggle' through it and come to our own understanding of how to model.*" Everyone confirmed that the degree of guidance/structure met their needs. They stressed the value-added benefit of the Year 2 Workshop in response to a question about how the session went beyond their first year training.

> *I can see into the models I used before knowing why they are built the way they are. It did meet my expectations. I have content I have to cover because of end of course assessments (ACT quality course). I feel more confident that I can make a mini unit that gives students a better opportunity to "uncover" and "test" their model.*

> *It was so easy in year one to focus on the curriculum itself and not so much on the why. This was about the why and the concept of modeling itself. I loved that we spent so much time "on our own," but Rick and Heidi (and Kathy, too) were there to provide support whenever we needed it. Thank you for "forcing" me to take this before I took physics.*

> *Model development. I now understand how to develop materials for the greatest benefit of my kids.*

> *I now understand why work units involve the variety of topics that they do.*

Year 2 workshop participants wanted to build on their progress and emphasized the importance of structured time for collaboration throughout the year. Several indicated that regular "*follow-ups will be great*," which included one who suggested that a "*shorter review session for after we have used modeling for two to three years.*"

> *Single model days beyond the "core" models used in year one. Does not matter if it is during the year or summer.*

> *The more time I spend with other teachers and sharing the better. These should occur during both the school year and subsequent summers.*

> *Third year? More model development? Another topic? How about breaking down models to see what/how or take any topic out of "book" and cover it with a unit (i.e., a topic given to us, not one we picked). Modeling rocks!*

> *Work with instructors and discuss how we are doing in creating our own various models.*

> *Getting together with the teachers that model is so helpful and important. I would love to have regular get-togethers just to keep in touch. In many ways, it is the interactions with other teachers that are the most profound.*

End of Workshop Survey and Post-survey Comparisons

Table 8 presents the results for a set of questions about the impacts on participants' understanding of modeling and student performance. We asked these at the end of the summer and then revisited them on the Post-survey. We asked the first year groups to respond to all the questions except for those directed to YEAR2. Specifically, all the first year participants answered questions about the impacts on their understanding of how to teach physics, physical science, chemistry, and the Ohio Graduation Test (OGT)/Ohio Achievement Assessment (OAA) as well as the performance of their students in these areas. "Not Applicable" was a response option for those who did not teach the listed subject. Appendix 7 presents the breakdown by workshop, as each group verified that the greatest impact occurred in their understanding of their respective subject area. For example, at year-end, all of the PHYS1 said they improved their understanding of how to teach physics and physical science effectively, as did all of the CHEM1 teachers with respect to chemistry.

Table 8: Better Understanding of Modeling/Teaching and Improved Student Performance[1]
—Sorted by High to Low Total Response by Post and Workshop within Category—

	End of Workshop TOTAL *N=54*	Post-survey TOTAL[2] *N=45*
Better Understanding of How to Use Modeling or Teach Discipline Area		
YEAR2: Use modeling in my classes.	100.0	100.0
Teach physical science effectively.	88.9	93.3
Teach chemistry effectively.	82.9	83.3
Teach physics effectively.	80.0	91.7
Teach science concepts on the state assessments (e.g., OGT or OAA)	68.2	63.6
Workshop Helped Me Improve Student Performance		
YEAR2: Improve student performance in my classes.	100.0	100.0
Improve student performance in physical science.	94.3	85.7
Improve student performance in chemistry.	85.3	69.2
Improve student performance in physics.	83.3	81.8
Improve student performance on the state assessments (e.g., OGT or OAA)	68.2	75.8

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.
[2]There were no statistically significant differences between follow-up responses compared to their pre-treatment responses for participants who responded to both surveys as measured by a Chi-square test.

All YEAR2 participants agreed that they improved their understanding of how to use modeling and improved student performance in their classes. At the end of the summer, most of the YEAR1 teachers (80-89%) confirmed that they enhanced their understanding of how to teach their respective subject areas effectively, and the level of agreement increased slightly by year-end (83-93%). With respect to the perceived impact on student performance, there was more variation, and there was a non-significant decrease in agreement by year-end on three of the four areas, with the largest decline occurring in the impact on student performance in chemistry (down to 69% on the Post-survey from 85% on the End of Workshop Survey). However, somewhat more at year-end (up to 76% from 68%) thought the training would enhance student performance on the state assessments.

PRE-SURVEY AND POST-SURVEY COMPARISONS

Appendices 8-13 provide comparisons from the Pre-survey, completed by participants before beginning participation in the Modeling Workshops, and the Post-survey administered at the final follow-up session on March 1, 2014, approximately nine months after the summer workshops. Appendices 8 and 9 provide responses to OBR questions about teachers' preparedness and instructional practices. Appendix 10 presents participants' opinions to IRC questions about science teaching and learning. Appendix 11 covers the extent to which they viewed teachers at their school as being interested in inquiry-based instruction and their principals as being supportive. Appendix 11 also includes questions about participants' service as a resource to other science teachers in their schools and districts. Appendix 12 covers IRC questions that measure respondents' opinions about their preparedness and experience with different teaching approaches, including hands-on and inquiry-based instruction, and their experience working with different student subgroups (e.g., females and students from various cultural backgrounds). Finally, Appendix 13 has teachers' self-reports about the extent to which they use various classroom practices at least weekly.

Changes in Opinions about Teaching Science, Instructional Practices, and Support

All of the participants initially confirmed being excited about teaching science (see Appendix 8) and most expressed interest in networking (96%), believed they had a good understanding of fundamental core content in their discipline (94%), and felt they were effective teachers (89%). By year-end, all felt they had a good understanding of fundamental core content in their discipline and were interested in networking with other professionals; slightly more (93%) also believed they were effective teachers. One was less excited about teaching, resulting in a modest drop in agreement with this item (98%). Teachers experienced significant growth in their understanding of methods necessary to teach science concepts effectively (up to 98% from 85%) and use of effective questioning techniques with students (grew to 96% from 79%). They also had non-significant gains in their understanding of how to assess student learning in multiple ways (moved from 85% to 98%), effective use of technology (increased from 70% to 87%), and relating the (Ohio Revised) Standards in Science (went from 74% to 87%).

In the OBR questions presented in Appendix 9, participants reported significantly increased classroom interaction involving a dialogue among teacher and students (up to 85% from 59%). Although not a significant gain, the extent to which the student role was "to apply inquiry and problem solving skills to discover solutions to problems" grew (to 84% from 64%). They also reported a modest increase in their use of alternative assessment methods (increase to 36% from 21%), which was especially dramatic for the PHYS1 group (rose to 57% from 17%). Somewhat fewer said that "instruction emphasizes broad coverage of information with little depth" (down to 5% from 20%), "Students generally learn concepts and processes through readings, lectures, and demonstrations" (down to 11% from 14%), and "Students generally work independently" (down to 9% from 13%); encouragingly, none of the YEAR2 group reported use of any of these three practices on either survey. However, although the PHYS1 participants became more able "to encourage the efforts and contributions of certain students or groups of students" (report of difficulties went down to 10% from 29%), one in YEAR2 (17%) specified having a problem with this aspect at year-end.

The results from IRC questions presented in Appendix 10 highlight changes in teachers' attitudes that are often associated with inquiry-based learning. The pre/post responses revealed a high level of agreement across all workshops on the following items.

- I enjoy teaching science (96% - 100%).
- The teacher should consistently use activities which require students to do original thinking (92% - 100%).
- Virtually all students can learn to think scientifically (83% - 96%).

As highlighted below, shifts in opinion were evident by year-end. Statistically significant changes consistent with increased use of inquiry-based instruction occurred in these items.

- Organize curriculum around the textbook (overall decreased from 17% to 2%).
- Agreement with "teachers should know the answers to most questions students ask about science" (overall decreased from 50% to 44%).
- Students should never leave science class feeling confused or stuck (PHYS1 decreased from 17% to 0%; overall decreased from 23% to 9%).

While not statistically significant, the shifts in the following questions were in the desired direction. The changes were minimal to moderate in most cases.

- An important issue is not whether students' answers to any science question are correct but whether students can explain their answers (overall increased from 82% to 89%).
- Good science teachers show students the correct way to answer questions they will be tested on. Overall, this decreased (from 32% to 20%) and all groups decreased their level of agreement (PHYS1 from 42% to 29%; CHEM1 from 17% to 6%; YEAR2 from 43% to 33%).

On two items in Appendix 10, the pattern with respect to greater alliance with the principals of inquiry-based instruction was inconsistent. These are described below.

- Learning for all students is enhanced by incorporating the contributions of different cultures. YEAR2 increased (from 57% to 83%); however, CHEM1 decreased (83% to 72%).
- Students learn science best in class with students of similar abilities (overall increased from 43% to 53%). Although the YEAR2 participants encouragingly had less agreement with this concept (went from 57% to 33%), both first year groups increased their agreement with this item.

Finally, there was one statement in this set in which the result went in the opposite direction from that advocated by inquiry-based learning.

- Some people are good at science and some just are not (YEAR 2 increased from 29% to 50%).

The questions in Appendix 11 cover the extent to which teachers felt there was school support and they personally served as a resource to their peers. At the onset, all of the YEAR2 teachers viewed their principals as supportive of innovative practices in science, with CHEM1 (82%) reporting a relatively high level, which were maintained at year-end. The PHYS1 group (58%), however, was more skeptical about their administrators' encouragement, but they reported significantly greater support in the spring (91%).

Initially, all but one YEAR2 participant (86%) described science teachers at their schools as interested in using "inquiry" instruction and active contributors to decisions about the science curriculum; the first year groups had less peer commitment to these two areas (59-63% and 46-68% respectively). By year-end, there was a modest increase in the PHYS1 and CHEM1 colleagues' receptiveness to inquiry-based instruction (67% for both groups). Although PHYS1 (71%) viewed teachers at their schools to be contributing more to decisions about the science curriculum at year end, fewer in CHEM1 (44%) felt this was true of their schools. Most in YEAR2 (86%) and CHEM1 (82%) initially said that colleagues at their school "regularly share ideas and materials related to science instruction," but this was less common at the PHYS1 (71%) workplace initially; during the project year, there appeared to be a modest improvement in the first year groups' experiences with this aspect (PHYS1 to 86% and CHEM1 to 89%).

On the Pre-survey, nearly everyone in the YEAR2 (86%) and CHEM1 (86%) said they served as "a resource for other science teachers" in their schools compared to only half in PHYS1 (50%); by year-end, PHYS1 significantly increased the extent to which they did this, while there was a non-significant decline in the proportion CHEM1 (down to 56%). At the beginning of the training, fewer in all groups served as such a resource at the district level (Overall=23%, PHYS1=13%, CHEM1=23%, and YEAR2=57%); there was noticeable growth in the YEAR2 group (83%) as a district resources during the project year.

<u>Changes in Preparation and Classroom Practices</u>

Appendix 12 shows teacher self-ratings, before taking the workshop and approximately nine months afterwards, about their own preparation to teach in specific ways. The most interesting findings are highlighted below.

Encouragingly, all of the YEAR2 participants (100%) reported on the Pre-survey that they felt prepared to implement inquiry, whereas the other two groups felt less ready (PHYS1=38% and CHEM1=57%). Their respective ratings of their ability to "Phrase questions to encourage more open-ended investigations" were nearly identical (PHYS1=38%, CHEM1=52%, and YEAR2=86%). The entire YEAR2 group was also confident about managing students using hands-on materials, presenting the applications of science concepts, using cooperative learning groups, teaching heterogeneous groups, and using science equipment as an integral part of science. Dr. Harper noted that additional evidence of their increased confidence is demonstrated by participants' desire to take a second discipline specific course rather than the YEAR 2 workshop. She explained, "*Every year, we have teachers that say, "Wow, I teach both chemistry and physics and I took one of those workshops and they did so much to help me with my teaching that I really want to take the other one."* They *"always encourage them to take the advanced workshop before they take the other year one workshop because we really think it is better for their overall development, and they agree with us after they have done it, but it is always a bit of a battle at the beginning. I think that speaks for the fact that it makes them feel more confident."*

With the exception of preparation to present the applications of science concepts on which CHEM1 (70%) and PHYS1 (71%) viewed their abilities as comparable, CHEM1 gave higher ratings to their skills (70-87%) compared to PHYS1 (54-67%) on these items. Such differences may be largely due to the fact the PHYS1 group has the least experienced teachers.

Upon entering the program, most were comfortable with their ability to encourage participation of females in science (79-86%). Although all but one in YEAR2 (86%) felt prepared to encourage the participation of underrepresented minorities and to inform students of career opportunities in science, the first year groups (63-70%) expressed less confidence. Nearly three-quarters of returnees (71%) were at ease teaching students from a variety of cultural backgrounds, while this was the case for only 54-57 percent of those new to the Modeling

Workshops. The greatest variation appeared in groups' readiness to use performance-based assessment in science (Overall=43%, PHYS1=29%, CHEM1=48%, and YEAR2=71%). Few from any group (4-29%) felt competent to use portfolios to assess student progress in science. Items on which there was significant progress by year-end are highlighted below.

- Implementing inquiry or discovery learning (PHYS1 increased from 38% to 100%; CHEM1 increased from 57% to 94%; overall increased from 54% to 98%).

- Managing a class of students who are using hands-on/manipulative materials (PHYS1 increased from 68% to 100%; overall increased from 80% to 98%).

- Phrasing questions to encourage more open-ended investigations (PHYS1 increased from 38% to 91%; CHEM1 increased from 52% to 100%; overall increased from 50% to 96%).

- Presenting the applications of science concepts (PHYS1 increased from 71% to 100%; overall increased from 74% to 96%).

- Using cooperative learning groups (PHYS1 increased from 58% to 91%; overall increased from 70% to 93%).

- Using science equipment as an integral part of science instruction (PHYS1 increased from 54% to 86%; overall increased from 67% to 87%).

- Using performance-based assessment in science (PHYS1 increased from 29% to 71%; overall increased from 43% to 71%).

- Using portfolios to assess student progress in science (CHEM1 increased from 13% to 33%; overall increased from 11% to 31%).

Participants also had additional non-significant improvements in preparation:

- Encouraging participation of underrepresented minorities in science (PHYS1 increased from 63% to 71%; YEAR2 increased from 86% to 100%)

- Teaching groups that are heterogeneous in ability (PHYS1 increased from 54% to 76%; CHEM1 increased from 78% to 83%; overall increased from 70% to 82%).

- Teaching groups from a variety of cultural backgrounds (PHYS1 increased from 54% to 71%; CHEM1 increased from 57% to 83%; YEAR2 increased from 71% to 83%; overall increased from 57% to 78%).
- Informing students of career opportunities in science (CHEM1 increased from 65% to 89%; overall increased from 69% to 78%).

- Encouraging participation of underrepresented minorities in science (PHYS1 increased from 79% to 91%; YEAR2 increased from 86% to 100%).

In general, respondents improved their skills on aspects associated with inquiry-based instruction as intended.

We also asked the teachers to report on the frequency that they typically used various activities in their classrooms in the prior school year. See Appendix 13 for the detailed results. Overall, this year's cohort, particularly those in the second year, initially reported heavier use of more traditional practices with their students than usual. On the Pre-survey, all the YEAR2 and CHEM1 participants reported having students doing small group work weekly, whereas this was the case with 83 percent in PHYS1, which grew to 95 percent by year-end. Everyone in YEAR2 and most in the first year groups (88-91%) confirmed use of teacher-created lessons initially and there were only slight changes on the Post-survey. This cohort's initial use of science equipment (64-71%) was lower than average, but there was an encouraging non-significant improvement (72-100%). Although everyone in YEAR2 said that their students "participate in dialogue with the teacher to develop an idea" each week, less than three-quarters of YEAR2 (71%) participants indicated weekly use of inquiry in their classrooms. While this was higher than reported by CHEM1 (50%) and PHYS1 (29%), the returning group's frequency of inquiry in classes trails that reported by the prior cohort (92%). The extent to which teachers demonstrated a scientific principle ranged from half to more than two-thirds (50-71%) and changed only modestly by the project's conclusion (62-83%)

Below are statistically significant changes in participants' daily/weekly use of several practices associated with inquiry-based instruction with their students occurred by the end of the year.

- Write their reasoning about how to solve a scientific problem (PHYS1 increased from 21% to 91%; CHEM1 increased from 23% to 65%; overall increased from 26% to 80%).
- Learn by inquiry (PHYS1 increased from 29% to 86%; overall increased from 43% to 82%).
- Engage in reflective thinking/writing about what they are learning (PHYS1 increased from 8% to 52%; overall increased from 25% to 57%).
- Make conjectures and explore possible methods to solve a scientific problem (PHYS1 increased from 33% to 86%; overall increased from 40% to 76%).
- Do hands-on/manipulative activities (overall increased from 70% to 89%).
- Participate in dialogue with the teacher to develop an idea (PHYS1 increased from 50% to 91%).
- Listen and take notes during presentation by teachers (PHYS1 decreased from 96% to 48%; overall decreased from 85% to 58%).
- Use worksheets from textbooks (PHYS1 decreased from 46% to 24%; YEAR2 decreased from 14% to 0%; overall decreased from 42% to 18%).

Mixed results:

- Read a science textbook (PHYS1 decreased from 35% to 10%). However, CHEM1 increased (from 5% to 22%).

YEAR-END OPINIONS ABOUT THE MODELING WORKSHOPS AND THEIR IMPACTS

Participants in the Modeling Workshops confirmed the impact of the program on their science instruction in their Post-survey responses.

<u>Opinions about Professional Development and Impacts - Open-ended Comments</u>

Participants confirmed the positive impact of the program on their science instruction in their Post-survey responses. In addition to the increased use of Socratic questioning, whiteboards, interactive notebooks, and performance assessments, teachers themselves expressed a greater "*depth of understanding*" and "*higher level of thinking*." One teacher commented that she changed "*everything*," and used the textbook "*very little*."

Below are selected responses from each group to the year-end question, "What kind of changes, if any, did you make in how you teach your science classes as a result of your Modeling Workshop experience this year?"

<u>PHYS1</u>

> *I did a complete makeover of my style to follow a modeling structure.*
>
> *I changed the way I order my units. I place labs and discovery activities first, and then follow with application questions.*
>
> *I found myself, in my AP classes, going concept first, and then words.*
>
> *Much more student-directed discussion, with students developing their own definitions and modifications of their knowledge. More hands-on activity along with more focused and more frequent assessments*

<u>CHEM1</u>

> *I completely changed my approach to teaching. I'm much more student and inquiry focused. I'm all about letting the kids learn through experience, evidence, and discourse as opposed to read and remember.*
>
> *I never use the textbook. Always using whiteboards. Questioning students.*
>
> *I wholly immersed myself in the modeling way of teaching; utilizing the methods, questioning, whiteboard session in my teaching of Chemistry, Physics, and Physical Science.*

<u>YEAR2</u>

> *I am much more comfortable modifying/creating materials for my class now that I understand the process of modeling.*
>
> *I used more inquiry and developed my own models for many units.*
>
> *My questioning techniques and my understanding of modeling has improved.*

Opinions about Professional Development and Impacts - Close-ended Results

The results from the OBR portion of the Post-survey (see Tables 9-11 and Table 14) provide additional evidence of the success of the Physical Science Modeling and Chemistry Workshops.

All confirmed that they learned effective questioning techniques, new instructional approaches, and inquiry-based hands-on activities they could use in their classes (Table 9). Nearly all (98%) verified improved teaching and increased enthusiasm for teaching. Most also said they learned multiple ways to assess student learning (96%). More than four-fifths (82%) felt they learned new content. The opinion about the extent to which they learned to use technology as a result of the professional development was mixed; more of the YEAR2 (83%) and PHYS1 (76%) agreed that they had, while only half (50%) of CHEM1 teachers felt this was the case.

Table 9: OBR Post-survey Questions about the Impact on Participating Teachers[1]

As a result of this professional development…	PHYS1 *N=21*	CHEM1 *N=18*	YEAR2 *N=6*	TOTAL *N=45*
a) I learned about Ohio's College and Career Ready Standards: (Common Core) Standards in Mathematics and/or (Ohio Revised) Standards in Science…	38.1	16.7	40.0	29.5
b) I learned new content (concepts, facts and definitions)…	85.7	77.8	83.3	82.2
c) I learned multiple ways to assess student learning…	95.2	94.4	100.0	95.6
d) I learned effective questioning techniques…	100.0	100.0	100.0	100.0
e) I learned how to use *new* technology in my classroom…	76.2	50.0	83.3	66.7
f) I learned new instructional approaches, methods and teaching strategies…	100.0	100.0	100.0	100.0
g) I learned inquiry-based, hands-on activities to use in my classroom…	100.0	100.0	100.0	100.0
h) Participation in this professional development *improved* my teaching …	100.0	94.4	100.0	97.8
i) Participation in this professional development *increased* my enthusiasm for teaching…	100.0	94.4	100.0	97.8

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.

Consistent with previous years, the question in Table 10 about the extent to which they learned about the (Ohio Revised) Standards in Science garnered the lowest level of agreement in the preceding set of items (30% overall); of note is that more of the YEAR2 (40%) and PHYS1 (38%) groups attested to an impact compared to CHEM1 (17%). On the other hand, most (89%) agreed with a similar question about whether the professional development "was linked to state and national standards (Table 10 on the following page). Furthermore, in Appendix 8, each group (83-91%) indicated that they understood the (Ohio Revised) Standards in Science, so this may be a moot issue.

Questions in Table 10 highlight participants' opinions about the professional development experience. High proportions (94-100% for each group) agreed that the workshops provided ample time to achieve the stated objectives, adequate follow-up, and useful resources and/or materials that would assist their classroom instruction. Everyone in PHYS1 and YEAR2 as well as all but one teacher in CHEM1 (94%) verified that the training was "high quality, sustained and intensive."

Table 10: OBR Post-survey Questions about Professional Development Experience[1]

This professional development…	PHYS1 *N=21*	CHEM1 *N=18*	YEAR2 *N=6*	TOTAL *N=45*
a) …provided ample time to achieve the stated objectives…	95.2	94.4	100.0	95.6
b) …provided adequate follow-up…	100.0	94.4	100.0	97.8
c) …provided useful resources and/or materials to assist with my instruction in the classroom…	95.2	100.0	100.0	97.8
d) …was high quality, sustained and intensive…	100.0	94.4	100.0	97.8
e) …was linked to state and national standards…	90.5	88.9	83.3	88.9

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.

Table 11 presents participants' opinions about the impacts on teachers' professionalism. All said they would recommend the program to other teachers and have shared their knowledge informally with colleagues. Although the majority of the YEAR2 teachers (80%) had formally shared what they learned with their colleagues, only about a third of each the first year groups (PHYS1=29% and CHEM1=31%) had done likewise.

Table 11: OBR Post-survey Questions about the Impact on Teachers' Professionalism[1]

This professional development had the following impacts on me…	PHYS1 *N=21*	CHEM1 *N=18*	YEAR2 *N=6*	TOTAL *N=45*
a) I have maintained contact (or plan to maintain contact) with other participants…	95.2	77.8	100.0	88.9
b) I have maintained contact (or plan to maintain contact) with college/university faculty who provided the professional development…	76.2	70.6	100.0	77.3
c) The program led to the establishment of a professional network among participants…	95.2	81.3	83.3	88.4
d) I have attended a professional association conference…	20.0	11.1	50.0	20.5
e) I have or would recommend this program to other teachers…	100.0	100.0	100.0	100.0
f) I have shared what I learned with colleagues through **informal** interactions…	100.0	100.0	100.0	100.0
g) I have shared what I learned with colleagues through **formal** interactions...	28.6	31.3	80.0	35.7
h) I have maintained contact (or plan to maintain contact) with the teacher leaders who provided the professional development…	80.0	70.6	100.0	79.1

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.

All in YEAR2 and all but one in PHYS1 (95%) had plans to maintain contact with other participants. In contrast, only about four-fifths in CHEM1 (78%) expected to stay in touch. Everyone in YEAR2 also planned to have continuing contact with the university faculty and the teacher leaders, whereas this was less likely for the first year groups—PHYS1 (80% for teacher leaders and 76% for faculty) and CHEM1 (71% for both types of instructional team members). Dr. Clarke noted that, "*Teacher-to-teacher networking is always an important part of the workshop. This year, many teachers expressed an interest in "networking" with me throughout the school year, remaining in touch, discussing chemistry. This has been a rewarding experience.*" Eighty-eight percent overall agreed that the program led to the establishment of a professional network among participants. Dr. Harper outlined how this development was especially fortuitous for those seeking employment.

> *We definitely saw that during the workshop, we had a couple of participants that were looking for jobs. There were a couple of people that were looking to hire. So, there was a lot of networking going on there. As a matter of fact, at least one person got the job that they have now through somebody that they met in the workshop.*

Half of the YEAR2 teachers (50%) said they had attended a professional association conference as a result of their participation in a modeling workshop (Table 11), but fewer in year one (PHYS1=20% and CHEM1=11%) attended such events. Actual participation in conferences is reported in Table 12, which shows that the overall attendance rate was about the same in 2013-2014 (43%) compared to 2012-2013 (46%); of interest is that CHEM1 increased their participation (from 39% to 53%).

Table 12: Participation in Science/Science Teaching Conferences[1]

Pre-survey					
		PHYS1 *N=24*	**CHEM1** *N=23*	**YEAR2** *N=7*	**TOTAL** *N=54*
2012-2013	None	54.2	60.9	57.1	57.4
	1	37.5	30.4	28.6	33.3
	2	8.3	8.7	14.3	9.3
	More than 2	0.0	0.0	0.0	0.0
Post-survey[2]					
		PHYS1 *N=21*	**CHEM1** *N=18*	**YEAR2** *N=6*	**TOTAL** *N=45*
2013-2014	None	61.9	47.1	50.0	54.5
	1	33.3	41.2	16.7	34.1
	2	0.0	11.8	33.3	9.1
	More than 2	4.8	0.0	0.0	2.3

[1]Percentages are based on those with valid response to item.
[2]Statistically significant differences highlighted are between follow-up responses compared to their pre-treatment responses for participants who responded to both surveys.
***Statistically significant difference with p-value < .01.

The IRC surveys also included two additional measures of networking. The first focused on membership in science professional organizations. Table 13 highlights that more than half (52%) of participants were members of a science professional organization at the start of the summer workshops, and this increased significantly to four-fifths (80%) by year-end. On the Post-survey, all of YEAR2 and more than three-quarters of the year one groups (76-77%) were members.

Table 13: Membership in a Science Professional Organization[1]

Member at beginning of 2012-2013 Modeling Workshop	Pre-survey			
	PHYS1 *N=24*	**CHEM1** *N=23*	**YEAR2** *N=7*	**TOTAL** *N=54*
Yes	50.0	47.8	71.4	51.9
No	50.0	52.2	28.6	48.1
Member during 2013-2014 School Year	**Post-survey[2]**			
	PHYS1 *N=21*	**CHEM1** *N=18*	**YEAR2** *N=6*	**TOTAL** *N=45*
Was a member prior to participating in Modeling	42.9	35.3	50.0	40.9
Became a member during a prior Modeling class	0.0	11.8	50.0	11.4
Became a member this year	33.3	29.4	0.0	27.3
Yes	76.2	76.5	100.0	79.5**
No	23.8	23.5	0.0	20.5

[1]Percentages are based on those with valid response to item.
[2]Statistically significant differences highlighted are between follow-up responses compared to their pre-treatment responses for participants who responded to both surveys.
**Statistically significant difference with p-value < .05.

Another measure of involvement in professional activities is the extent to which participants were active in modeling and science listservs (see Appendix 14). As would be expected the YEAR2 group reported the most initial activity—a high 86 percent specified weekly use of a national modeling listserv. The Modeling Workshops most likely contributed to the significant increases to first year groups' awareness and use of such online resources. By year-end, there were significant increases in participation overall in the national (went from 25% to 77%) and other (went from 20% to 64%) modeling listservs. In addition, there was significant growth in teachers' use of science in general listservs (use of national ones went from 27% to 56% and use of other listservs went from 22% to 47%). Although one PHYS1 teacher expressed a preference for an online bulletin board rather than a listserv, a CHEM1 teacher found the listserv as well as the occasional get-togethers to be helpful, "*especially when problem solving with different levels of modeling experience*."

Dr. Harper observed, "*This year, we have seen more activity on the listserv than we have seen in the past.*" She explained how one participant who had become active national through "*national discussions on how to do certain things and looking for resources… but looking at the whole national network of people that he now has access to for ideas on how to implement things."* The individual had already expressed interest in being "*trained to be a workshop leader,"* which was *"the first time"* she recalled *"anybody saying anything like that to me this quickly after they took their first workshop."* She also pointed out that a "*hot*" online discussion topic this year was "*Ohio and the Student Learning Objectives (SLOs)*" that are part of the new Teacher Evaluation System.

> *There has been a fair amount of discussion on the local listserv this year, often driven by questions from some of our newer participants who are also younger teachers about things that they can do or "does anybody know" or "I was thinking about doing this and my administrator said he doesn't think that will work, but I think somebody else probably did that and it was okay." That has been a nice little support network to see develop this year in that particular context.*

All but one of the teacher-instructors (83%) also confirmed their use of a national listserv, including half (50%) who specified weekly activity.

Table 14 presents responses to close-ended questions about the impact on students. All in YEAR2 and the majority of in year one (PHYS1=80% and CHEM1=72%) felt their students were "more attentive, enthusiastic and involved in classroom activities" as a result of the professional development. More than four-fifths of two groups (PHYS1=86% and YEAR2=83%) also confirmed "improvement in the quality of student work," while fewer of the CHEM1 participants (61%) thought this was true of their students. Although two-thirds (67%) of YEAR2 claimed students were participating in science and math activities outside of the classroom to a greater degree, only 38-39 percent in the first year groups confirmed such growth.

Table 14: OBR Post-survey Questions about Impact on Students[1]

This professional development had the following impacts on my students…	PHYS1 *N=21*	CHEM1 *N=18*	YEAR2 *N=6*	TOTAL *N=45*
a) My students are more attentive, enthusiastic and involved in classroom activities…	81.0	72.2	100.0	80.0
b) The quality of student work is noticeably improved…	85.7	61.1	83.3	75.6
c) My students are participating in science and math activities outside of the classroom to a greater degree…	38.1	38.9	66.7	42.2

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.

The PIs relayed their impressions about the impact of the course on students. Dr. Clarke, said, "*Participants became much more willing and confident to implement strategies to promote student-centered learning in their classes."* Dr Harper gave an example of the changes experienced by one teacher.

> *We typically hear "Oh, this has such a huge impact on my teaching" or "I now know a lot better what my students are thinking than what I knew before." That is one of the things we have been hearing a lot. We have one teacher who found that his students, he had always had a good report with his students, but they actually questioned him on some of the things that he was doing with them in the classroom in a way he had not seen them do before. He actually found that he was explaining to the students a little bit more about what these additional benefits were that he expected them to get as a result of being instructed the way that they were.*

She also outlined additional changes in teacher/student interaction.

> *Mostly, we see teachers talk about the fact that they are spending more time getting to know what their students really think and try to help them develop appropriate scientific understanding. Whereas before, they might have assumed that people were learning things or thought they could not help them anymore. They see a lot more student articulation of their ideas and they are changing the way that they incorporate labs into their classes.*

In summary, participants acknowledged numerous impacts from the training on their instruction and correspondingly on their students.

Participants' Recommended Changes to the Workshops and Follow-up Sessions

Participants generally described the Modeling Workshops as a highly successful professional development offering. Few recommended substantive changes to the training. While everyone reported enjoying the workshop overall, participants from each group provided recommendations when asked, "In your opinion, what aspects of this workshop could be improved?" Similarly, they offered additional advice on the Post-survey when asked, "Are there any modifications that you would recommend be made to the follow-up sessions?" Below is a summary of their feedback.

Requested Changes Specific to the Workshops at the End of the Summer

At the conclusion of the summer training, PHYS1 teachers mostly requested more time for practice and feedback on questioning/model techniques. They also made minor critiques of the room, speakers, and participant demographics.

> *Articles were very outdated. Isn't there something more recent? Lunches. I have had enough nitrates to last me for years.*
>
> *More time for questioning and more feedback on the effectiveness of my questions.*
>
> *By week three, we understand the concept of how to do modeling for the students. We need more practice questioning. Less student mode, more teacher questioning in second half of workshop.*
>
> *Structure of whiteboard questioning. Let us register earlier for the modeling website to check out the materials. Help out physics people with chemistry and chemistry for physical science teachers.*
>
> *More written or verbal feedback from the questioning exercises. Also making sure every participant has the chance to question or present in student mode.*
>
> *Guest speakers not a good use of time. More paradigm labs and deployments, less worksheets.*
>
> *Keep participant acceptance to strictly science content teachers.*
>
> *The room needs to be changed. The temperature was freezing. This is ridiculous. I wore two pairs of socks, long underwear and two sweat shirts everyday. A room was available with windows where we could have allowed the heat in! Nothing was done about the temperature after many asked. It would actually save the district money to not treat the room like a refrigerator.*

The chemistry group desired more recent articles and more "dynamic" guest speakers. Some also made requests about the amount of time spent on certain activities.

> *Speakers did not add much valuable information to our growth as teachers.*
>
> *The second speaker's talk, it was disorganized and rushed. The speakers seemed to be "phoning it in" rather than being engaged and actively discussing the ideas.*

A little more time looking at the book and binder content and comparing it to what teachers practicing modeling (our instructors) do, especially where they insert their own spin on the units. More current articles to reflect on. More diversity of topics with articles. Some less academic articles. I feel good about it, but I need to gain a lot more confidence. I will start on that this summer. More time but that would be hard.

I felt that some down time could have been more effective. Sometimes breaks lasted too long to the point that I wanted to get moving.

Any more recent research? How has modeling improved student understanding (data). How has modeling improved teacher prep programs?

Less crappy articles and substitute some worksheet time for a better overall picture of the unit topics and how they fit together throughout the "story."

Less time working on worksheets. More types of assessments and their actual application in the classroom.

YEAR2 had the fewest criticisms, and none described major issues.

Bring in more chemistry research.

Perhaps a little more information and resources about building a modeling unit.

Making sure year two participants are well placed into the workshop. But overall, I had another exciting and amazing year. Thank you.

Guest speakers. Perhaps have speakers with modeling research.

<u>Requested Changes Specific to the Follow-up Sessions at Year-end</u>

Participants generally described the follow-up sessions as successful. A PHYS1 teacher commented that the follow-up sessions were "*fantastic and a highlight of my year!*" A CHEM1 teacher wrote, "*If anything, I would have liked more!*" Only 13 teachers (29%) offered substantive recommendations for modifications to the sessions, and these focused primarily on approach and content. Below are selected responses to the question, "Are there any modifications that you would recommend be made to the follow-up sessions?

<u>PHYS1</u>

Less time questioning each other as though we were "clueless" students and trying to act like clueless students. That got tedious after awhile.

We don't need to spend as much time in student mode. We can go a little faster. We get the cycle as well as we can our first year, but we need to hit the important turns of the units we didn't get to in the summer.

In the first follow up, we spent a lot of the time doing the same things from the workshop, which was boring, redundant, and not very helpful.

I'd like to see more topics introduced during the sessions. I liked how they would introduce a topic, show us the pitfalls and expected student responses, and how to guide them toward the correct questions to learn the topic.

CHEM1

More year two presentations and resources.

Possibly a physical science course.

Would love more "share your modeling activity."

YEAR2

For year two, follow-up number two should be closer to Modelpalooza.

Two rounds of modeling a unit to help refine the technique and approach.

Other Requested Changes or Additions at Year-end

When asked to describe additional activities or supports that would help them continue in their development of modeling, participants offered practical suggestions focused on learning from mentors and more efficient ways to communicate with colleagues. Below are representative comments.

PHYS1

Observation of other more advanced modelers from my district.

I'd like to hear how teachers deal with the huge amount of content while maintaining a modeling approach. What do they speed up? How do they incorporate questioning while lecturing through topics?

Ongoing communication via an online bulletin board rather than a listserv. It's more user-friendly, easier to access specific topics and find old topics.

CHEM1

Encourage experienced teachers to return for another Year 2 session.

A mentor program would be the best thing—an experienced modeler to talk to and share resources with throughout your first year.

More ability to access answer keys and a more complete physical science course.

YEAR2

Follow-up advanced workshops, etc.

A PHYS1 teacher and a CHEM1 teacher both suggested that modeling instruction should be tailored to and used at the middle school and elementary school levels.

PARTICIPANT OPINION ABOUT THE SPEAKERS

Below is detailed feedback from participants about the guest speakers respectively at the summer session and at one of the follow-up sessions. Such guests have generally received mixed reviews. The team took a different approach at year-end by offering a multi-session “Modelpalooza” that was much better received.

Speakers at the Summer Workshops

Two guest speakers presented at the 2013 summer session (Table 15). Doug Vallette was perceived as moderately effective by all groups (55-86%). YEAR2 reported the most interaction with this speaker (83%), while CHEM1 participants had very little interaction (15%). Half (54%) of the group overall viewed Steve Cessna’s presentation as effective, with YEAR2 (86%) giving more favorable ratings compared to the first year participants (PHYS1=33% and CHEM1=65%). In contrast with the other speaker, interaction with Cessna was rather low among each group (25-36%).

Table 15: Workshop Presenter Rated Effective[1]

	PHYS1 *N=24*	CHEM1 *N=23*	YEAR2 *N=7*	TOTAL *N=54*
a) Doug Vallette presentation.	66.7	54.5	85.7	64.2
b) My interaction with Doug Vallette.	50.0	15.4	83.3	40.7
c) Steve Cessna presentation.	33.3	65.2	85.7	53.7
d) My interaction with Steve Cessna.	33.3	35.7	25.0	33.3

[1]Percent of participants who indicated that the speaker was "Very Effective" or "Somewhat Effective." Percentages are based on those with valid response to item.

When asked about guest speakers, most responded with neutral or positive feedback. Overall, participants either had no comments to share or gave mixed reviews, with some saying “*they were fine*.” Some preferred the first speaker to the second, which may indicate that speaker topics need to be better tailored to the audience. One person requested a speaker specifically, “*Can we get Diane Boyce herself*?” Finally, several reported that the room was not appropriate for speakers, making them difficult to hear.

> *Doug Vallette was very dynamic and had an interesting way of sharing his data.*
>
> *I liked Doug’s talk but found Steve’s to be vague. I think NOS is critical but his talk was lacking relevance.*
>
> *Since I am not a physics person, Doug’s presentation was not as useful. Really liked Steve’s NOS presentation and test.*
>
> *I did not find it useful because I did not understand the point.*
>
> *I thought both were interesting. I would have liked to see almost a panel discussion to see more ideas.*
>
> *I would have rather been working on an energy lab on questioning and white-boarding than listening to Steve Cessna.*

Programs were well put together. Very enjoyable. Do not schedule them for after lunch.

Both presentations had glitches, but the interaction/discussions were fantastic.

First speaker poor acoustics. Second speaker scattered thoughts.

Acoustics and AV equipment issues hampered their effectiveness.

The mixed opinion is at least partly likely due to the fact that the audience is very diverse with respect to experience with modeling and discipline areas represented.

<u>Speakers at Follow-up Sessions</u>

This year, the Project Director explained the plan to take "*a slightly different format than in past years*." Although as in prior follow-up sessions they expected "to have our advanced participants present their units to the other folks," four of the group had "*made other plans*" such that they ended up including presentations from instructional team members as well. Participants had a choice of the presentations listed in Table 16, and they were to "*choose one option*" from "*each set of sessions*."

The 20 who were in attendance at the March 1 Follow-up Session rated nearly all of the speakers in Modelpalooza as effective. The only Modelpalooza session on which all of the participants did not rate it as at least "somewhat effective" was "Circuits" in Session 3 (it received a 78% rating from PHYS1, resulting in 87% overall); this session also had the greatest number of attendees (N=15).

Table 16: Modelpalooza Presenters Rated Effective[1]

	PHYS1 *N=11*	CHEM1 *N=6*	YEAR2 *N=3*	TOTAL *N=20*
a) **Session 1** - Standards-based grading - Brian Carpenter	100.0	100.0	100.0	100.0
b) **Session 1** - Adjusting Modeling for Different Student Abilities - Joe Griffith and Cathy Mehl	100.0	100.0	100.0	100.0
c) **Session 1** - CASTLE Electricity - Holly McTernan	100.0	100.0	NA	100.0
d) **Session 2** - PhET Simulations in the Chemistry Classroom - Ted Clark	100.0	100.0	100.0	100.0
e) **Session 2** - Expert-Novice Differences in Scientific Problem Solving - Kathy Harper	100.0	100.0	100.0	100.0
f) **Session 3** - Equilibrium - Liz Emmer	100.0	100.0	100.0	100.0
g) **Session 3** - Circuits (physical science level) - Lori Bostic, Jon Richardson, and Marie Wenzke	77.8	100.0	100.0	86.7
h) **Session 4** - Acids and Bases - Stacey Raymond	100.0	100.0	NA	100.0
i) **Session 4** - Cheers to Rates of Change - Doug Forrest and Mary Whalen	100.0	100.0	100.0	100.0

[1]Percent of participants who indicated that the speaker was "Very Effective" or "Somewhat Effective." Percentages are based on those with valid response to item. The number of ratings for each session ranged from three (Equilibrium and Cheers to Rates of Change) to 15 (Circuits).

Participants praised the multi-session approach led by experienced modelers.

Brian's session was very informative.

Great! I would happily attend again next year.

Just wish it lasted longer.

Nice change from the summer format.

Based on the feedback, Modelpalooza was successful and a better fit with teachers' needs compared to most invited speakers.

OPINIONS OF THE TEACHER-INSTRUCTORS

IRC administered a brief online survey to the six teacher-instructors who were directly involved in instructing a Modeling Workshop and all responded. The questions focused on the impacts that the instructional team members attributed to the program.

Table 17 presents the number of teachers from the teacher-instructors' schools and districts who had participated in a Modeling Workshop. Half (50%) of the Ohio-based teacher-instructors had more than two teachers from their school/district who had completed a modeling session, ranging from 3-4 teachers to more than six.

Table 17: Teacher-Instructor Survey – Number of Teachers from School and District

Number of Teachers	Teacher-Instructors *N=6*			
	From School		From District	
	N	%	N	%
1-2	3	50.0	3	50.0
3-4	1	16.7	1	16.7
5-6	1	16.7	1	16.7
More than 6	1	16.7	1	16.7

[1]Percentages are based on those with valid response to item.

Teacher-instructors spoke about the impact on teachers, especially new ones, at their schools.

Other chemistry teachers are interested in modeling and are asking for help in learning how to teach this way. A modeling presentation was part of the in-service in November.

Having teachers here using modeling has caused others to take notice of the techniques and success. Even those science teachers that have not adopted modeling have moved their classes toward an inquiry style of classroom.

Our two new teachers, who enrolled in modeling this past summer, have been able to transition more easily and have a big impact already in our department. I think modeling has really helped student interest in science in our school and also helped improve the rigor of our intro courses.

One teacher who took the workshop evolved from an unserious teacher to a serious and motivated one.

One teacher-instructor, however, explained that additional participation from his school was not feasible, "*I am the only Chemistry/Physics teacher in my district--(a small district). The other science teachers have either coaching duties during the summer or summer employment that precludes them from attending the Modeling Workshop*."

The teacher-instructors confirmed their agreement with all the close-ended opinion questions. They enjoyed working as a Modeling Workshop instructor and verified that modeling positively impacted participating teachers/faculty at their schools. They also confirmed that modeling had a positive impact on the students at their schools (see Table 18 and Appendix 15).

Table 18: Teacher-Instructor Survey – Opinions about Modeling Workshops —Questions Ordered by Percent and Mean—

	Teacher-Instructors N=6			
	Agree[1]			
	N	%	Mean[2]	S.D.
Modeling has positively impacted students at my school.	6	100.0	1.00	.000
Working as an instructor had additional positive impacts on my own teaching.	6	100.0	1.00	.000
My collegial network has grown as a result of working with the Modeling Workshops.	6	100.0	1.00	.000
Modeling has positively impacted participating teachers/faculty at my school.	5	100.0	1.83	2.041
I enjoyed working as a Modeling Workshop instructor.	5	100.0	2.00	2.000
As a result of the Modeling Workshops, science teachers/faculty at my school are collaborating to a greater extent.	5	100.0	2.33	1.862

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.
[2]Lower mean score indicates a higher level of agreement, as "Strongly Agree" was represented by the value of 1 and "Strongly Disagree" had a value of 5.

Moreover, everyone agreed that working as an instructor had additional positive impacts on their own teaching, including contributing to their collegial network. Finally, they attributed greater collaboration among science teachers/faculty at their schools to the training.

Respondents spoke highly of the Modeling Workshops. One simply said, "*It's awesome*." Others described specific personal impacts.

> *In my 23 years of teaching and engaging professional development for teachers at a host of institutional sites and theoretical emphases, the Modeling Workshop is the best, most useful in direct application to the classroom. The encouragement and affective support for teachers, many of whom come with rather frustrating classroom experiences makes a profound difference. A learning community is built and supported (I still have frequent contact with several teachers from the original workshop I attended). The commitment of Drs. Harper and Clark, their patience to interact with participants, to clarify difficult concepts and offer encouragement and advice is of such high value. There is no professional development experience that I would endorse with as much enthusiasm as the Modeling Workshop.*

When I took the Modeling Workshops as a student, they were the single best professional development that I have ever done. As an instructor, I really want to make sure that my participants have that same experience.

The first year Modeling Workshop made me reevaluate and change my complete philosophy of teaching. The second year modeling really helped me fine tune. Teaching and interacting with OSU professors collaboratively has really helped to push me further and think more about my teaching. It was almost as impactful as the initial modeling course.

It has become part of my instruction, now at the college level. A modeling activity I developed for my college class (equilibrium) made a huge impact on the class, and they asked for more.

We also inquired about the number of requests received from participants (Table 19). All teacher-instructors had received requests from current participants, with two-thirds (67%) occurring less than monthly. Only three responded to the question about contact from former participants and only one (17%) reported any contact, and that was less than monthly.

Table 19: Teacher-Instructor Survey – Requests from Current and Former Participants

	Teacher-Instructors *N=6*			
	Current		Former	
Frequency of Requests from Participants	**N**	**%**	**N**	**%**
At least once a week	0	0.0	0	0.0
Approximately once every two weeks	1	16.7	0	0.0
At least once a month	1	16.7	0	0.0
Less often than monthly	4	66.7	1	16.7
Never	0	0.0	2	33.3
No response	0	0.0	3	50.0

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement.

With respect to assisting participants, one gave the following example of an especially successful tool.

I share a DVD containing sets of video podcasts that I have made for chemistry students with those teachers who take the Year 1 Chemistry and Year 2 Advanced Modeling Workshop. I have received a fair amount of positive feedback as well as requests for help on how to teach the difficult AP Chemistry topics.

Another added, "*I'd love to see a more permanent means of communicating with participants*."

Finally, a teacher-leader spoke about the need to address the statewide demand for modeling, "*Teachers in the northern part of the state are reluctant to travel to Columbus for three weeks; I think that a workshop in the northern part of the state would be well received*."

Conclusions and Next Steps

The 2013-14 Modeling Workshop participants (especially the PHYS1 group) included more teachers just starting out their careers than usual. Nevertheless, there was still a nice mix of veteran and novice teachers. While the surveys revealed that participants had a high level of responsibility for the type of courses that are the focus for Modeling Workshops, YEAR1 teachers had less preparation with inquiry-based practices (Appendix 12). They also revealed less frequent use of such approaches within their classrooms (Appendix 13) compared to YEAR2 teachers. In addition, except for the YEAR2 group, which probably reflects the impact of their prior participation, another significant impact was teachers' increased use of online networking.

By summer-end, all 54 participants confirmed that they gained skills in how to use inquiry in the classroom and that the workshop was a successful professional development overall. Everyone also agreed that modeling inquiry was a worthwhile and a valuable practice. High proportions reported improvement of their content knowledge, attitude toward science instruction, and ability to be effective teachers as a result of the workshops. YEAR1 participants responded positively to the training, emphasizing the value of collaborative discussions and networking with other science teachers. They appreciated the introduction to new classroom practices. In contrast, since the YEAR2 teachers possessed a greater understanding of modeling practices, this group benefited from the deeper scope of their workshop activities. In addition, everyone in the second year group viewed the amount of guidance/structure as appropriate. The vast majority of participants felt that their questions and concerns were adequately addressed and reported that they would recommend the Modeling Workshops to their peers. Encouragingly, most thought that their experience would help them improve student performance, and at year-end, they confirmed evidence of such changes. Dr. Harper summarized the 2013-14 cohort's progress, "*We felt really good at the end of the summer. We felt like it was a group that really bought into it for the most part. They were very enthusiastic. They all talked very much about things that they wanted to do in the future and continuing their development in this area."*

At the end of the summer training, everyone verified enjoying the workshop overall. For example one PHYS1 participant concluded, "*Probably the best professional development I have ever attended."* At year-end, all participants said that they had or would recommend the program to other teachers and had informally shared what they learned with other their colleagues. Nevertheless, there were some criticisms about the workshops from each group. PHYS1 teachers requested more time for practice and feedback on questioning/model techniques, "*More written or verbal feedback from the questioning exercises.*" The chemistry group desired more recent articles and more "*dynamic*" guest speakers. One participant noted that the time in the chemistry session could have been used more effectively. Finally, unlike the preceding cohort, YEAR2 teachers had the fewest criticisms. Two wanted more specific research topics covered ("*chemistry research" and "modeling research"*).

By year-end, participants attested to numerous significant impacts in their content knowledge and comfort with inquiry, hands-on activities, science equipment, and alternative assessment with students. The PIs reflected on the impacts on teachers' content knowledge and application of what they learned. Dr. Clark summarized:

> *The impact on the participating teachers was significant in terms of both content understanding and pedagogy. I had the pleasure of observing and participating in thoughtful discussions in all sections of the workshop and came away with the impression that participants were benefiting in ways they had not anticipated. For example, many participants anticipated learning new "classroom techniques" (typical of other professional development programs), but they did not foresee how their conceptual framework for understanding science would be improved.*

The Modeling Workshops strengthens teachers' "*conceptual framework*" and thereby provides an important foundation to the inquiry-based pedagogical changes that the team models.

Dr. Harper shared specific examples of participants' increased understanding, "*We did have two special education people, inclusion teachers, take the workshop, and they said, 'Oh wow, yeah, I learned more. I know more science knowledge and I feel like I can do a better job in the science classroom.'"* She added, "*We have an elementary school teacher that had taken the chemistry workshop a number of years ago that came back and took physics this year. She was specifically looking for more physics content."* However, she noted that this individual was eager to "*get together a group of elementary school teachers to come back and do the advanced workshop with her because she would really like to take this new knowledge and work on developing some more appropriate curriculum for the elementary school based on these principles. She feels like she has learned a lot and wants to apply to the next level. She just needs to get a team around her to help her do that."*

With respect to the follow-up sessions, Modelpalooza was especially well received, as the approach satisfied participants' ongoing request for speakers who are experienced teachers who had used modeling with students and could provide practical advice. They would like more activities like this that would give more opportunities for sharing by YEAR2. Respondents also recommended reducing the amount of time spent in "*student mode*" and urged that the instructional team go beyond what had already been covered during the summer. Although no one complained about the coverage of the standards, based on the lower than average ratings on the standards-specific questions, the team might want to review to ensure that the course is appropriately addressing the (Ohio Revised) Standards in Science.

At year-end, the PIs talked about some possible changes going into the upcoming 2014-15 and future workshops. As part of expanding the instructional team's capacity and potential for sustainability, they are also adding team members in chemistry and physics from OSU. In addition, for the first time, they are bringing in two former participants who will be "*leaders in training"* that will help them ensure that they have a sufficient number of teacher-leaders. They also have a former participant serving as a "*leader in training"* at a Pennsylvania workshop.

Dr. Clarke discussed plans to increase the focus on addressing participants' misconceptions. He explained, *"High school teachers often hold profound misconceptions in terms of energy and how it relates to chemical reactions. Participants in this workshop were no exception. However, their understanding in the area dramatically improved following activities and discussions in the workshop."* He concluded, *"In upcoming workshops I plan to give more attention (at the end of the workshop) to how the participant's understanding was transformed and how this may provide insights into promoting conceptual change in their students."*

Possible future additions included adding a "*short workshop for incorporating engineering principles into teaching science."* Dr. Harper added, "*There is interest in this nationally, not just at the state level," as* "*chemistry teachers are the ones that are being asked to teach engineering when a district decides that they need to start addressing it."* This summer, she was scheduled to lead a focus group on this topic at the American Modeling Teachers Association (AMTA) annual meeting the end of June. She was expecting "*our more experienced participants and workshop leaders"* to attend the conference. In addition, she is working with another group on *"how Ohio's science standards and the next generation science standards fit together."*

In closing, as with prior cohorts, there continues to be a high demand for ongoing professional development on modeling and continued contact. Teachers spoke enthusiastically about the experience and were eager to refine their emerging skills with the approach. YEAR2 participants especially emphasized the importance of structured time for collaboration throughout the year.

APPENDICES

Appendix 1
Physical Science and Chemistry Modeling Workshops
Description of Teachers[1]

	PHYS1 *N=24*	CHEM1 *N=23*	YEAR2 *N=7*	TOTAL *N=54*
Gender				
Female	41.7	65.2	42.9	51.9
Male	58.3	34.8	57.1	48.1
Race/Ethnicity				
White, non-Hispanic	100.0	100.0	100.0	100.0
Age				
Under 30	37.5	21.7	14.3	27.8
31-40	25.0	47.8	0.0	31.5
41-50	25.0	13.0	57.1	24.1
51-60	12.5	17.4	28.6	16.7
Position				
Teacher	95.8	87.0	100.0	92.6
Special Education, Resource or Inclusion Teacher	4.2	4.3	0.0	3.7
Other (Not Specified)	0.0	8.7	0.0	3.7
Grade Level Taught				
Primary (K-3)	4.2	0.0	0.0	1.9
Middle (7-8)	8.3	4.3	0.0	5.6
High School (9-12)	87.5	95.7	100.0	92.6
School Type				
Public School District	87.5	91.3	85.7	88.9
Community School, Charter School or Nonpublic School	12.5	8.7	14.3	11.1
Classroom Type				
Math only	4.2	0.0	0.0	1.9
Science only	95.8	95.7	85.7	94.4
Math and Science	0.0	0.0	14.3	1.9

[1]Percentages are based on those with valid response to item.

Appendix 1
Physical Science and Chemistry Modeling Workshops
Description of Teachers[1]
—Continued—

	PHYS1 *N=24*	CHEM1 *N=23*	YEAR2 *N=7*	TOTAL *N=54*
Years of Teaching Experience				
Less than 1 year	8.3	13.0	0.0	9.3
1-2 years	16.7	13.0	0.0	13.0
3-5 years	29.2	8.7	28.6	20.4
6-10 years	16.7	21.7	28.6	20.4
11-19 years	16.7	34.8	28.6	25.9
20 years or more	12.5	8.7	14.3	11.1
Years Taught at Current School				
Less than 1 year	20.8	27.3	0.0	20.8
1-2 years	20.8	31.8	14.3	24.5
3-5 years	25.0	4.5	42.9	18.9
6-10 years	16.7	18.2	14.3	17.0
11-19 years	16.7	13.6	14.3	15.1
20 years or more	0.0	4.5	14.3	3.8
Highest Degree Received				
Bachelor's Degree	41.7	8.7	42.9	27.8
Master's Degree	54.2	87.0	42.9	66.7
Doctorate	4.2	4.3	14.3	5.6
Degree Areas[2]				
Science Education	62.5	52.2	71.4	59.3
Earth Science or Geology	8.3	13.0	14.3	11.1
Mathematics Education	0.0	0.0	0.0	0.0
Biology or Life Science	12.5	47.8	14.3	27.8
Physics or Physical science	25.0	26.1	14.3	24.1
Mathematics	0.0	0.0	14.3	1.9
Chemistry or Biochemistry	8.3	65.2	71.4	40.7
Environmental Science	0.0	0.0	0.0	0.0
Engineering	4.2	4.3	0.0	3.7
Other	12.5	26.1	14.3	18.5

[1]Percentages are based on those with valid response to item.
[2]Total can add to more than 100 percent, as respondent could obtain degree in more than one area.

Appendix 2
Physical Science and Chemistry Modeling Workshops
Sections of Physics, Physical Science, and Chemistry[1]
—Percentage Taught in 2012-2013 and 2013-2014—

	TOTAL *Pre=54, Post=45*					
	Physics		Physical Science		Chemistry	
	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014
None	61.1	64.4	44.4	44.4	48.1	53.3
1-2	25.9	26.7	29.6	24.4	20.4	15.6
3-4	9.3	6.7	16.7	22.2	25.9	22.2
5-6	3.7	2.2	9.3	8.9	5.6	8.9
	PHYS1 *Pre=24, Post=21*					
	Physics		Physical Science		Chemistry	
	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014
None	41.7	47.6	41.7	47.6	66.7	66.7
1-2	33.3	33.3	20.8	19.0	16.7	14.3
3-4	16.7	14.3	29.2	23.8	16.7	14.3
5-6	8.3	4.8	8.3	9.5	0.0	4.8
	CHEM1 *Pre=23, Post=18*					
	Physics		Physical Science		Chemistry	
	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014
None	87.0	88.9	52.2	38.9	34.8	50.0
1-2	13.0	11.1	30.4	27.8	26.1	22.2
3-4	0.0	0.0	4.3	22.2	30.4	16.7
5-6	0.0	0.0	13.0	11.1	8.7	11.1
	YEAR2 *Pre=7, Post=6*					
	Physics		Physical Science		Chemistry	
	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014
None	42.9	50.0	28.6	50.0	28.6	16.7
1-2	42.9	50.0	57.1	33.3	14.3	66.7
3-4	14.3	0.0	14.3	16.7	42.9	16.7
5-6	0.0	0.0	0.0	0.0	14.3	0.0

[1]Nonrespondents to each item were coded to having answer of “None.”

Appendix 3A
Physical Science and Chemistry Modeling Workshops
Districts and Private Schools Represented

District Count	District/Charter/Private/Other	N	%
1	Amherst Local Schools	1	1.9
2	Beechwood City Schools	1	1.9
3	Bexley City Schools	1	1.9
4	Big Walnut Local Schools	1	1.9
5	Canal Winchester Local Schools	1	1.9
6	Columbus City Schools	10	18.5
7	Dublin City Schools	2	3.7
8	Fayette Local Schools	1	1.9
9	Gallia County Local Schools	1	1.9
10	Indian Lake Local Schools	1	1.9
11	Johnston Monroe Local Schools	1	1.9
12	Kent City Schools	1	1.9
13	Logan Elm Local School District	1	1.9
14	Mechanicsburg Exempted Village	1	1.9
15	New Albany Plain Local	2	3.7
16	Oak Hills Local Schools	1	1.9
17	Olentangy Local Schools	2	3.7
18	Pickerington Local School District	1	1.9
19	Riverside Local Schools	2	3.7
20	South-Western City Schools	3	5.6
21	Southwest Licking Local Schools	2	3.7
22	Sycamore Community Schools	1	1.9
23	Tiffin City Schools	1	1.9
24	Tuslaw Local School District	1	1.9
25	Westerville City Schools	1	1.9
26	Worthington City Schools	2	3.7
	Serves multiple districts - Metro Early High School	1	1.9
	Charter - Horizon Science Academy	2	3.7
	Private - Laurel School	2	3.7
	Private - Columbus Torah Academy	1	1.9
	Private - Independent Catholic	1	1.9
	Other - Graduate Student	1	1.9
	Other - Looking for a Job	1	1.9
	Other - OTH-Pre-service Teacher	1	1.9
	Other - Substitute Teacher	1	1.9
	TOTAL	**54**	**100.0**

Appendix 3B
Physical Science and Chemistry Modeling Workshops
Description of School Districts and Schools[1]

Public School Districts Represented	County	School District Effectiveness Rating	School where Participants Teach	School Effectiveness Rating	Number of Participants
Amherst Local Schools	Lorain	Excellent	Marion L Steele HS	Excellent	1
Beechwood City Schools	Cuyahoga	Excellent	Beachwood HS	Excellent	1
Bexley City Schools	Franklin	Excellent with Distinction	Bexley HS	Excellent	1
Big Walnut Local Schools	Delaware	Excellent with Distinction	General Rosecrans	Excellent with Distinction	1
Canal Winchester Local Schools	Franklin	Excellent	Canal Winchester HS	Excellent	1
Columbus City Schools	Franklin	Continuous Improvement	Briggs HS	Continuous Improvement	3
Columbus City Schools	Franklin	Continuous Improvement	Columbus Alternative HS	Excellent	2
Columbus City Schools	Franklin	Continuous Improvement	Columbus Downtown HS	Continuous Improvement	1
Columbus City Schools	Franklin	Continuous Improvement	Columbus Global Academy	Continuous Improvement	1
Columbus City Schools	Franklin	Continuous Improvement	South HS	Academic Watch	1
Columbus City Schools	Franklin	Continuous Improvement	Walnut Ridge HS	Continuous Improvement	1
Columbus City Schools	Franklin	Continuous Improvement	West HS	Continuous Improvement	1
Dublin City Schools	Franklin	Excellent with Distinction	Dublin Coffman HS	Excellent	1
Dublin City Schools	Franklin	Excellent with Distinction	Dublin Jerome HS	Excellent	1
Fayette Local Schools	Fulton	Excellent	Fayette HS	Excellent	1
Gallia County Local Schools	Gallia	Effective	River Valley HS	Excellent	1
Indian Lake Local Schools	Logan	Excellent with Distinction	Indian Lake HS	Excellent	1
Johnston Monroe Local Schools	Licking	Excellent with Distinction	Johnstown HS	Excellent	1
Kent City Schools	Portage	Excellent with Distinction	Theodore Roosevelt HS	Excellent	1
Logan Elm Local School District	Pickaway	Excellent with Distinction	Logan Elm HS	Excellent	1
Mechanicsburg Exempted Village	Champaign	Excellent	Mechanicsburg HS	Excellent with Distinction	1
New Albany Plain Local	Franklin	Excellent with Distinction	New Albany HS	Excellent	2
Oak Hills Local Schools	Hamilton	Excellent	Oak Hills HS	Excellent	1
Olentangy Local Schools	Delaware	Excellent with Distinction	Olentangy HS	Excellent	1
Olentangy Local Schools	Delaware	Excellent with Distinction	Orange HS	Excellent	1
Pickerington Local School District	Fairfield	Excellent with Distinction	Lakeview JHS	Excellent	1
Riverside Local Schools	Lake	Excellent with Distinction	Riverside JR/SR HS	Excellent	2
					Continued on following page

School and district ratings are from the Ohio Department of Education 2010-2011 report cards http://ilrc.ode.state.oh.us/default.asp.

Appendix 3B
Physical Science and Chemistry Modeling Workshops
Description of School Districts and Schools[1]
—Continued—

Public School Districts Represented	County	School District Effectiveness Rating	School where Participants Teach	School Effectiveness Rating	Number of Participants
Southwest Licking Local Schools	Licking	Excellent with Distinction	Watkins Memorial HS	Excellent	2
South-Western City Schools	Franklin	Excellent	Franklin Heights HS	Continuous Improvement	1
South-Western City Schools	Franklin	Excellent	South-Western Career Academy	Not available	2
Sycamore Community Schools	Hamilton	Excellent with Distinction	Sycamore HS	Excellent	1
Tiffin City Schools	Seneca	Excellent	Tiffin Columbian HS	Excellent	1
Tuslaw Local School District	Stark	Excellent	Tuslaw HS	Excellent	1
Westerville City Schools	Franklin	Excellent with Distinction	Westerville South	Excellent	1
Worthington City Schools	Franklin	Excellent with Distinction	Worthington Kilbourne HS	Excellent	2
Not employed by public school at beginning of summer workshop but previous experience and plans to work in public schools.					4
				TOTAL	**47**

Community Schools, Charter Schools, Nonpublic Schools or Other Institutions Represented	Diocese [if applicable]	County	School Local Report Card Designation/ Rating (from ODE) [if applicable]	Number of Participants
Horizon Science Academy - Columbus		Franklin	Effective	2
The Metro School		Franklin	Excellent	1
Laurel School		Cuyahoga		1
The Wellington School		Franklin		1
Columbus Torah Academy		Franklin		1
St. Edward	Independent Catholic	Cuyahoga		1
			TOTAL	**7**

TOTAL NUMBER OF PARTICIPANTS	**54**

School and district ratings are from the Ohio Department of Education 2010-2011 report cards http://ilrc.ode.state.oh.us/default.asp.

Appendix 4
Physical Science and Chemistry Modeling Workshops
Opinions about Workshops and Initial Impacts[1]
—Questions Ordered by Appearance on Survey—

		PHYS1 *N=24*	CHEM1 *N=23*	YEAR2 *N=7*	TOTAL *N=54*
a)	Adequate time was allowed for participants to reflect on and relate material to their experience and needs.	75.0	100.0	100.0	88.9
b)	Participants' questions and concerns were addressed effectively.	95.8	100.0	100.0	98.1
c)	I improved my content knowledge.	95.8	95.7	100.0	96.3
d)	I gained skills in complex thinking and reasoning.	83.3	91.3	100.0	88.9
e)	I gained skills in how to use inquiry in my classroom.	100.0	100.0	100.0	100.0
f)	This workshop contributed positively to my attitude about science.	95.8	95.7	100.0	96.3
g)	This workshop enhanced my confidence in teaching science.	70.8	95.7	100.0	85.2
h)	I increased my ability to see connections among science concepts.	91.3	95.7	100.0	94.3
i)	I increased my ability to see connections between science and mathematics.	87.5	87.0	85.7	87.0
j)	I have a better understanding of how to apply the science standards.	45.8	73.9	85.7	63.0
k)	Overall, this workshop was a successful professional development experience.	100.0	100.0	100.0	100.0
l)	I would recommend this workshop to other teachers.	95.8	100.0	100.0	98.1
m)	I feel prepared to provide professional development on the covered workshop-specific activities for teachers in my building.	45.8	69.6	100.0	63.0
n)	I feel better prepared to encourage science activities in my building.	79.2	91.3	100.0	87.0
o)	This workshop has helped me become a more effective teacher.	87.5	100.0	100.0	94.4
p)	Year 2 Workshop Only: The amount of guidance/structure was appropriate.	NA	NA	100.0	100.0

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.

Appendix 5
Physical Science and Chemistry Modeling Workshops
Increased Understanding from the Workshops[1]
—Questions Ordered by Appearance on Survey—

		PHYS1 *N=24*	CHEM1 *N=23*	YEAR2 *N=7*	TOTAL *N=54*
a)	Effective applications of inquiry-based instruction in classrooms.	100.0	100.0	100.0	100.0
b)	Strategies that can be used to improve students' science performance.	100.0	100.0	100.0	100.0
c)	Application of Ohio's science standards.	33.3	65.2	100.0	55.6
d)	The technology required for effective instruction in science.	87.5	73.9	100.0	83.3
e)	Effective uses of alternative assessment.	87.5	91.3	100.0	90.7
f)	Strategies for facilitating change in science instruction in my building.	87.5	60.9	100.0	77.8
g)	Awareness of current research in science education.	100.0	91.3	85.7	94.4
h)	Ability to utilize current research in science education in my classes.	79.2	78.3	85.7	79.6

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.

Appendix 6
Physical Science and Chemistry Modeling Workshops
Workshop Activities Rated Worthwhile[1]
—Questions Ordered by Appearance on Survey—

		PHYS1 *N=24*	CHEM1 *N=23*	YEAR2 *N=7*	TOTAL *N=54*
a)	Overall interaction with the other participants.	100.0	100.0	100.0	100.0
b)	Overall interaction with workshop facilitators.	100.0	100.0	100.0	100.0
c)	Modeling of inquiry.	100.0	100.0	100.0	100.0
d)	Examples on how to apply district standards.	42.1	57.1	71.4	53.2
e)	Introduction to various sources of curriculum materials (books, websites, etc.).	100.0	90.9	100.0	96.2
f)	Reading assignments (research articles).	70.8	87.0	100.0	81.5
g)	Discussion of reading assignments.	75.0	95.7	100.0	87.0
h)	Purchase of educational/classroom materials.	87.5	95.5	100.0	92.5
i)	Year 2 Workshop Only: Large blocks of "free" time spent working on curriculum.	NA	NA	100.0	100.0

[1]Percent of participants who rated each aspect as "Very Worthwhile" or "Somewhat Worthwhile." Percentages are based on those with valid response to item.

Appendix 7
Physical Science and Chemistry Modeling Workshops
Better Understanding of Modeling/Teaching and Improved Student Performance[1]
—Full Results—

	End of Workshop Survey				Post-survey[2]			
	PHYS1	CHEM1	YEAR2	TOTAL	PHYS1	CHEM1	YEAR2	TOTAL
	N=24	*N=23*	*N=7*	*N=54*	*N=21*	*N=18*	*N=6*	*N=45*
Year 1 Participants Only								
a) I have a better understanding of how to teach physics effectively.	95.5	37.5	NA	80.0	100.0	50.0	NA	91.7
b) I have a better understanding of how to teach physical science effectively.	81.0	100.0	NA	88.9	100.0	81.8	NA	93.3
c) I have a better understanding of how to teach chemistry effectively.	50.0	100.0	NA	82.9	64.3	100.0	NA	83.3
d) This workshop has helped me improve student performance in physics.	95.5	50.0	NA	83.3	94.4	25.0	NA	81.8
e) This workshop has helped me improve student performance in physical science.	90.0	100.0	NA	94.3	88.2	81.8	NA	85.7
f) This workshop has helped me improve student performance in chemistry.	58.3	100.0	NA	85.3	58.3	78.6	NA	69.2
g) I have a better understanding of how to teach science concepts on the state assessments (e.g., OGT or OAA).	63.6	72.7	NA	68.2	70.6	56.3	NA	63.6
h) This workshop is helping my students to be better prepared for the science portion of the state assessments (e.g., OGT or OAA).	63.6	72.7	NA	68.2	77.8	73.3	NA	75.8
Year 2 Participants Only								
i) I have a better understanding of how to use modeling in my classes.	NA	NA	100.0	100.0	NA	NA	100.0	100.0
j) This workshop will help me improve student performance in my classes.	NA	NA	100.0	100.0	NA	NA	100.0	100.0

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.
[2]There were no statistically significant differences between follow-up responses compared to their pre-treatment responses for participants who responded to both surveys as measured by a Chi-square test.

Appendix 8

Physical Science and Chemistry Modeling Workshops

Teacher Opinions and Attitudes in OBR Pre-survey and Post-survey [1]

	Pre-survey				Post-survey [2]			
	PHYS1	CHEM1	YEAR2	TOTAL	PHYS1	CHEM1	YEAR2	TOTAL
	N=24	*N=23*	*N=7*	*N=54*	*N=21*	*N=18*	*N=6*	*N=45*
a) I have a good understanding of fundamental core content in my discipline.	95.8	90.9	100.0	94.3	100.0	100.0	100.0	100.0
b) I have a good understanding of relating classroom activities to Ohio's College and Career Ready Standards: (Common Core) Standards in Mathematics and/or (Ohio Revised) Standards in Science.	79.2	63.6	85.7	73.6	90.5	83.3	83.3	86.7
c) I have a good understanding of how to assess student learning in multiple ways.	87.5	77.3	100.0	84.9	100.0	94.4	100.0	97.8
d) I have a good understanding of effective questioning techniques and its use in the classroom.	79.2	72.7	100.0	79.2	100.0	88.9	100.0	95.6*
e) I have a good understanding of how to use technology effectively in the classroom.	70.8	63.6	85.7	69.8	95.2	77.8	83.3	86.7
f) I have a good understanding of the methods necessary to teach math and/or science concepts effectively.	87.5	77.3	100.0	84.9	100.0	94.1	100.0	97.7**
g) I believe I am an effective teacher.	91.7	81.8	100.0	88.7	95.2	88.9	100.0	93.3
h) I am excited about teaching in my subject area.	100.0	100.0	100.0	100.0	100.0	94.4	100.0	97.8
i) I am interested in networking with teachers and other professionals.	95.8	95.5	100.0	96.2	100.0	100.0	100.0	100.0

[1] Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.
[2] Statistically significant differences highlighted are between follow-up responses compared to their pre-treatment responses for participants who responded to both surveys as measured by a Chi-square test.
*Statistically significant difference with p-value < .10.
**Statistically significant difference with p-value < .05.

Appendix 9
Physical Science and Chemistry Modeling Workshops
Teacher Classroom Practices in OBR Pre-survey in IRC Pre-survey and Post-survey[1]

	Pre-survey				Post-survey[2]			
	PHYS1	CHEM1	YEAR2	TOTAL	PHYS1	CHEM1	YEAR2	TOTAL
	N=24	*N=23*	*N=7*	*N=54*	*N=21*	*N=18*	*N=6*	*N=45*
a) Classroom interaction involves a dialogue among teacher and students.	50.0	59.1	85.7	58.5	90.5	76.5	83.3	84.1**
b) Students generally work independently.	16.7	13.6	0.0	13.2	14.3	5.9	0.0	9.1
c) Instruction emphasizes broad coverage of information with little depth.	27.3	18.2	0.0	19.6	10.0	0.0	0.0	4.8
d) Student role is to apply inquiry and problem solving skills to discover solutions to problems.	54.2	66.7	85.7	63.5	90.5	76.5	83.3	84.1
e) Students generally learn concepts and processes through readings, lectures, and demonstrations.	12.5	19.0	0.0	13.5	14.3	11.8	0.0	11.4
f) I find it difficult to encourage the efforts and contributions of certain students or groups of students.	29.2	14.3	0.0	19.2	9.5	11.8	16.7	11.4
g) I generally assess students' progress using alternative methods (e.g., open-response questions, hands-on performance, portfolios, observation).	16.7	19.0	42.9	21.2	57.1	11.8	33.3	36.4

[1]Percent of participants who indicated that the specified classroom teaching approach was a close match (value of 4 or 5) with their position. Percentages are based on those with valid response to item.
[2]Statistically significant differences highlighted are between follow-up responses compared to their pre-treatment responses for participants who responded to both surveys.
**Statistically significant difference with p-value < .05.

Appendix 10

Physical Science and Chemistry Modeling Workshops

Teacher Opinions and Attitudes in IRC Pre-survey and Post-survey[1]

	Pre-survey				Post-survey[2]			
	PHYS1	CHEM1	YEAR2	TOTAL	PHYS1	CHEM1	YEAR2	TOTAL
	N=24	*N=23*	*N=7*	*N=54*	*N=21*	*N=18*	*N=6*	*N=45*
a) Virtually all students can learn to think scientifically.	91.7	95.7	85.7	92.6	90.5	94.4	83.3	91.1
b) Students learn science best in classes with students of similar abilities.	41.7	39.1	57.1	42.6	66.7	44.4	33.3	53.3
c) I enjoy teaching science.	100.0	95.7	100.0	98.1	100.0	100.0	100.0	100.0
d) I organize my curriculum around the textbook.	16.7	17.4	14.3	16.7	0.0	5.6	0.0	2.2**
e) The teacher should consistently use activities which require students to do original thinking.	91.7	95.7	100.0	94.4	100.0	94.1	100.0	97.7
f) Teachers should know the answers to most questions students ask about science.	45.8	47.8	71.4	50.0	42.9	42.9	50.0	44.4**
g) Students should never leave science class feeling confused or stuck.	17.4	26.1	28.6	22.6	0.0**	11.1	33.3	8.9**
h) An important issue is not whether students' answers to any science question are correct but whether students can explain their answers.	83.3	78.3	85.7	81.5	90.5	83.3	100.0	88.9
i) Some people are good at science and some just are not.	16.7	21.7	28.6	20.4	20.0	22.2	50.0	25.0
j) Learning for all students is enhanced by incorporating the contributions of different cultures.	70.8	82.6	57.1	74.1	71.4	72.2	83.3	73.3
k) Good science teachers show students the correct way to answer questions they will be tested on.	41.7	17.4	42.9	31.5	28.6	5.6	33.3	20.0

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.
[2]Statistically significant differences highlighted are between follow-up responses compared to their pre-treatment responses for participants who responded to both surveys.
**Statistically significant difference with p-value < .05.

Appendix 11
Physical Science and Chemistry Modeling Workshops
School Support of Science Instruction and Teacher as a Resource[1]

	Pre-survey				Post-survey[2]			
	PHYS1	CHEM1	YEAR2	TOTAL	PHYS1	CHEM1	YEAR2	TOTAL
	N=24	*N=23*	*N=7*	*N=54*	*N=21*	*N=18*	*N=6*	*N=45*
a) Most science teachers at my school would like to use an “inquiry” style of teaching.	62.5	59.1	85.7	64.2	66.7	66.7	83.3	68.9
b) Most science teachers in my school contribute actively to making decisions about the science curriculum.	45.8	68.2	85.7	60.4	71.4	44.4	83.3	62.2
c) Most science teachers in my school regularly share ideas and materials related to science instruction.	70.8	81.8	85.7	77.4	85.7	88.9	83.3	86.7
d) I regularly serve as a resource for other science teachers in my school.	50.0	86.4	85.7	69.8	71.4*	55.6	83.3	66.7
e) I regularly serve as a resource for other science teachers in my district.	12.5	22.7	57.1	22.6	23.8	22.2	83.3	31.1
f) My principal is supportive of innovative approaches to teaching science.	58.3	81.8	100.0	73.6	90.5**	83.3	100.0	88.9

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.
[2]Statistically significant differences highlighted are between follow-up responses compared to their pre-treatment responses for participants who responded to both surveys.
*Statistically significant difference with p-value < .10.
**Statistically significant difference with p-value < .05.

Appendix 12
Physical Science and Chemistry Modeling Workshops
Opinions about Preparedness in IRC Pre-survey and Post-survey [1]

	Pre-survey				Post-survey[2]			
	PHYS1	CHEM1	YEAR2	TOTAL	PHYS1	CHEM1	YEAR2	TOTAL
	N=24	*N=23*	*N=7*	*N=54*	*N=21*	*N=18*	*N=6*	*N=45*
a) Manage a class of students who are using hands-on/manipulative materials.	66.7	87.0	100.0	79.6	100.0*	94.4	100.0	97.8*
b) Use cooperative learning groups.	58.3	73.9	100.0	70.4	90.5*	94.4	100.0	93.3*
c) Implement inquiry or discovery learning.	37.5	56.5	100.0	53.7	100.0***	94.4***	100.0	97.8***
d) Present the applications of science concepts.	70.8	69.6	100.0	74.1	100.0**	88.9	100.0	95.6**
e) Phrase questions to encourage more open-ended investigations.	37.5	52.2	85.7	50.0	90.5***	100.0**	100.0	95.6***
f) Use science equipment as an integral part of science instruction.	54.2	69.6	100.0	66.7	85.7*	83.3	100.0	86.7*
g) Teach groups that are heterogeneous in ability.	54.2	78.3	100.0	70.4	76.2	83.3	100.0	82.2
h) Teach students from a variety of cultural backgrounds.	54.2	56.5	71.4	57.4	71.4	83.3	83.3	77.8
i) Inform students of career opportunities in science.	66.7	65.2	85.7	68.5	66.7	88.9	83.3	77.8
j) Use performance-based assessment in science.	29.2	47.8	71.4	42.6	71.4**	72.2	66.7	71.1**
k) Use portfolios to assess student progress in science.	4.2	13.0	28.6	11.1	23.8	33.3*	50.0	31.1**
l) Encourage participation of females in science.	79.2	81.8	85.7	81.1	90.5	77.8	100.0	86.7
m) Encourage participation of underrepresented minorities in science.	62.5	69.6	85.7	68.5	71.4	66.7	100.0	73.3

[1]Percent of participants who indicated "Very Well Prepared" or "Prepared but Want More." Percentages are based on those with valid response to item.
[2]Statistically significant differences highlighted are between follow-up responses compared to their pre-treatment responses for participants who responded to both surveys.
*Statistically significant difference with p-value < .10.
**Statistically significant difference with p-value < .05.
***Statistically significant difference with p-value < .01.

Appendix 13
Physical Science and Chemistry Modeling Workshops
Weekly Classroom Activities in IRC Pre-survey and Post-survey [1]

	Pre-survey				Post-survey [2]			
	PHYS1	CHEM1	YEAR2	TOTAL	PHYS1	CHEM1	YEAR2	TOTAL
	N=24	*N=23*	*N=7*	*N=54*	*N=21*	*N=18*	*N=6*	*N=45*
a) Listen and take notes during presentation by teacher	95.8	77.3	71.4	84.9	47.6***	61.1	83.3	57.8**
b) Watch the teacher demonstrate a scientific principle	66.7	50.0	71.4	60.4	61.9	77.8	83.3	71.1
c) Work in pairs/teams/small groups	83.3	100.0	100.0	92.5	95.2	100.0	100.0	97.8
d) Read a science textbook	34.8	4.5	42.9	23.1	9.5*	22.2**	33.3	17.8
e) Participate in dialogue with the teacher to develop an idea	50.0	86.4	100.0	71.7	90.5**	77.8	100.0	86.7
f) Make conjectures and explore possible methods to solve a scientific problem	33.3	45.5	42.9	39.6	85.7***	66.7	66.7	75.6***
g) Do hands-on/manipulative activities	70.8	63.6	85.7	69.8	95.2	77.8	100.0	88.9**
h) Write their reasoning about how to solve a scientific problem	20.8	22.7	57.1	26.4	90.5***	64.7**	83.3	79.5***
i) Learn by inquiry	29.2	50.0	71.4	43.4	85.7***	72.2	100.0	82.2***
j) Use worksheets from textbooks	45.8	45.5	14.3	41.5	23.8**	16.7	0.0***	17.8***
k) Use teacher-created lessons	87.5	90.5	100.0	90.4	85.7	100.0	83.3	91.1
l) Engage in reflective thinking/writing about what they are learning	8.3	31.8	57.1	24.5	52.4***	64.7	50.0	56.8**
m) Use science equipment (e.g., measurement tools and graphing calculators)	66.7	63.6	71.4	66.0	85.7	72.2	100.0	82.2

[1]Self-report by teacher indicating that activity occurred "Once or twice a week" or "Almost daily." There was no missing data for this set of items.
[2]Statistically significant differences highlighted are between follow-up responses compared to their pre-treatment responses for participants who responded to both surveys.
*Statistically significant difference with p-value < .10.
**Statistically significant difference with p-value < .05.
***Statistically significant difference with p-value < .01.

Appendix 14
Physical Science and Chemistry Modeling Workshops
Participation in Modeling and Science Listservs[1]
— IRC Pre-survey, Post-survey, and Teacher-Instructor Survey—

		National Listservs		Other Listservs	
		Modeling	Science in General	Modeling	Science in General
IRC Pre-survey					
TOTAL (N=54)	At least once a week	18.9	13.5	11.8	10.0
	Approximately once every two weeks	0.0	0.0	0.0	0.0
	At least once a month	1.9	5.8	2.0	2.0
	Less often than monthly	3.8	7.7	5.9	10.0
	Never	75.5	73.1	80.4	78.0
YEAR2 (N=17)	At least once a week	85.7	50.0	71.4	50.0
	Approximately once every two weeks	0.0	0.0	0.0	0.0
	At least once a month	0.0	16.7	0.0	0.0
	Less often than monthly	14.3	0.0	28.6	16.7
	Never	0.0	33.3	0.0	33.3
IRC Post-survey[2]					
TOTAL (N=45)	At least once a week	45.5	30.8	35.7	10.5
	Approximately once every two weeks	4.5	10.3	11.9	26.3
	At least once a month	6.8	2.6	7.1	5.3
	Less often than monthly	20.5	12.8	9.5	5.3
	Never	22.7***	43.6***	35.7***	52.6**
YEAR2 (N=6)	At least once a week	66.7	60.0	50.0	0.0
	Approximately once every two weeks	0.0	0.0	0.0	40.0
	At least once a month	16.7	20.0	0.0	0.0
	Less often than monthly	16.7	20.0	0.0	0.0
	Never	0.0	0.0	50.0	60.0
Teacher-Instructor Survey					
Teacher-Instructors *(N=6)*	At least once a week	50.0	25.0	40.0	0.0
	Approximately once every two weeks	0.0	25.0	0.0	40.0
	At least once a month	0.0	0.0	20.0	0.0
	Less often than monthly	33.3	25.0	20.0	20.0
	Never	16.7	25.0	20.0	40.0

[1]Percentages are based on those with valid response to item.
[2]Statistically significant differences highlighted are between follow-up responses compared to their pre-treatment responses for participants who responded to both surveys.
**Statistically significant difference with p-value < .05.
***Statistically significant difference with p-value < .01.

Appendix 15
Physical Science and Chemistry Modeling Workshops
Teacher-Instructor Survey – Opinions about Modeling Workshops
—Questions Ordered by Appearance on Survey—

	Teacher-Instructors *N=6*			
	Agree[1]			
	N	%	*Mean*[2]	*S.D.*
a) I enjoyed working as a Modeling Workshop instructor.	5	100.0	2.00	2.000
b) Modeling has positively impacted participating teachers/faculty at my school.	5	100.0	1.83	2.041
c) Modeling has positively impacted students at my school.	6	100.0	1.00	.000
d) As a result of the Modeling Workshops, science teachers/faculty at my school are collaborating to a greater extent.	5	100.0	2.33	1.862
e) Working as an instructor had additional positive impacts on my own teaching.	6	100.0	1.00	.000
f) My collegial network has grown as a result of working with the Modeling Workshops.	6	100.0	1.00	.000

[1]Percent of participants who indicated that they "Strongly Agree" or "Agree" with each statement. Percentages are based on those with valid response to item.
[2]Lower mean score indicates a higher level of agreement, as “Strongly Agree” was represented by the value of 1 and “Strongly Disagree” had a value of 5.