# Modeling Instruction for Physical Science and Chemistry in Ohio 2007-2008

## Evaluation Annual Report

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## Introduction

The Physical Science and Chemistry Modeling Workshops were designed to demonstrate techniques and strategies that high school physical science and chemistry teachers could utilize in their classrooms that would result in more inquiry-based learning experiences for their students. This marks the fourth year that the Ohio Board of Regents (OBR) has funded a Physical Science Modeling initiative directed by faculty at The Ohio State University (OSU). Implementation this year involved a major expansion in which three modeling programs were offered during the same 3-week period in June. These included the initial Physical Science Modeling Workshop (previously offered in 2004-05 and 2006-07), the Year 2 continuation course (first implemented in 2005-06), and a newly developed Chemistry Modeling session (aspects of this class were piloted during the 2006-07 Physical Science Modeling Workshop). The following abbreviations will be used to denote the respective workshops: PS1 = Physical Science Year 1, PS2 = Physical Science Year 2, and CHEM = Chemistry.

### Instructional Team

Dr. Kathleen A. Harper, Director of Undergraduate Course Development in OSU's Department of Physics, is the Project Director and has been one of the co-Principal Investigators since the program was first funded in 2004-05. Dr. Andrew F. Heckler, Assistant Professor of Physics at OSU, is currently the Project Co-Director. Drs. Harper and Heckler have shared responsibility for development and implementation of this project since it was first initiated. Dr. Ted Clark, Instructional Lab Supervisor in Ohio State's Chemistry Department, was a co-instructor of the Chemistry course. Dr. Anita Roychoudhury, Associate Professor of Education at Ohio State, assisted with the design and instruction of the summer workshops, with the intention of ensuring consistency of the activities with the Ohio content standards.

For the second year in a row, four high school teachers from districts in Central Ohio served as the primary instructors, working in conjunction with the OSU faculty to lead class activities. Jason Cervenec, a science teacher at Worthington City Schools, had previously participated in a Physical Science Modeling workshop in another state and had been one of the OSU instructors since the initial implementation. The other teacher-instructors (Doug Forrest of Pickerington City Schools, and Mary Battershell along with Jessica Mamais of Olentangy Local Schools) had completed both years of the Physical Science Modeling workshops and assisted with the 2006-07 class. This component was especially useful as it gave teachers concrete evidence that the approach could work with a wide range of high school students. In addition, the workshop had active involvement of two school administrators, Susy Rhett, the Director of the Middle School and High School Curriculum for Columbus City Schools (CCS), and Melinda Farry, Principal at Olentangy High School.

### Participants and Evaluation Surveys

A total of 46 teachers completed the 3-week summer course. Surveys were developed by Institutional Research Consultants (IRC), the external evaluator, and administered by the instructors. There were two Pre-Surveys, one required by OBR and one developed by IRC. These surveys covered participants' opinions about science teaching, instructional practices, and demographics. This report provides analysis of most of the OBR questions and all the IRC items. IRC combined the two preliminary surveys, but a graduate student administered the two Pre-Surveys separately. Although we achieved high response rates on both (96% for the OBR portion and 91% for the IRC items), the separation of the two surveys complicated our preliminary analyses and matching with the Post-Survey; however, we were able to eventually able to match both sets of Pre-surveys to the corresponding Post-surveys.

The IRC End of Workshop survey administered on the last day of the course queried participants about the effectiveness of the course implementation and the anticipated impact on their instructional practices; a high 96 percent returned the End of Workshop survey. The combined OBR/IRC Post-Survey was returned by only 72 percent of participants. Most of the PS1 teachers (88%) completed the Follow-up Survey. The CHEM group (with 72%) had the next highest response rate. Only half (50%) of the PS2 teachers participated in this final survey; this group had their one and only follow-up session in the fall, and the Project Director forgot to request the needed survey. She subsequently e-mailed the Post-Surveys to the PS2 class.

**Table 1: Survey Response Rates by Workshop**

| Workshop | Total in Program | OBR Pre-Survey | | IRC Pre-Survey | | End of Workshop | | OBR/IRC Post-Survey | |
|---|---|---|---|---|---|---|---|---|---|
| | | Surveys | Return Rate | Surveys | Return Rate | Surveys | Return Rate | Surveys | Return Rate |
| PS1 | 16 | 15 | 93.8 | 16 | 100.0 | 15 | 93.8 | 14 | 87.5 |
| PS2 | 12 | 11 | 91.7 | 10 | 75.0 | 11 | 91.7 | 6 | 50.0 |
| CHEM | 18 | 18 | 100.0 | 17 | 94.4 | 18 | 100.0 | 13 | 72.2 |
| **TOTAL** | **46** | **44** | **95.7** | **43** | **91.3** | **44** | **95.7** | **33** | **71.7** |

All participants were teachers. The group represented a total of 24 districts and two private schools (see Appendix 1 on page 21). Most participants (96%) taught in public schools, and the two private schools (4%) were from the Columbus Diocese (Bishop Ready and Bishop Watterson high schools). The districts with the greatest number of teachers were Columbus City Schools (CCS) and Olentangy Local Schools; each of these districts sent six teachers (13%). These districts also had an administrator actively involved in the implementation. This year, CCS also began its Science Leadership Specialist program in which all science teachers are required to become Specialists and take part in approved in-service offerings. The Modeling Workshops were one of the professional development options available to high school Science Specialists; two of the six Modeling participants (33%) indicated that were a Science Specialist.

Eight of the 46 participants (17%) were located in counties more than an hour's drive from the Olentangy High School training site. This project year, as part of extending this opportunity statewide, the PIs requested funding which allowed them to reimburse teachers whose residence was outside the central Ohio service area but who arranged to live near the workshop site during the 3-week session, and seven teachers took advantage of this offer. The Project Director noted, "A couple cited that this was what made them finally apply for the workshop after thinking about it in previous years."

## Physics, Physical Science, and Chemistry Classes

All but one teacher in each of the pre- and post-survey groups indicated teaching at least one Physics, Physical Science, or Chemistry course. Thus, these teachers taught the types of science intended to benefit most from the Modeling approach. We first reviewed the course loads for all the teachers across the three Modeling Workshops (see Table 2 on the next page). Almost two-thirds (65%) taught one or more physical science classes in their schools during the 2006-07 school year, but this dropped to just over half (52%) in the current year. More than one-third (37%) had three or more Physical Science sections in the prior year, and slightly fewer (33%) had this many classes in 2007-08. About half of the teachers teach chemistry (44% in 2006-07 and 46% in 2008-09), with about a third (33% and 27% respectively) teaching three or more Chemistry sections each year. Fewer teachers (40% each year) led physics classes in 2006-07. But, in the current year, nearly half (49%) taught physics, with nearly a third (30%)

teaching three or more physics sections. The 14 percent decline in those teaching physical science appears to be concentrated among the CHEM participants; these teachers taught a greater number of chemistry sections in 2007-08.

**Table 2: Sections of Physics, Physical Science, and Chemistry[1]**
**—Percentage Taught in 2006-07 and Teaching in 2007-08—**

| | TOTAL *Pre=43, Post=33* | | | | | |
|---|---|---|---|---|---|---|
| | Physics | | Physical Science | | Chemistry | |
| | 2006-07 | 2007-08 | 2006-07 | 2007-08 | 2006-07 | 2007-08 |
| None | 60.5 | 51.5 | 34.9 | 48.5 | 55.8 | 54.5 |
| 1-2 | 14.0 | 18.2 | 27.9 | 18.2 | 11.6 | 18.2 |
| 3-4 | 20.9 | 18.2 | 25.6 | 21.2 | 23.3 | 9.1 |
| 5-6 | 4.7 | 12.1 | 11.6 | 12.1 | 9.3 | 18.2 |
| More than 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | PS1 *Pre=16, Post= 14* | | | | | |
| | Physics | | Physical Science | | Chemistry | |
| | 2006-07 | 2007-08 | 2006-07 | 2007-08 | 2006-07 | 2007-08 |
| None | 31.3 | 21.4 | 31.3 | 35.7 | 81.3 | 71.4 |
| 1-2 | 25.0 | 28.6 | 25.0 | 21.4 | 6.3 | 21.4 |
| 3-4 | 31.3 | 35.7 | 37.5 | 35.7 | 12.5 | 7.1 |
| 5-6 | 12.5 | 14.3 | 6.3 | 7.1 | 0.0 | 0.0 |
| More than 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | PS2 *Pre=10, Post=6* | | | | | |
| | Physics | | Physical Science | | Chemistry | |
| | 2006-07 | 2007-08 | 2006-07 | 2007-08 | 2006-07 | 2007-08 |
| None | 70.0 | 50.0 | 10.0 | 16.7 | 90.0 | 83.3 |
| 1-2 | 0.0 | 16.7 | 30.0 | 33.3 | 0.0 | 0.0 |
| 3-4 | 30.0 | 16.7 | 20.0 | 0.0 | 10.0 | 16.7 |
| 5-6 | 0.0 | 16.7 | 40.0 | 50.0 | 0.0 | 0.0 |
| More than 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | CHEM *Pre=17, Post=13* | | | | | |
| | Physics | | Physical Science | | Chemistry | |
| | 2006-07 | 2007-08 | 2006-07 | 2007-08 | 2006-07 | 2007-08 |
| None | 82.4 | 84.6 | 52.9 | 76.9 | 11.8 | 23.1 |
| 1-2 | 11.8 | 7.7 | 29.4 | 7.7 | 23.5 | 23.1 |
| 3-4 | 5.9 | 0.0 | 17.6 | 15.4 | 41.2 | 7.7 |
| 5-6 | 0.0 | 7.7 | 0.0 | 0.0 | 23.5 | 46.2 |
| More than 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

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

Physics and/or physical science teachers predominated the PS1 Workshop. Of the 16 teachers enrolled, 69 percent taught Physics, 69 percent taught physical science, and 19 percent taught chemistry in 2006-07. In 2007-08, a higher proportion of this group taught physics (79%) and chemistry (29%), whereas the percentage teaching physical science classes stayed relatively stable (64%).

The PS2 participants were primarily physical science teachers. Of the 10 respondents, 90 percent taught physical science in 2006-07. In the current year, this group also taught more physics (increased from 30% to 50%) and chemistry (increased from 10% to 17%).

In contrast, and as one might expect, most of the CHEM Workshop participants taught chemistry (88% in 2006-07 and 77% in 2007-08). Although there was an 11 percent decline in those teaching chemistry, the proportion teaching 5-6 sections doubled (from 24% to 46%). Correspondingly, there was a drop in the extent to which this group taught physical science classes (from 47% to 23%).

These results confirm that participating teachers have a high level of responsibility for physics, physical science, and chemistry classes at their schools. The Modeling instruction is applicable to the courses they teach and their students will potentially benefit from the change in instructional practices. The shifts in course assignments suggest that participants, especially those in the CHEM group, are increasingly being assigned to higher-level discipline-specific courses rather than the more general physical science classes required for ninth graders.

## Background of Participating Teachers

Appendix 2 on pages 21-23 provides teachers' demographics on all available items. Since we had a higher response rate on the Pre-Survey, the results from that survey will be provided and the Post-Survey results will only be mentioned if there was notable variation. The teachers were evenly represented on gender, with 52 percent male and 48 percent female. Respondents to the Pre-Survey were almost exclusively white (91%). The only minorities present were three blacks (7%), and one Hispanic (2%). More than four-fifths (86%) were under 41 years old, which is about the same as last year.

The workshops were targeted to high school teachers, and almost all participants (98%) taught at this grade level. Those attending the PS1 and CHEM workshops were more experienced than those attending last year's Physical Science workshop. Among last year's cohort, 41 percent had less than six years of experience, which includes one (6%) who was new to teaching and two (12%) who had taught for only 1-2 years. None of this year's participants was in their first year of teaching. By workshop, nearly one-fifth (19%) of the teachers in the PS1 class, more than two-fifths (44%) of those in PS2, and one-quarter (24%) of the CHEM participants had less than six years of experience. Teachers in the PS2 session participated in the prior year's Physical Science workshop, and this group continues to have a lower level of teaching experience relative to other workshop cohorts.

On the other hand, 74 percent of the total had six years or more of teaching experience, including nearly one-quarter (24%) with 20 years or more and one-third (33%) with 11 to 19 years of experience. The distribution of highly experienced teachers (six or more years of experience) was as follows in the three workshops: More than four-fifths (81%) of the PS1 group, more than half (56%) of the PS2 teachers, and slightly more than three-quarters (76%) of those in the CHEM workshop. More than one-third (34%) of the teachers had taught at their current schools for only one or two years (PS1=31%, PS2=33%, and CHEM=38%). Slightly more (36%) had been at their current schools for 11 or more years; this was true of 38 percent of the PS1 and CHEM teachers, but only 33 percent of the PS2 group.

Over three-fourths (76%) of the teachers had Master's degrees. The primary degree areas included Science Education (74%), Biology or Life Science (33%), Physics/Physical Science (28%), and Chemistry/Biochemistry (26%). The teachers' degree backgrounds varied by workshop. High percentages of all the groups had general Science Education degrees (CHEM=82%, PS1=69%, and PS2=70%). The next most frequently identified degree areas for the PS1 participants were Biology or Life Science and Physics/Physical Science, both of which were mentioned by half (50%) of the group. The PS2 group also had a high proportion with Physics/Physical Science (40%), but only 10 percent had specialized in Biology or Life Science. Not surprisingly, a high percentage of the CHEM participants (41%) had degrees in Chemistry/Biochemistry, whereas this was the case for much smaller proportions of the Physical Science groups (10-11% in each). Of note is that one-third (30%) of the PS2 teachers had degrees in "Other" areas.

Almost all (93%) held Secondary Science certification, 12 percent were certified in Secondary Mathematics, and 12 percent had certification in other areas. More than half (55%) of the workshop participants had been enrolled in a college-level mathematics or science course in the past year. All the participants in PS2 had such a course in the past year (the Year 1 Modeling course if nothing else). All the PS1 respondents indicated having taken such courses within the past 5 years, whereas this was the case for 93 percent of the CHEM group.

Appendix 3 on page 24 provides participants' responses regarding their involvement in specific professional activities. By year-end, a third (33%) of the participants had taken part in a national or state science teacher association meeting compared to only 9 percent who did this in 2006-07. However, their involvement in physical science conferences declined (from 23% to 12%). The extent to which they taught science-related in-services (initially 14% and 12% at year-end) or received an award for science teaching (went from 16% to 15%) stayed relatively stable. Progress on these professional development indicators did not show a consistent pattern for the different workshop groups. Nonetheless, the PS1 teachers grew significantly in the number of national and state science teacher association meetings attended (increased from 0% to 33%) and their participation in physical science conferences (0% to 17%).[1]

Table 3 on the following page provides additional detail about participants' professional activities. This question asked them to report the number of science/science teaching conferences they had attended in 2006-07 and 2007-08. Seventy-one percent of the Modeling teachers attended at least one session in the prior year and this increased to 74 percent in 2007-08. Although the PS1 and CHEM groups attended fewer conferences, the PS2 group went from a third (33%) not attending a conference to all having attended at least one conference by the end of the current school year (half attended two events). A similarly high percentage on the OBR Post-Survey (see Table 10 on page 16) said they attended a professional association conference as a result of the Modeling course (PS1= 79%, PS2=67%, CHEM=39%, and overall=61%).

[1] Throughout the report, the Chi-square measure of association test is used to test for significant differences between Pre-Survey and Post-Survey results for participants who responded to both surveys.

**Table 3: Participation in Science/Science Teaching Conferences[1]**

| | | Post-Survey Only | | | |
|---|---|---|---|---|---|
| | | Physical Science Year 1 *N=14* | Physical Science Year 2 *N=6* | Chemistry *N=13* | TOTAL *N=33* |
| **2006-07** | None | 23.1 | 33.3 | 33.3 | 29.0 |
| | 1 | 23.1 | 66.7 | 33.3 | 35.5 |
| | 2 | 15.4 | 0.0 | 16.7 | 12.9 |
| | More than 2 | 38.5 | 0.0 | 16.7 | 22.6 |
| **2007-08** | None | 30.8 | 0.0 | 33.3 | 25.8 |
| | 1 | 15.4 | 50.0 | 58.3 | 38.7 |
| | 2 | 23.1 | 50.0 | 0.0 | 19.4 |
| | More than 2 | 30.8 | 0.0 | 8.3 | 16.1 |

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

Table 4 below reveals that slightly more than half of the Modeling participants were members of a science professional organization at the onset of the course. By year-end, more than a third said they had joined a professional organization as a result of the Modeling course; two of three (67%) of the PS2 indicated they became a member.

**Table 4: Membership in a Science Professional Organization[1]**

| | Pre-Survey Only | | | |
|---|---|---|---|---|
| | Physical Science Year 1 *N=16* | Physical Science Year 2 *N=10* | Chemistry *N=17* | TOTAL *N=43* |
| Yes | 56.2 | 50.0 | 56.2 | 54.8 |
| No | 43.8 | 50.0 | 43.8 | 45.2 |
| | **Post-Survey Only** | | | |
| **As a result of this professional development…** | **Physical Science Year 1** *N=14* | **Physical Science Year 2** *N=6* | **Chemistry** *N=13* | **TOTAL** *N=33* |
| I have joined a regional, state, or national professional organization | 35.7 | 66.7 | 23.1 | 36.4 |

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

This section shows that there was substantial variation in the background of each of the workshop groups. The PS1 group had a strong background in physics/physical science and a high percentage of veteran teachers. This group was more likely to be active in various professional development activities. The CHEM group similarly was highly prepared in the targeted discipline area and had a predominance of highly experienced teachers. This group, however, was much less professionally active, possibly because there was not a survey question specifically about participation in chemistry professional conferences. The PS2 teachers initially began taking part in the Modeling course in 2006-07, and compared to the PS1 or CHEM groups, they had less teaching experience and discipline specific training. The PS2 teachers appear to have especially benefited from their second year of Modeling. The review of the impacts in the next section further confirms this finding.

## Pre-Survey and Post-Survey Comparisons

Appendices 4-9 on pages 25 to 30 provide comparisons from the Pre-Surveys, done before the Physical Science Modeling Workshop, and the Post-Surveys administered in February, approximately eight months afterwards.

Appendices 4 and 5 present participants' opinions about science teaching and learning, and how they viewed their teaching roles before and after taking the workshop. Appendix 6 covers the extent to which they viewed teachers at their school as interested in inquiry-based instruction and in the science curriculum, the participants served as a resource to other science teachers in their schools and districts, and their principals were supportive. Appendix 7 measures respondents' opinions about their preparedness and experience with different teaching approaches, including hands-on and inquiry teaching, and their experience working with different student subgroups (e.g., females and students from various cultural backgrounds). Finally, Appendices 8 and 9 provides information about their use of various classroom practices.

Appendices 4 and 8 summarize opinion items from the OBR Surveys. The questions in Appendices 5-7 and Appendix 8 are from the IRC Surveys.

### Opinions about Science Instruction and Classroom Practices

The OBR survey questions in Appendix 4 on page 25 suggest that workshop participants were generally self-confident and highly capable teachers upon entering the program. Encouragingly is that by year-end, the percentage agreeing with each item increased, and a few gains represented significant growth. The PS1 made significant progress on three items, and the CHEM group as well as the participants overall demonstrated significant increases in one area respectively. The statistically significant results are highlighted below

- I have a good understanding of the methods necessary to teach math and/or science concepts effectively (PS1 increased from 73% to 100%; overall increased from 77% to 100%).

- I have a good understanding of authentic assessment methods used to measure student performance (PS1 increased from 64% to 93%).

- I have a good understanding of effective questioning techniques and its use in the classroom (PS1 increased from 73% to 100%).

- I have a good understanding of relating classroom activities to Ohio's Academic Standards (CHEM increased from 72% to 92%).

The IRC Pre- and Post-Survey results reported in Appendix 5 on page 26 similarly revealed a high level of agreement across workshops with values often associated with the successful implementation of inquiry-based instruction[2]:

- Virtually all students can learn to think scientifically (93% - 100%).

- I enjoy teaching science (90% - 100%).

[2]The percent of participants who indicated that they "Strongly Agree" or "Agree" is indicated in parentheses at the end of each statement. See full Appendix tables beginning on page 25 for responses to all survey items within each question set.

- The teacher should consistently use activities which require students to do original thinking (88%-100%).

Significant growth was realized on the following items, which are key to inquiry-based learning:

- An important issue is not whether students' answers to any science question are correct but whether students can explain their answers (CHEM increased from 53% to 100%; overall increased from 63% to 91%).

- Learning for all students is enhanced by incorporating the contributions of different cultures (Overall increased from 72% to 85%).

- Good science teachers show students the correct way to answer questions they will be tested on (CHEM declined from 41% to 8%; overall declined from 33% to 16%).

Appendix 6 on page 27 provides evidence that participating teachers taught in professional environments that are generally supportive of new science teaching efforts. Most of the respondents on both surveys (82% - 100%) agreed their "principal is supportive of innovative approaches to teaching science." Peer support for science teaching was much more varied across workshops. In particular, the PS2 teachers in particular appeared to be in environments in which receptiveness to science teaching innovation may have been weak. Interestingly, it was precisely the PS2 group that experienced significant growth on this aspect. At year-end, half of the PS2 agreed that teachers at their school contributed to making decisions about the science curriculum (increased from 20% on the Pre-Survey) and that most science teachers in their schools regularly shared ideas and materials related to science curriculum (was initially only 40% of the group). It is possible that as these teachers became increasingly confident in their second year of Modeling that they began to take on more of a leadership role in their schools, which resulted in teachers school-wide becoming more actively involved.

The Modeling groups also varied substantially in the extent to which they agreed that "Most science teachers at my school would like to use an 'inquiry' style of teaching." There was not a consistent pattern on this item with respect to the differences between the Pre-Survey and Post-Survey values (PS1= 63% to 64%, PS2=40% to 67%, and CHEM=77% to 69%). Nonetheless, the PS2 group, which started with the lowest level of agreement, experienced the greatest increase, though it was a non-significant gain.

There were also contradictory responses in the extent to which participants viewed themselves as a resource to other science teachers in their schools and district. There was little change overall (resource in my school decreased from 72% to 71%, resource to my district increased from 19% to 25%). Within the groups, the PS2 teachers increasingly viewed themselves as a resource (in my school increased from 40% to 83%, in my district increased from 10% to 33%). Fewer in the PS1 group said they were a resource in their schools (from 94% to 77%), but slightly more indicated they were a district resource (increased to 36% from 25%). The CHEM group had declines on both items (school went down to 58% from 71%, district declined to 8% from 18%).

In summary, there were significant gains for the PS1 teachers with respect to their understanding of effective science instructional practices, alternative assessment, and questioning techniques. The CHEM group experienced a significant gain in their ability to apply Ohio's Academic Standards to classroom activities. All the groups entered the program with general opinions consistent with inquiry-based instruction; however, the CHEM teachers made significant progress in their understanding of key practices associated with Modeling, specifically the focus on having students explain their answers and develop their own understanding of science concepts. The PS1 group experienced significant gains towards fostering a school environment that is more supportive of actively, involved science teachers.

## Changes in Preparation and Classroom Practices

Appendix 7 on page 28 shows teacher opinions, before taking the workshop and eight months afterwards, about their own preparation to teach in specific ways. Respondents grew significantly in their comfort with using inquiry learning, teaching heterogeneous groups, and utilizing performance-based assessment strategies:

- Implement inquiry or discovery learning (PS1 increased from 63% to 100%; CHEM increased from 53% to 82%; and overall increased from 67% to 90%).

- Phrase questions to encourage more open-ended investigations (PS1 increased from 38% to 93%; overall increased from 58% to 90%).

- Teach groups that are heterogeneous in ability (CHEM increased from 77% to 91%).

- Use performance-based assessment in science (PS1 increased from 31% to 79%; CHEM increased from 35% to 64%; and overall increased from 37% to 74%).

- Use portfolios to assess student progress in science (CHEM increased from 6% to 46%; overall increased from 12% to 36%).

The set of OBR survey questions in Appendix 8 on page 29 ask teachers to rank their classroom practices along a continuum for extremes. The teachers showed a general pre-disposition to inquiry-based learning. Since high percentages of teachers entered the program with opinions consistent with the following classroom teaching practices, this was especially the case for the PS2 group, which already had participated in the PS1 class. Although the overall gains were not significant, their starting place and progress is documented below:

- Classroom interaction involves a dialogue among teacher and students (overall from 73% to 82%).

- Student role is to apply inquiry and problem solving skills to discover solutions to problems (overall from 73% to 88%).

Nonetheless, both the PS1 and CHEM groups demonstrated significant growth:

- “Students generally work in groups cooperatively” versus “Students generally work independently (CHEM increased from 53% to 77% in having students collaboratively work in groups).

- “Instruction focuses on the central ideas of a discipline, covering fewer topics in depth” versus “Instruction emphasizes broad coverage of information with little depth” (PS1 increased from 33% to 71% in use of instruction focused on central ideas of a discipline).

- “Student role is to receive/recite factual information and/or to answer questions using repetitive routines” versus “Student role is to apply inquiry and problem solving skills to discover solutions to problems” (PS1 increased from 73% to 93% in use of inquiry).

- “Students generally learn concepts and processes using hands-on approaches” versus “Students generally learn concepts and processes through readings, lectures, and demonstrations” (PS1 increased from 27% to 86% in use of hands-on activities).

The teachers were also asked to report on the frequency that they typically implemented various classroom activities in their classrooms in the prior school year. Appendix 9 on page 30 provides the detailed results. The Pre-Survey response revealed a high level of use of some of the practices associated with inquiry-based instruction. For example, high percentages of the teachers (86%) said that they have students using hands-on/manipulative activities and use teacher-created lessons at least once a week. In other areas, relatively low percentages of the PS1 and CHEM groups on the initial survey said their students did the activity weekly. There were significant gains on the following practices:

- Learn by inquiry (PS1 increased from 31% to 79%; CHEM increased from 35% to 80%; overall increased from 40% to 77%). It is also of note PS2 started out at a high 60 percent and increased modestly to 67 percent weekly use.

- Engage in reflective thinking/writing about what they are learning (PS1 increased from 38% to 43%; CHEM increased from 24% to 64%; overall increased from 40% to 52%). Disconcertingly, PS2 started out at a high 70 percent but was down to 50 percent on they year-end survey. Please note that the statistical significance tests are based on the matched surveys only, but the percentages reported are for all available responses. The Pre-Survey versus Post-Survey changes for the subset of participants who responded to both surveys was greater than what is reflected by the percentage differences reported here.

- Make conjectures and explore possible methods to solve a scientific problem (PS1 increased from 38% to 86%).

- Write their reasoning about how to solve a scientific problem (PS1 increased from 25% to 64%).

- Listen and take notes during presentation by teacher (CHEM decreased from 82% to 64%).

These results are supported in open-ended comments made by teachers in response to the Post-Survey 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?” Specific examples included:[3]

> *I have modified my current materials to fit modeling techniques. I use white boarding, increased questioning, and reflection. I have increased the student involvement in my class.*

[3] The complete set of responses except for those shown here are provided in Appendix 14 (pages 35-36).

*I enjoy giving students the learning opportunity to be the teacher. Using white boards for group work allows me to observe easily that students are or are not on task. The activities demand constant engagement of every student. It is wonderful to watch!*

*Modeling has changed my life. I have always been enthusiastic about what I do. Now I am becoming excited about what my students can do. I wish I would have been involved in a workshop like this 17 years ago! It was the most useful workshop I have ever been involved with.*

*I have switched to complete inclusion in inquiry learning. Students do the vast majority of the thinking and talking. I have become more of a guide on the side. Students spend time defending their ideas as opposed to checking only for right or wrong answers.*

At the end of the project year, Modeling participants' once again demonstrated an increasing commitment to inquiry-based practices. Teachers were correspondingly were doing less lecturing.

## Summer Workshop and Follow-up Results

Of the 46 teachers who completed the 3-week summer courses, 44 filled out an End of Workshop survey. Appendices 10 and 11 on pages 31 and 32 provide participants' responses to questions respectively about the impact of the session and the extent to which their understanding increased as a result of their experience.

Appendix 10 on page 31 presents participants' opinions about the workshop at its conclusion. All respondents would recommend the workshop and agreed that it was a successful professional development experience. The entire group said they gained skills in how to use inquiry in their classrooms and increased their understanding of how to teach physical science effectively. All PS2 teachers and 78 to 93 percent in the other two workshops agreed that: participants' questions and concerns were addressed effectively; adequate time was allowed for participants to reflect on and relate material to their experience and needs; and they felt better prepared to encourage science activities in their buildings.

All PS1 and PS2 workshop participants and most (83-94%) of the CHEM group believed that they increased their ability to see connections among science concepts; gained skills in how to use inquiry in their classrooms; and improved their content knowledge. Similarly, all PS1 and PS2 workshop participants and most (83-89%) of the CHEM group agreed that the workshop contributed positively to their attitudes about science; enhanced their confidence in teaching science; and helped them become a more effective teacher. The PS2 workshop had the highest ratings of all three workshops on all measures listed in Appendix 10 except for two (both of which had very high 82% ratings for the PS2 workshop).

The two lowest related areas at the end of the summer workshop were:

- I have a better understanding of how to apply the science standards (PS1=87%, PS2=82%, CHEM=50%, and Overall=71%).

- I feel prepared to provide professional development on the covered workshop-specific activities for teachers in my building (PS1=67%, PS2=91%, CHEM=56%, and Overall=68%).

The 2007 summer experience suggests that the standards were fairly well addressed in the PS1 and PS2 classes. In the fall 2007 preliminary report, we recommended that the instructional staff might want to add coverage of the standards with the CHEM group. This suggestions appears to have been implemented, as by year-end, the CHEM teachers were the only group to have a significant increase (from 72% to 92%) their "Understanding of relating classroom activities to Ohio's Academic Standards (see Appendix 4 on page 26). Providing professional development to others is not a requirement of the Modeling course. Nonetheless, the high response given by the PS2 teachers on this item suggest that as participants expand their Modeling expertise, they are sharing their knowledge with other teachers.

Appendices 11 and 12 on pages 32-33 provide additional detail on specific gains in their understanding as a result of the workshop. All the PS1 and PS2 participants and 89 percent of the CHEM workshop participants agreed in the End of Workshop survey that they had a better understanding of how to effectively teach physical science/chemistry, with similar results in the Post-Survey (see Appendix 11). At the end of the workshops 94 percent of the CHEM participants and all of the PS1 and PS2 participants increased their understanding of strategies for effectively teaching physical science/chemistry. What is more, PS2 participants and 93 to 94 percent of the others agreed that the workshop would help them improve student performance in physical science/chemistry. Post-survey results several months later showed that all of the PS1 and PS2 respondents still felt that the workshop had helped them improve student performance in physical science. However, only just over two-thirds (69%) of the CHEM workshop participants agreed that the workshop had in fact helped them improve student performance in chemistry.

As with prior implementations of the Modeling workshops, teachers appreciated the interaction with instructors and other teachers as well as the opportunity to get a clearer understanding on inquiry. Comments included:

> *Interaction with other teachers. Better understanding of inquiry as well as modeling. Most useable materials/workshop I have attended.*
>
> *Student mode was very useful for uncovering areas where students' ideas could diverge or actually be incorrect. All interactions with instructors were very positive! Thanks! Great alternative assessment ideas. Teaching tends to be insular during the school year--basically enjoyed the interactions.*
>
> *I benefited most from the student labs and white-boarding because my content knowledge increased and I gained an appreciation of the student perspective, difficulties, and misconceptions.*

The teachers were also asked to rate the value of specific workshop activities. These results are provided in Table 5 on the subsequent page. Appendix 13 on page 34 has the items in the order of appearance on the survey.

**Table 5: Workshop Activities Rated Worthwhile[1]**
**—Questions Ordered by High to Low Total Response—**

| | Physical Science Year 1 *N=15* | Physical Science Year 2 *N=11* | Chemistry *N=18* | TOTAL *N=44* |
|---|---|---|---|---|
| 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 |
| Purchase of educational/classroom materials. | 100.0 | 100.0 | 100.0 | 100.0 |
| Large blocks of "free" time spent working on curriculum. | NA | 100.0 | NA | 100.0 |
| Modeling of inquiry. | 100.0 | 100.0 | 94.4 | 97.6 |
| Introduction to various sources of curriculum materials (books, websites, etc.). | 86.7 | 100.0 | 88.9 | 90.7 |
| Discussion of reading assignments. | 80.0 | 90.0 | 88.9 | 86.0 |
| Reading assignments (research articles). | 86.7 | 100.0 | 72.2 | 83.7 |
| Overall interaction with teachers that previously participated in workshop. | 64.3 | 88.9 | 81.3 | 76.9 |
| Examples on how to apply district standards. | 63.6 | 88.9 | 37.5 | 58.3 |

[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.

As was true last year, the most highly rated aspects were the collegial interaction with other participants and facilitators, the purchase of the educational/classroom materials, and modeling of inquiry. The teachers in the PS2 Workshop uniformly felt that the large blocks of “free” time spent working on curriculum were very or somewhat worthwhile.[4]

Most of the teachers (91%) across the three workshops rated the “Introduction to various sources of curriculum materials (books, websites, etc.)” as worthwhile. The reading assignments were also received high rating from the PS1 (87%) and PS2 (100%) groups, but the CHEM teachers (72%) appeared to find them less valuable. Teachers from both the PS1 and CHEM group complained that some of the readings were outdated and they would have liked to have read more current articles:

> *Some of the articles were tedious and repeated the same ideas. Also, a number of the articles were quite old (7-10 years). Please re-evaluate the usefulness of each article.*
>
> *More current readings—I’m sorry but a reading from the 80s is not “current.” Readings every other night—this way we have more of a chance of reflection.*
>
> *Articles could be updated to include more recent research.*

The rating of the interaction with teachers who previously participated in the workshop ranged from the high of PS2 (89%) and CHEM (81%) to the low of PS1 (64%). It is likely that some of the visitors already knew teachers in the PS2 and CHEM sessions, as they would have also

[4] Participants in the other two workshops were not asked this question because the workshops were not designed to include large blocks of “free” time to work on curriculum.

completed a prior PS1 course. PS1 participants gave the lowest ratings to “Examples on how to apply district standards” (64% “Very Worthwhile” or “Somewhat Worthwhile”). The CHEM workshop rating of such examples was even lower (38%), but as discussed earlier in this report, the staff successfully addressed this issue by year-end.

Ratings of individual workshop guest presenters were discussed in the interim report from fall 2007. Future workshops may want to consider having presenters take on a more active role. For example, one respondent suggested:

> *I would like for the speakers to teach a lesson on something they would teach and how they would teach it. I think that would be more effective in showing Modeling’s benefits than their PowerPoints.*

The results from the OBR follow-up survey (see Tables 6-9 below and on the following pages) further verified the success of the Physical Science Modeling and Chemistry Workshops. The teachers learned new approaches, enhanced their skills through their own use of hands-on activities, and increased their understanding of alternative assessment techniques. While 86 percent of PS1 and 83 percent of PS2 workshop participants also added to their knowledge of concepts, facts, and definitions, only 54 percent of CHEM participants gained new knowledge from the workshops. It is possible that the explanation for this difference is that CHEM teachers may have had stronger content knowledge upon entering the course (see Appendix 2 on pages 22-23). The teacher assessments administered by the Modeling team revealed a similar content knowledge difference between the CHEM and PS1 groups.

**Table 6: OBR Questions about Impact on Teacher[1]**

| As a result of this professional development… | Physical Science Year 1 *N=14* | Physical Science Year 2 *N=6* | Chemistry *N=13* | TOTAL *N=33* |
|---|---|---|---|---|
| a) I learned new concepts, facts, and definitions | 85.7 | 83.3 | 53.8 | 72.7 |
| b) I learned new instructional approaches | 100.0 | 100.0 | 84.6 | 93.9 |
| c) I learned about alternative forms of assessment such as open response questioning, hands-on performance, portfolios, and observation | 85.7 | 100.0 | 76.9 | 84.8 |
| d) I participated in hands-on activities that I now use in my own classroom | 100.0 | 100.0 | 84.6 | 93.9 |

[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.

PS1 and PS2 participants uniformly agreed with each of the professional development measures that are part of a high quality experience (see Table 7). The rating of the linkage of professional development to state and national standards improved this year. CHEM workshop participants were also generally positive about their professional development, especially in regards to provision of adequate follow-up (92%). Most (85% for each item) also verified that it included instructional techniques that were appropriate, provided useful methods for the transferability of new knowledge and skills to the classroom, and was of high quality, sustained, and intensive (85% each). Over three-fourths (77%) felt that the CHEM workshop had addressed their professional needs, provided ample time to achieve stated objectives, and that it was linked to state and national chemistry standards.

**Table 7: OBR Questions about Professional Development Experience[1]**

| As a result of this professional development… | Physical Science Year 1 *N=14* | Physical Science Year 2 *N=6* | Chemistry *N=13* | TOTAL *N=33* |
|---|---|---|---|---|
| a) The professional development addressed my professional **needs** | 100.0 | 100.0 | 76.9 | 90.9 |
| b) The instructional **techniques** used during the professional development were appropriate for reaching the intended objectives | 100.0 | 100.0 | 84.6 | 93.9 |
| c) The professional development provided ample **time** to achieve the stated objectives | 100.0 | 100.0 | 76.9 | 90.9 |
| d) The professional development provided adequate **follow-up** | 100.0 | 100.0 | 92.3 | 97.0 |
| e) The professional development provided useful methods for **transferring** new knowledge and skills to the classroom | 100.0 | 100.0 | 84.6 | 93.9 |
| f) The professional development was high quality, sustained, and intensive | 100.0 | 100.0 | 84.6 | 93.9 |
| g) The professional development was linked to state and national standards | 100.0 | 100.0 | 76.9 | 90.9 |

[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.

In response to post-survey OBR questions, PS1 and PS2 workshop teachers also rated the potential impact on students (Table 8). High percentages of the PS1 (93%) and PS2 (83%) teachers agreed that as a result of their participation in the Modeling course, there is more student attentiveness, enthusiasm, and involvement. Most also agreed that there had been an improvement in the quality of student work (PS1=79% and PS2=83%). The results are similar to last year's reports. On the other hand, just as the impact on CHEM workshop teachers was less, they reported less impact on their students. About two-thirds (67%) of the CHEM participants agreed that "My students are more attentive, enthusiastic, and involved in classroom activities," but fewer than six out of ten (58%) felt that "The quality of student work is noticeably improved."

**Table 8: OBR Questions about Impact on Students[1]**

| As a result of my participation in this professional development program… | Physical Science Year 1 *N=14* | Physical Science Year 2 *N=6* | Chemistry *N=13* | TOTAL *N=33* |
|---|---|---|---|---|
| a) My students are more attentive, enthusiastic, and involved in classroom activities | 92.9 | 83.3 | 66.7 | 81.3 |
| b) The quality of student work is noticeably improved | 78.6 | 83.3 | 58.3 | 71.9 |
| c) My students are participating in science and math activities outside of the classroom to a greater degree | 14.3 | 33.3 | 25.0 | 21.9 |

[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.

Only 14 percent of the students of PS1 teachers were participating to a greater degree in science and math activities outside of the classroom, compared to 63 percent last year. The response from the PS2 (33%) and CHEM (25%) were similarly low. It is not clear why the proportion is substantially lower than the prior year. Nonetheless, the reasons behind the lower response are likely due to factors beyond the scope of the Modeling project such as budget cuts to school-based extracurricular activities.

In terms of the impact on teachers' professionalism, greater proportions of PS1 and PS2 participants than in last year's physical science workshop maintained contact with other participants (PS1=85%, PS2=100%) and with the college/university faculty who provided the professional development (PS1=92%, PS2=100%). More also said the programs led to the establishment of a professional network among participants (PS1=93%, PS2=83%). All CHEM workshop participants said that the program had led to the establishment of a professional network, and 92 percent had maintained contact with other participants. However, less than two-thirds (62%) of the CHEM participants had maintained contact with the college/university faculty who had provided the professional development.

**Table 9: OBR Questions about Impact on Teachers' Professionalism[1]**

| As a result of this professional development… | Physical Science Year 1 *N=14* | Physical Science Year 2 *N=6* | Chemistry *N=13* | TOTAL *N=33* |
|---|---|---|---|---|
| a) I have maintained contact (or plan to maintain contact) with other participants | 84.6 | 100.0 | 92.3 | 87.9 |
| b) I have maintained contact (or plan to maintain contact) with college/university faculty who provided the professional development | 92.3 | 100.0 | 61.5 | 81.3 |
| c) The program led to the establishment of a professional network among participants | 92.9 | 83.3 | 100.0 | 93.9 |
| d) I have joined a regional, state, or national professional organization | 35.7 | 66.7 | 23.1 | 36.4 |
| e) I have attended a professional association conference | 78.6 | 66.7 | 38.5 | 60.6 |
| f) I have or would recommend this program to other teachers | 100.0 | 83.3 | 92.3 | 93.9 |
| g) I have shared what I learned with colleagues through **informal** interactions | 100.0 | 83.3 | 84.6 | 90.9 |
| h) I have shared what I learned with colleagues through **formal** interactions | 28.6 | 50.0 | 15.4 | 27.3 |

[1]Percent of participants who indicated "Yes" to each statement. Percentages are based on those with valid response to item.

Between 83 and 100 percent of participants, depending on the workshop, had shared what they had learned with colleagues, through informal interactions, and had or would recommend their workshops to other teachers. These ratings are only slightly lower than last year's 100 percent ratings. Half of the PS2 participants, 29 percent of PS1 participants had shared what they learned through formal interactions with colleagues,[5] yet only 15 percent of CHEM workshop colleagues had done so.

There was notable growth in the extent to which participants had joined a regional, state, or national professional organizations compared to last year (only 13%). Two-thirds (67%) of PS2 teachers, more than a third of PS1 participants (36%), and nearly a quarter of the CHEM group (23%) were new members.

Similarly, only 13 percent of last year's participants said they had attended a professional association conference. This year, over three-quarters (79%) of PS1 and two-thirds (67%) of PS2 participants had attended a professional association conference. A smaller proportion of CHEM workshop participants (39%) had attended such an event.

[5] About 25 percent had done so after last year's Physical Science workshop.

Open-ended comments similarly confirmed that the Modeling experience was having the intended impacts on participants and students (see pages 35-36).

*I do more group thinking and sharing of ideas. I white board in all my classes. My 9th graders really like explaining their results. Sometimes each group will brainstorm together, and then share their results with the rest of the class, but I had to tone it down because all we were doing were worksheets. The kids really missed out on the hands-on activities.*

*My students are even more involved with the evolution of science concepts on a daily basis than they were before. I have given additional tools to help me implement more of an inquiry-based curriculum.*

*Much more student centered, more dialogue between students, more writing, and more critical thinking.*

*I use whiteboards more often to allow students to draw particles and explain concepts. I try to integrate inquiry and students' approach to problem solving whenever possible. I discuss the application of modeling techniques with other teachers who have attended the workshop.*

*Since I was in year two, my group and I developed curriculum for freshman for the chemistry/periodic table unit. This unit was very in-depth, with multiple activities to allow the students to see trends, to make predictions, and to discover. For the most part, I used this unit in its entirety, and I loved it. I have also taken to white boards, but not to the extent I would like to. My classes are just too big right now, and the students are too immature to handle extensive work on white boards. It always gets inappropriate, or with only one person doing the work, etc.*

*I have worked to change my instruction from having students know a list of items to having students be able to reason out scientific thought. I try to get students to construct their own mental model of the subject and then I challenge that model through lab activities, teacher questioning and cooperative learning.*

The workshops and follow-up sessions were generally well received. As one CHEM participant noted, "*The follow up sessions were very helpful, I don't have any suggestions for improvement.*" Teachers did not appear to have major complaints. Nonetheless, they generously shared their ideas about ways that the sessions could be improved. Two, for example, offered specific ideas relevant to the CHEM workshop follow-up sessions:

*The only thing I would have liked would be doing more of the labs that were in the given materials. [I need to] learn more on how to change the labs that I do now to Modeling labs.*

*I took the chemistry modeling course this past summer. However, 2 out of the 3 follow-up sessions were not centered on chemistry ideas. I would have liked to see more chemistry content during the follow-up sessions (especially 2nd semester topics).*

Others suggested the following potential enhancements to the Modeling experience:

*They did a good job showing us additional ideas or ways of doing. I would like a monthly meeting to help remind me what to do and how to do it.*

*Continued exposure with other teacher professionals to enhance teaching skills. Develop/learn additional modeling curriculum for physical science and physics not taught in Year 1.*

*Perhaps a little more practice at conducting Modeling lessons. Further investigations of activities not covered during 1st workshop. More "sharathon."*

*Short (1 week?) workshops where teachers can meet to discuss how they have applied modeling and learn additional techniques.*

*A physical science class with materials appropriate for that level course. It is really hard to adapt materials from the physics curriculum, and time consuming.*

*Maybe a modification for the Freshman physical science that is a combination of physics and chemistry that can be rolled out on a semester basis.*

*In the summer, a modeling conference and perhaps a Modeling teachers association.*

*Time to meet and share. Ideally, I'd love to go "watch" someone who thinks they have it down. So much of my questions and hesitations are in grading, participation (or lack of), or student absences. So I guess this would be during the school year, but it's just SOOO busy.*

*Shorter follow-up sessions during year OR "informal gas sessions." Even as I gain experience, these modeling follow-ups help. More active local listserve. More on how a model develops, including examples of real student thinking.*

*More sharing of ideas through email. I would like more money for classroom supplies. Answer keys to double check my knowledge.*

*I am uncertain about answers to some of the worksheets. I know I don't have ALL of the answers, but I am uncomfortable that I don't have something/someone to check myself against. I am a biologist first, chemist second, and then a physicist by training. I still am unsure of myself and my answers. Maybe a blog or blackboard discussions would help for us who aren't as certain about the topic. We could go over the worksheets we didn't get to during the course of the summer class.*

*Web page needs work--difficult to navigate.*

*Semester hour credit towards licensure.*

The above comments underline the impact of Modeling on participants and potential value of ongoing follow-up that may go beyond the Modeling workshops. As teachers begin to develop their Modeling skills, they have new questions about teaching and learning, and they want to talk with others engaged in this method of instruction. The sentiment from one PS2 teacher underscored this phenomenon, "*Make it available for 3 years!!!*" The instructional team also attested to teachers' enthusiasm about Modeling and desire to continue their involvement.

Although the expansion of the Modeling workshops from one to three has been an effort to address this need for further professional development and interaction with like-minded colleagues, participants appear to want additional and continuing contact. Since time to do this during the school year is recognized as problematic, some teachers suggested the possibility of additional internet communication via the internet (through e-mails, a more active listserv, a blog, and a better web site) as a potential solution. It might even be possible to begin to use web-based meetings for interaction with Modeling teachers who want more frequent interaction than the follow-ups. In addition, such on-line meetings might be a useful substitute for those who have conflicts with the in-person follow-ups.

## Conclusions and Recommendations

The Physical Science and Chemistry Modeling workshops met their goal of providing the 46 participating high school physical science and chemistry teachers with discipline-specific strategies that are enabling them to expand their use of inquiry-based instruction with their students. There were significant impacts on each group of participants. The PS1 teachers had the most gains with respect to the use of inquiry. The CHEM group experienced progress with respect to their understanding and application of the standards. The PS2 group became increasingly confident with their Modeling skills and more active as leaders in their schools and districts. Participants also made progress with respect to their understanding and use of alternative assessment techniques. One respondent summed up the experience: "*The Modeling workshop is an excellent program. I discuss my experiences with everyone I see. Just keep evolving the sessions."*

The Modeling courses continue to offer a worthwhile, practical approach for teaching physical science, physics, and chemistry. Moreover, the project is well implemented and well received. Given that this project year represented a major expansion in the number of teachers served, the instructional team did an exceptional job of handling the logistics required for essentially offering three courses in one project.

At year-end, we also surveyed the four teachers who served as instructors and interviewed the PI. The instructional team confirmed the positive impact on the participants, emphasizing their developing Modeling skills, enhanced understanding of physical science concepts, and growing teacher collegiality. Three of the four teacher instructors completed the OSU Modeling courses, and they shared some of the ongoing impacts that they have experienced. One of the most emphasized was the increase in teacher collaboration within their own schools as well as statewide. Comments included:

> *Certainly, I think our collaborative efforts have increased in frequency. I also believe it is easier to collaborate and be more productive since so many of the staff have the Modeling workshops in their background. Although in its early stages, I believe Modeling is going to positively impact the curriculum at my school. More teachers are coming to the conclusion that teaching less material for greater understanding is the right direction for curriculum development.*

> *We have been able to exchange best practices and design inquiry-based materials. I openly discuss ideas with the other Modeling-trained teachers in my building. I have been able to use the Modeling techniques in biology and the whiteboards are regularly borrowed by other biology teachers for our genetics*

*unit. The number of students enrolling in our enriched classes and upper-level science classes has increased dramatically. Modeling has given us the tools to more effectively teach all students. Our building is a little unusual in that we collaborated a lot before Modeling, but now more of us are on the same page with techniques and areas of focus.*

*There has been continuity in instruction between teachers. So as students go from one class to another there is vertical alignment in strands that cross the disciplines. Also, there has been great discussions about teaching; informal collaboration has been spontaneous and very beneficial to all. I can bounce ideas off other teachers that have taken the Modeling, and we can work out new models and activities together. The collaboration has been the biggest benefit.*

*Basically, it has promoted a better collegiality, and most importantly it has made more instruction student-focused instead of teacher-focused. I would like to require all our physics and chemistry teachers to take Modeling classes, as the ones who haven't need it the most.*

These teachers have actively encouraged others from their schools to take the Modeling workshops. As a result, a total of 16 teachers from their four schools have also gone through at least one course, which in effect is producing a critical mass of Modeling instruction and budding systemic change at these schools. One of the responding teacher-staff members wrote:

*The more teachers who become involved, the better and more consistent our instruction becomes. I think this is most useful in terms of the process skills students gain, as it's nice to have students who've already has a teacher who models; they are so much better prepared to think.*

A major achievement of the Modeling workshops is that they are having a potentially long-term, sustained, system-wide impact in some of the involved schools that exceeds the project's original goals. In addition, a consultant from the Ohio Department of Education observed the Modeling workshops, which resulted in her encouraging teachers at schools involved in the Ohio High School Program Models Initiative who are specifically working on science curriculum to apply; three teachers from this statewide project have been accepted into the 2008-09 workshops. This development combined with the expansion of funding support for teachers coming from locations across the state will likely extend Modeling's statewide impact.

The Modeling workshops are going to expand again in the upcoming project year. The team will add a session focused on the Ohio Graduation Test and there will also be more teachers involved in 2008-09. The staff should maintain the approach established to date while making needed adjustments. Changes they may want to include in the summer workshops are more current research articles for the reading assignments, the addition of more review and processing time to ensure that all participants understand the concepts, and invited presenters who are more interactive and demonstrate the use of Modeling. The Modeling staff should also review participants' suggestions (see page 18) and pursue those that appear most likely to meet teachers' needs. Some of these may go beyond the workshop and may possibly be more appropriate for a Modeling Association that would need to be supported by membership fees.

# Appendix 1
## Physical Science and Chemistry Modeling Workshops
### Districts Represented

| District | County | Teachers | |
|---|---|---|---|
| | | N | % |
| 1. Amherst Exempted Village | Lorain | 1 | 2.2 |
| 2. Anna Local Schools | Shelby | 1 | 2.2 |
| 3. Barberton | Summit | 1 | 2.2 |
| 4. Bexley | Franklin | 1 | 2.2 |
| 5. Big Walnut Local | Delaware | 1 | 2.2 |
| 6. Columbus City Schools | Franklin | 6 | 13.0 |
| 7. Crestline Exempted Village | Crawford | 1 | 2.2 |
| 8. Dayton Public Schools | Montgomery | 1 | 2.2 |
| 9. Dublin City Schools | Franklin | 4 | 8.7 |
| 10. Fairbanks | Union | 1 | 2.2 |
| 11. Great Oaks/Laurel Oaks | Clinton | 1 | 2.2 |
| 12. Hilliard City Schools | Franklin | 1 | 2.2 |
| 13. Mt Vernon City SD | Knox | 1 | 2.2 |
| 14. New Albany Plain Local | Franklin | 2 | 4.3 |
| 15. Olentangy Local Schools | Delaware | 6 | 13.0 |
| 16. Patrick Henry Local | Henry | 1 | 2.2 |
| 17. Perrysburg Exempted SD | Wood | 1 | 2.2 |
| 18. Pickerington Local Schools | Fairfield | 3 | 6.5 |
| 19. Shaker Heights | Cuyahoga | 1 | 2.2 |
| 20. Southwestern City Schools | Franklin | 2 | 4.3 |
| 21. Tiffin City Schools | Seneca | 1 | 2.2 |
| 22. Triad Local Schools | Champaign | 1 | 2.2 |
| 23. Upper Arlington | Franklin | 1 | 2.2 |
| 24. Worthington City Schools | Franklin | 4 | 8.7 |
| Private - Columbus Diocese | Franklin | 2 | 4.3 |
| | **TOTAL** | **46** | **100.0** |

# Appendix 2
## Physical Science and Chemistry Modeling Workshops
### Description of Teachers[1]

| | Pre-Survey | | | | Post-Survey |
|---|---|---|---|---|---|
| | Physical Science Year 1 *N=15 / 16* | Physical Science Year 2 *N=11 / 10* | Chemistry *N=18 / 17* | TOTAL[2] *N=44 / 43* | *N=33* |
| **Gender** | | | | | |
| Male | 33.3 | 54.5 | 66.7 | 52.3 | 45.5 |
| Female | 66.7 | 45.5 | 33.3 | 47.7 | 54.5 |
| **Race/Ethnicity** | | | | | |
| White, non-Hispanic | 100.0 | 100.0 | 77.8 | 90.9 | 93.9 |
| Black, non-Hispanic | 0.0 | 0.0 | 16.7 | 6.8 | 3.0 |
| Hispanic | 0.0 | 0.0 | 5.6 | 2.3 | 3.0 |
| **Age** | | | | | |
| Under 30 | 18.8 | 30.0 | 25.0 | 23.8 | 15.6 |
| 30 Years or Less | 31.3 | 30.0 | 18.8 | 26.2 | 21.9 |
| 31-40 Years | 37.5 | 30.0 | 37.5 | 35.7 | 34.4 |
| 41-50 Years | 6.2 | 10.0 | 18.8 | 11.9 | 25.0 |
| 51-60 Years | 6.2 | 0.0 | 0.0 | 2.4 | 3.1 |
| **Grade Level Taught[3]** | | | | | |
| Grade 5-8 | 0.0 | 0.0 | 5.6 | 2.3 | 0.0 |
| Grade 9-12 | 100.0 | 100.0 | 94.4 | 97.7 | 100.0 |
| **Years of Teaching Experience** | | | | | |
| Less than 1 year | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1-2 years | 0.0 | 11.1 | 11.8 | 7.1 | 3.0 |
| 3-5 years | 18.8 | 33.3 | 11.8 | 19.0 | 18.2 |
| 6-10 years | 18.8 | 11.1 | 17.6 | 16.7 | 15.2 |
| 11-19 years | 37.5 | 22.2 | 35.3 | 33.3 | 36.4 |
| 20 years or more | 25.0 | 22.2 | 23.5 | 23.8 | 27.3 |
| **Years Taught at Current School** | | | | | |
| Less than 1 year | 0.0 | 0.0 | 0.0 | 0.0 | 6.1 |
| 1-2 years | 31.3 | 33.3 | 37.5 | 34.1 | 15.2 |
| 3-5 years | 31.3 | 33.3 | 18.8 | 26.8 | 30.3 |
| 6-10 years | 0.0 | 0.0 | 6.3 | 2.4 | 9.1 |
| 11-19 years | 31.3 | 22.2 | 25.0 | 26.8 | 30.3 |
| 20 years or more | 6.3 | 11.1 | 12.5 | 9.8 | 9.1 |

[1]Percentages are based on those with valid response to item.
[2]The total for the IRC Pre-Survey is 43 and the total for the OBR Pre-Survey is 44. Gender, race/ethnicity, and grade data are from the OBR Pre-Surveys.
[3]Total can add to more than 100 percent, as respondent could teach grades in more than one category.

# Appendix 2
## Physical Science and Chemistry Modeling Workshops
### Description of Teachers[1]
### —Continued—

| | Pre-survey | | | | Follow-up Survey |
|---|---|---|---|---|---|
| | Physical Science Year 1 *N=16* | Physical Science Year 2 *N=10* | Chemistry *N=17* | TOTAL *N=43* | *N=33* |
| **Highest Degree Received** | | | | | |
| Bachelor's Degree | 25.0 | 30.0 | 12.5 | 21.4 | 18.8 |
| Master's Degree | 68.8 | 70.0 | 87.5 | 76.2 | 78.1 |
| Doctorate | 6.3 | 0.0 | 0.0 | 2.4 | 3.1 |
| **Degree Areas[2]** | | | | | |
| Science Education | 68.8 | 70.0 | 82.4 | 74.4 | 69.7 |
| Earth Science or Geology | 25.0 | 0.0 | 11.8 | 14.0 | 12.1 |
| Mathematics Education | 6.3 | 0.0 | 5.9 | 4.7 | 0.0 |
| Biology or life science | 50.0 | 10.0 | 29.4 | 32.6 | 36.4 |
| Physics or Physical science | 50.0 | 40.0 | 0.0 | 27.9 | 30.3 |
| Mathematics | 0.0 | 10.0 | 5.9 | 4.7 | 6.1 |
| Chemistry or biochemistry | 11.1 | 10.0 | 41.2 | 25.6 | 30.3 |
| Environmental Science | 6.3 | 0.0 | 5.9 | 4.7 | 6.1 |
| Engineering | 0.0 | 0.0 | 5.9 | 2.3 | 6.1 |
| Other | 6.3 | 30.0 | 5.9 | 11.6 | 18.2 |
| **Last Enrollment in Science/Math College Course** | | | | | |
| In the past year | 43.8 | 100.0 | 37.5 | 54.8 | NA |
| 1-2 years ago | 12.5 | 0.0 | 37.5 | 19.0 | NA |
| 3-5 years ago | 43.8 | 0.0 | 6.3 | 19.0 | NA |
| 6-10 years ago | 0.0 | 0.0 | 6.3 | 2.4 | NA |
| More than 10 years ago | 0.0 | 0.0 | 12.5 | 4.8 | NA |
| **State Certification[3]** | | | | | |
| Emergency or Temporary Certificate | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Elementary Grades Certification | 0.0 | 0.0 | 5.9 | 2.3 | 0.0 |
| Middle Grades Certification | 0.0 | 0.0 | 11.8 | 7.0 | 3.0 |
| Secondary Science Certification | 100.0 | 90.0 | 88.2 | 93.0 | 90.9 |
| Secondary Mathematics Certification | 6.3 | 10.0 | 17.6 | 11.6 | 12.1 |
| Other Certification | 6.3 | 20.0 | 11.8 | 11.6 | 6.1 |
| Not Applicable | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

[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.
[3]Total can add to more than 100 percent, as respondent could obtain certification in more than one area.