External Evaluation Final Project Report

Improving the Quality of Arizona Teachers of Physical Sciences and Mathematics

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Final Project Evaluation Report

Year 1 January 3, 2008 to June 30, 2009
Year 2 July 1, 2009 to June 30, 2010
No-cost Extension July 1, 2010 to January 31, 2011
# Table of Contents

*Executive Summary* ................................................................. 1  
*Introduction to the Project* .................................................. 3  
*Program Success Reflected in Testimonials* ................................. 3  
  - The Ministry of Education in Singapore .................................. 3  
  - Summer 2008 Teachers .................................................. 3  
  - Summer 2009 Teachers .................................................. 3  
  - Summer 2010 Teachers .................................................. 4  
  - Mentored Teachers ..................................................... 4  
  - School Year Saturday Follow-up Workshops ............................ 4  
*Dissemination* ......................................................................... 5  
*Implementation Surveys 2009 and 2010* ...................................... 5  
  - Feedback about the ABOR ITQ from Summer 2009 Participants ....... 6  
  - Feedback about the ABOR ITQ from Summer 2008 Participants ....... 7  
  - Physics 2009-10 and 2008-09 Implementation .......................... 8  
  - Chemistry 2009-10 and 2008-09 Implementation ....................... 10  
  - Physical Science 2009-10 and 2008-09 Implementation ................ 11  
*Program Continuation* ................................................................ 13  
*Summers 2008 and 2009 Courses, Enrollment and Assessments* ........ 13  
*Objective 1 Summative Information* .......................................... 15  
  - Pre/Post Testing Results for summer 2008 teachers .................. 16  
  - Pre/Post Testing Results for Summer 2009 and Summer 2010 Teachers .................................................. 16  
  - Results of the "Highly Qualified" Teacher Survey ...................... 23  
  - Highly qualified Status and Credits Earned ............................ 24  
*Objective 2 Summative Information* .......................................... 24  
*Mentoring in 2008-09 and 2009-10* ........................................... 27  
*Strengthening Modeling Instruction in AZ* .................................... 29  
  - Information about the 2009-10 Saturday Follow-Up Workshops ........ 29  
  - Participants Evaluation of the 2009-10 Saturday Workshops ........ 30  
  - Administrators Meetings 2008-09 ...................................... 35  
  - Fall 2009 Meetings with Three School Districts ....................... 36  
*Observations of 2008-09 Saturday Follow-up Workshops* ............... 38  
  - Physics (August 23, 2008) ............................................. 38  
  - Physical Science and Math (September 27, 2008) ....................... 39  
  - Physical Science and Math (January 24, 2009) ......................... 40  
*Appendix A: Project Logic Model and Evaluation Plan* .................... 42  
*Appendix B: 2009-10 Implementation Survey* ............................. 46  
  - 2009-10 Teacher Feedback about ABOR ITQ ......................... 46  
  - 2008-09 Teacher Feedback about ABOR ITQ ......................... 49  
*Appendix C: Pre/post test results for summer 2008 teachers* .......... 53  
*Appendix D: FCI and MBT Analysis by Dr. Jackson (February 2011)* .......... 56  
*Appendix E: Comments from Teachers on the HQ Survey* ............... 58

ASU ITQ #ITQ08-01 ASU (Final External Evaluation Report)
Executive Summary

From 2008 through 2010, 288 Arizona high school and metro Phoenix middle school teachers of mathematics and the physical sciences (most teaching out-of-field and/or in low SES LEAs) participated in professional development consisting of modeling workshops, other content courses and follow-up sessions intended to improve pedagogy and ultimately to increase students’ understanding of mathematics and science content as a result of teachers’ better instructional strategies. During the 2008 and 2010 summer sessions, the Arizona teachers were joined by 21 physics and chemistry teachers sent by the Ministry of Education in Singapore specifically to experience modeling instruction.

Testimonials from individuals who participated in the summer sessions and follow-up Saturdays, including those who had been mentored, indicated their high level of satisfaction with the modeling workshops. They noted that students who experience modeling instruction are more engaged in learning and interacting with their peers and the curriculum.

Dissemination of project findings has been accomplished through publication of a journal article, oral presentation at a national conference, newsletter feature and emailing of an annual report to hundreds of educators and state leaders. Other strategies include expansion to other schools and future contacts with the new Arizona Superintendent of Instruction and the district U.S. Representative.

Implementation surveys administered by the Project Director in 2009 and 2010 garnered feedback on content, methods, coordination with other science and/or math colleagues, and the extent to which the modeling workshops enhanced pedagogy and content knowledge. Teachers provided information about their implementation of instructional methods consistent with modeling including modeling discourse. Respondents were very positive about the value of modeling both for students’ learning and for improving instruction. Challenges included the time demands of modeling and the need for more support (resources, practice and additional professional development).

In response to a Physics Implementation survey completed in 2009 and 2010, the majority of teachers reported that the Modeling Workshop(s) enhanced their teaching pedagogy at a high level and improved their content knowledge in physics at a high level. A few noted that they had been able to coordinate their physics courses with science and math colleagues so that the courses enhanced each other and students learned more. Teachers also reported the extents to which each of the nine Mechanics units and six components of modeling instruction were implemented.

In response to a Chemistry Implementation survey completed in 2009 and 2010, the majority of teachers reported that the Modeling Workshop(s) enhanced their teaching pedagogy at a high level and improved their content knowledge in chemistry at a high level. A significant number of teachers noted that they had been able to coordinate their physics courses with science colleagues so that the courses enhanced each other and students learned more; a few noted that coordination with math colleagues had been successful. Teachers also reported the extents to which each of the nine Chemistry units and six components of modeling instruction were implemented.

In response to a Physical Science Implementation survey completed in 2009 and 2010, the majority of teachers reported that the Modeling Workshop(s) enhanced their teaching pedagogy at a high level and improved their content knowledge in physical science at a high level. A few noted that they had been able to coordinate their physical science courses with math colleagues so that the courses enhanced each other and students learned more. Teachers also reported the extents to which each of the five units and six components of modeling instruction were implemented.

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Continuation of the professional development services has been negatively impacted by fewer funding opportunities. In summer 2010 120 teachers participated in the ASU Modeling Instruction program, choosing from five different Modeling Workshops, an astronomy course, and a Leadership Workshop. In summer 2011 a full set of eight summer courses will be offered, with funding relying on out-of-state enrollees’ tuition to pay instructor wages, donations from local companies and counting on 50 tuition exemptions from the College of Liberal Arts and Natural Sciences.

The project’s objectives to increase student and teacher content knowledge were met. Students and teachers gained content knowledge based on increases in pretest and posttest mean scores on concept inventories including the Force Concept Inventory, Mechanics Baseline Test, Chemical Concepts Inventory, Physical Science Concept Inventory, Mathematics Concept Inventory, Assessment of Basic Chemistry Concepts, Conceptual Survey in Electricity and Magnetism, Simplified Force Concept Inventory, Matter Concept Inventory, Diagnostic Electric Circuits Test, and the Conceptual Survey in Electricity and Magnetism.

During fall semester 2009, two Modeling Instruction Mentors mentored sixteen chemistry teachers and four physical science teachers who had expressed interest in being mentored. Mentoring included classroom visits followed by either phone conversations or follow-up visits in which teachers were provided feedback. Teachers evaluated the benefits of being mentored, as well as the performance of individuals who provided mentoring, and indicated high levels of satisfaction.

A retired expert physics and chemistry teacher, Earl Barrett, was hired as a short-term consultant to establish a self-sustaining mechanism in Phoenix Union High School District for education and communication among school principals, assistant principals and teachers who use modeling instruction. The Phoenix Union High School District Science Specialist led a series of educational sessions for principals and assistant principals in the district. The purpose of the training meetings was to show administrators what modeling instruction looked like so when they evaluate teachers they are more aware of what the best practices are in Modeling Instruction. Through this project’s work with the school district, administrators were encouraged to help teachers incorporate these practices, specifically, to do labs, utilize modeling best practices and use technology.

Earl Barratt was hired as a short-term consultant during fall semester 2009 to establish a self-sustaining mechanism in Gilbert and Chandler school districts for education and communication among school principals, assistant principals, physics teachers and chemistry teachers who use modeling instruction. He surveyed all the physics teachers in the two districts in November and December 2009. He also surveyed all the physics and chemistry teachers in Deer Valley SD and met with school administrators. Following meetings with district administrators and a study of the survey responses from the physics and chemistry teachers, the consultant noted that teachers using modeling to reform pedagogy need the support and encouragement of the district administration, that the mid-year assessment of student performance did not align with the modeling sequence in chemistry and that this situation needs to be addressed. Mr. Barrett recommended a dialogue with modeling leaders dealing with this issue and the lack of equipment needed to fully employ Modeling Instruction.

Follow-up Saturday workshops provided teachers with an opportunity for ongoing professional development. They included teachers with modeling skills and modeling instruction novices. The RTOP or RTOP assessment materials was an important component of each workshop, and the external evaluator observed that it would make sense for the RTOP to be introduced during the summer professional development sessions so that teachers understand that it is an important component of implementing modeling.
Introduction to the Project

The project’s goal was to provide professional development in modeling instruction to 75 Arizona high school and metro Phoenix middle school teachers of physics, chemistry, physical science, and mathematics, most out-of-field and/or in low SES LEAs, each summer for two years in three-week modeling workshops and other content courses with three full-day follow-up sessions yearly. The project envisioned that through participation in the modeling instruction professional development teachers would become more highly qualified and highly effective. The implementation plan included providing principals an initial training session and continuous involvement in the project.

The anticipated outcomes for teachers included improved pedagogy by incorporating the modeling cycle, inquiry methods, critical and creative thinking, cooperative learning, and sound use of classroom technology. Modeling workshops included thematic strands in scientific modeling, structure of matter, energy, use of computers as scientific tools, and discipline-specific content. Mathematics instruction was integrated through mathematical modeling. The ultimate aim was to increase students’ understanding of content through better instructional strategies.

The lead partner LEA was Phoenix Union High School District (PUHSD) and other formal partners were high-need charter schools in metro Phoenix. Informal partners were schools throughout Arizona. Dr. Jane Jackson, Co-Principal Investigator, reported that 54 teachers became Highly Qualified (NCLB) as a result of participating in Modeling Instruction professional development supported by ASU ITQ grants in 2006-2010 and an additional 16 teachers are still progressing toward becoming Highly Qualified (HQ).

Program Success Reflected in Testimonials

THE MINISTRY OF EDUCATION IN SINGAPORE

In summers 2006, 2007, 2008, and 2010, the Ministry of Education in Singapore sent a total of 21 of their best physics and chemistry teachers here! Since Singapore students have the highest math and science scores in international tests this speaks highly for the quality of Modeling Instruction. Because of the H1N1 flu outbreak, Singapore did not send teachers in 2009. (Dr. Jackson, Co-Principal Investigator)

SUMMER 2008 TEACHERS

Thanks to taking physics modeling course work, I am highly qualified in physics.

I learned a tremendous amount and am all fired up to teach physics this fall!

I learned more about teaching and physics this summer than in 5 years of college!

I LOVE this program!

It was, without a doubt, the single greatest professional development experience of my career.

SUMMER 2009 TEACHERS

This year, my school (three teachers in eight sections of regular and three sections of honors physics) implemented CASTLE for studying electrical circuits. Even the average students from other times in
the year could discuss the physics of an electrical circuit with more accuracy than AP students who had studied circuits without CASTLE.

Awesome, wonderful program; it helps students to really understand physics.

Great curriculum; our entire chemistry and physics departments are modeling and it's working really well.

Major turnarounds for some students: increased confidence led to 10 student internships in the Future Renewable Electrical Engineering Delivery and Management Program at ASU.

Modeling class prepared me for teaching physical science with confidence.

SUMMER 2010 TEACHERS

I found the Physics II modeling class to be incredibly educational, on both pedagogical and content levels.

Thank you so much for giving AZ teachers the chance to take the modeling classes without charge. I know that I learned a lot, and I can't wait to try to implement as much as possible this coming school year.

Attending the workshops this summer was amazing; and now that I am in the classroom I am so glad that I attended the workshops! I will be coming back for more!

My students seem to be taking to the modeling really well. I am having a lot of fun teaching it.

MENTORED TEACHERS

Our Mentor has been an inspiration in modeling; he has great listening skills and useful suggestions.

His mentoring was extremely useful. Although I have been modeling for a few years it was great to have a fresh pair of eyes in my classroom. He pointed out things which were going well in my classroom which I had previously taken for granted. We talked about how other modeling teachers have taught the same lab in different ways which I found very useful. It was a great experience.

Many thanks to our Mentor; he is a wonderful teacher, and Dr. Jane Jackson is a wonderful organizer of the program.

Our Mentor is awesome.

I thank the Mentor for the encouragement, guidance and support that she gave me throughout the mentorship process.

I highly recommend that our Mentor continue the magic that she brings to our partnership and the benefits that my students gain by engaging in this collegial process.

SCHOOL YEAR SATURDAY FOLLOW-UP WORKSHOPS

I'm so glad I came.
This (January 24, 2009) has been the best Saturday meeting.

Modeling exercises keep student highly engaged and excited about the lesson.

Modeling Instruction lets students take control of their work and teach one another; this increases peer-to-peer interaction.

An advantage of Modeling Instruction is that students are challenged to think and figure out concepts. The curriculum is not a cookbook.

**Dissemination**

Dr. Jane Jackson, Project Director, wrote the article, *Arizona State University’s preparation of out-of-field physics teachers: MNS summer program*, which was published in the *Journal of Physics Teacher Education Online*, 5(4), summer 2010. This article was part of the dissemination plan in this project’s funded proposal, specifically, dissemination to national K-12 physics leaders:

Results of our work will be disseminated to the Arizona Science Coordinators listserv (120 subscribers), state leaders in K-12 science education, Arizona Department of Education, Arizona K-12 Center, the Governor’s P-20 Council Staff and Teachers Committee and national K-12 physics leaders. Dissemination at local and state levels entails expansion to other schools.

In July 2010, Dr. Jackson also gave a ten-minute oral presentation to 65 people on ASU’s preparation of out-of-field physics teachers at the American Association of Physics Teachers (Portland, OR). Dr. Jackson also emailed an annual report of the Modeling Program’s Arizona activities to several hundred educators and state leaders in all other categories listed in the project’s dissemination plan. (At the time this report was written Dr. Jackson had strategies to inform the new Arizona Superintendent of Instruction and her new district U.S. Representative about the Modeling Program at ASU.)

The Master of Natural Science program was featured in the July 2009 *Physics Flash* published by the ASU Department of Physics.

**Implementation Surveys 2009 and 2010**

The Implementation Survey was administered by Dr. Jane Jackson, PD, and results were summarized by Dr. Shaw, External Evaluator. The survey consisted of fixed choice (1 to 5, 5 high) items on content, methods, coordination with other science and/or math colleagues, and the extent to which the modeling workshops enhanced pedagogy and content knowledge. The open response item on the Implementation Survey was: What do you want ABOR and/or ITQ staff to know? In 2010 Janis Goldstein followed up by phone with participants who did not respond quickly to the e-mail survey. Seventy-six teachers responded out of 78 queried. (Janis’ background includes 38 years high school teaching experience and two ASU Chemistry Modeling Workshops.)

Teachers provided information about their implementation of instructional methods consistent with modeling including modeling discourse. The definition used for modeling discourse was stated: Modeling discourse is classroom discourse that’s focused on scientific models. Modeling discourse can include Socratic questioning, but the questioning is focused on the MODEL. It can include circle white-boarding (board meetings), but it’s more than that; it’s done throughout the entire modeling cycle. Dr. David Hestenes’ explanation of modeling discourse was quoted, “The teacher subtly guides students..."
through the activities with modeling discourse: which means that the teacher promotes framing all classroom discourse in terms of models and modeling. The aim is to sensitize students to the structure of scientific knowledge, in both declarative and procedural aspects."

FEEDBACK ABOUT THE ABOR ITQ FROM SUMMER 2009 PARTICIPANTS

In all, 38 (50%) of the 76 respondents provided input via the open-response question of the implementation survey, 23 by e-mail and 15 by participating in phone interviews. Of this total, 13 were physics teachers (four with degrees in physics and eight out-of-field), 14 were chemistry teachers, and 11 were physical science teachers (seven at the middle school/junior high level and four at the high school level). Feedback from summer 2009 participants was gathered at the end of the 2009-10 school year.

All the responses are compiled in Appendix B of this report. In general, respondents were highly positive about the value of modeling instruction, both from the perspective of its effect on student learning and its impact on their own skills and understanding as teachers. More specifically, respondents identified the following positive impacts for students:

- Helps overcome shyness.
- Increases confidence.
- Improves achievement.
- Leads to more meaningful understanding of the content.
- Increases problem solving skills.
- Facilitates successful completion of homework.
- Improves retention of information.
- Increases engagement and enjoyment.
- Requires students to take responsibility for their own work and their own learning.
- Makes student think, unlocks how to think.
- Students learn to discover information and build consensus.

Respondents identified the following benefits of modeling instruction and the ITQ training for their practice:

- Better understanding of content and the Œwhy of what I do.Ó
- More confident in understanding of the material.
- Works well with groups of mixed ability students.
- Inspires creativity and new methods in teaching.
- Increases teaching effectiveness.
- Supports a more student-centered classroom.
- Teachers become facilitators of learning.
- Merges content and teaching in a positive way.
- ŒBest class for learning how to teach anything.Ó
- Teaching materials and strategies were valuable.
Issues and challenges mentioned by respondents included:

- Balancing the time demands of modeling against the need to cover required content.
- Combining modeling with the pace required by AP courses.
- Complaints from parents/students that approach is too rigorous.
- Lack of equipment or lab space.
- Difficulty of math models for 9th grade students.
- Need for more guidance about classroom management and engaging student participation.
- Acknowledging the benefits of the approach, it is a paradigm shift that will not happen without more support than a summer class, especially given the other demands of teaching.

FEEDBACK ABOUT THE ABOR ITQ FROM SUMMER 2008 PARTICIPANTS

The Implementation Survey was completed in spring 2009 by ABOR ITQ-supported teachers who participated in the 2008 Modeling Instruction workshops and courses at Arizona State University. All the 2008-09 responses by teachers on the implementation survey are compiled in Appendix B of this report.

Respondents were very positive about the value of modeling instruction both for students learning and for improving instruction. More specifically, respondents identified the following positive impacts for students:

- More "ah-ha" moments.
- Improved understanding and retention of concepts.
- Increased student involvement in the learning process.
- Growing ability to "problem solve" and think critically.
- Learning to observe and explain the world around them and justify claims they make.
- Makes chemistry more meaningful.

One teacher offered this example of improved student understanding, "Students know density as mass/volume, but could not draw or identify particle diagrams of objects having different densities until approached via modeling."

Respondents identified multiple benefits of modeling instruction for their practice. A new teacher wrote, "The workshops helped me tremendously. Another teacher indicated that modeling instruction, "Revolutionized both the way I teach and think about teaching." These were summer 2008 workshop characteristics and activities that were most helpful in implementation of Modeling Instruction:

- The use of circle whiteboards ("a great idea").
- Integration of science and math.
- The professional development model of teachers learning from other teachers.
- Experiments that students set up and design themselves.
- Real world context.
- Resources for purchasing equipment and technology.

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• Program comprehensiveness that includes workshops, materials and continued support through listservs and school year workshops.

Issues and challenges mentioned by respondents included:
• Lack of time for planning.
• Inadequate space for materials and storing supplies.
• Tendency to resort to "telling" instead of "questioning".
• Block scheduling does not allow time for nine chemistry units.
• Struggling with asking probing questions.
• Incorporating the school and district requirements into physical science.
• Understanding of charge or of solutions with the chemistry modeling material is inadequate.

One teacher suggested posting all the modeling resources online. Another wrote about modeling's influence on being highly qualified: Modeling has made me a better teacher. I have taught 16 years in the public schools, and only in the last two years, in my own personal opinion, have I been "highly qualified".

PHYSICS 2009-10 AND 2008-09 IMPLEMENTATION

The Physics Implementation survey was completed by 47 2008-09 and 2009-10 physics teachers: 21 teachers in spring 2009 and 26 teachers in spring 2010. Most of the responding teachers (90% in 2009 and 92% in 2010) reported that the Modeling Workshop(s) enhanced their teaching pedagogy at a high level (ratings of 4 and 5 on a scale of 1 to 5, high), and many (65% in 2009 and 83% in 2010) of the teachers reported that the workshop(s) improved their content knowledge in physics at a high level. High levels of coordination of physics courses with science and mathematics colleagues so that the courses enhanced each other, and thus students learned more occurred at higher percentages during the 2009-10 school year than the 2008-09 school year: 5% in 2009 (science) compared to 17% in 2010 (science) and <1% in 2009 (math) compared to 4% in 2010 (math).

The extents to which each of the nine Mechanics units were implemented were rated by teachers (1=not at all or insignificant, 3 = somewhat, and 5 = fully or substantially). Mean implementation ratings are displayed in the following line chart. In both 2008-09 and 2009-10 the Mechanics units most fully implemented were Unit 2 (Particle Moving with Constant Velocity), Unit 3 (Uniformly Accelerating Particle Model) and Unit 4 (Free Particle Model: Inertia and Interactions). The lowest levels of implementation both years were Unit 8 (Central Force Particle Model) and Unit 9 (Impulsive Force Model).
Teachers also reported the extent to which they implemented six components of modeling instruction. High implementation levels were indicated on a 1 to 5 scale (1 = not at all or insignificant, 3 = somewhat and 5 = fully or substantially). The modeling manual and other handouts from the workshop, white-boarding and cooperative groups were the modeling instruction components used the most. The following charts display the percentages of implementation ratings of each of the six modeling instruction components by the physics teachers during school years 2008-09 and 2009-10.
CHEMISTRY 2009-10 AND 2008-09 IMPLEMENTATION

The Chemistry Implementation survey was completed by 59 2008-09 and 2009-10 chemistry teachers: 26 teachers in spring 2009 and 33 teachers in spring 2010. Over three-fourths of the responding teachers (80% in 2009 and 87% in 2010) reported that the Modeling Workshop(s) enhanced their teaching pedagogy at a high level (ratings of 4 and 5 on a scale of 1 to 5, 5 high), and the same percentage (68% in 2009 and 68% in 2010) of the teachers reported that the workshop(s) improved their chemistry content knowledge at a high level. High levels of coordination of chemistry courses with science colleagues so that the courses enhanced each other, and thus students learned more occurred at a substantially higher percentage during the 2009-10 school year than the 2008-09 school year: 41% in 2009 compared to 72% in 2010 but about the same for coordination with math teachers: 4% in 2009 and 3% in 2010.

The extents to which each of the nine Chemistry units were implemented were rated by teachers (1 = not at all or insignificant, 3 = somewhat, and 5 = fully or substantially). Mean implementation ratings are displayed in the following line chart. In both 2008-09 and 2009-10 the Chemistry unit most fully implemented was Unit 1 (Simple Particle: Describing Matter). The lowest levels of implementation both years were Unit 8 (Counting Bonded Particles: The Mole) and Unit 9 (Rearranging Bonded Particles: Chemical Potential Energy).

Chemistry teachers also reported the extent to which they implemented six components of modeling instruction. High implementation levels were 4 and 5 on a 1 to 5 scale (1 = not at all or insignificant, 3 = somewhat and 5 = fully or substantially). The modeling manual and other handouts from the workshop and cooperative groups were the modeling instruction components used the most. The following charts display the percentages of implementation ratings of each of the six modeling instruction components by the physics teachers during school years 2008-09 and 2009-10.
The Physical Science Implementation survey was completed by 45 2008-09 and 2009-10 physics teachers: 27 teachers in spring 2009 and 18 teachers in spring 2010. Teachers reported that the Modeling Workshop(s) enhanced their teaching pedagogy (75% in 2009 and 72% in 2010) and their physical science content knowledge (63% in 2009 and 83% in 2010) at a high level (ratings of 4 or 5 on a scale of 1 to 5, 5 high). High levels of coordination of physical science courses with mathematics colleagues so that the courses enhanced each other, and thus students learned more occurred at a higher percentage during the 2009-10 school year (17%) than the 2008-09 school year (4%).

The extents to which each of the five units were implemented were rated by teachers (1=not at all or insignificant, 3 = somewhat, and 5 = fully or substantially). Mean implementation ratings are displayed in the following line chart. The means differed more for physical science than they did in chemistry and physics. Units 2 and 4 were implemented at the highest levels during the two school years. The Physical Science Units were:

Unit 1: Models of measurement: geometric properties of matter and motion

Unit 2: Modeling physical properties of matter: density

Unit 3: Small particle model of matter, phases and energy transfer

Unit 4: Force, Newton’s Laws (not in manual; done in second course)

Unit 5: Basic Chemistry (not in manual; done in second course)
Physical Science teachers also reported the extent to which they implemented six components of modeling instruction. High implementation levels were labeled on a 1 to 5 scale (1 = not at all or insignificant, 3 = somewhat and 5 = fully or substantially). Cooperative groups were the methods most frequently implemented. The following charts display the percentages of implementation ratings of each of the six modeling instruction components by the physics teachers during school years 2008-09 and 2009-10.

**2009-10 Implementation by Physical Sc Teachers**

<table>
<thead>
<tr>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whiteboarding</td>
<td>23%</td>
<td>28%</td>
<td>23%</td>
<td>28%</td>
<td>23%</td>
</tr>
<tr>
<td>Circle Whiteboarding</td>
<td>39%</td>
<td>28%</td>
<td>33%</td>
<td>28%</td>
<td>28%</td>
</tr>
<tr>
<td>Socratic Questioning</td>
<td>17%</td>
<td>11%</td>
<td>17%</td>
<td>17%</td>
<td>23%</td>
</tr>
<tr>
<td>Modeling Discourse</td>
<td>6%</td>
<td>11%</td>
<td>28%</td>
<td>17%</td>
<td>23%</td>
</tr>
<tr>
<td>Cooperative Groups</td>
<td>6%</td>
<td>11%</td>
<td>17%</td>
<td>17%</td>
<td>23%</td>
</tr>
<tr>
<td>Modeling Manual/Handouts</td>
<td>6%</td>
<td>11%</td>
<td>17%</td>
<td>17%</td>
<td>23%</td>
</tr>
</tbody>
</table>

**2008-09 Implementation by Physical Sc Teachers**

<table>
<thead>
<tr>
<th>Component</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whiteboarding</td>
<td>19%</td>
<td>19%</td>
<td>19%</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Circle Whiteboarding</td>
<td>48%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
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<tr>
<td>Socratic Questioning</td>
<td>3%</td>
<td>24%</td>
<td>24%</td>
<td>24%</td>
<td>24%</td>
</tr>
<tr>
<td>Modeling Discourse</td>
<td>33%</td>
<td>33%</td>
<td>33%</td>
<td>33%</td>
<td>33%</td>
</tr>
<tr>
<td>Cooperative Groups</td>
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<td>33%</td>
<td>33%</td>
<td>33%</td>
<td>33%</td>
</tr>
<tr>
<td>Modeling Manual/Handouts</td>
<td>33%</td>
<td>33%</td>
<td>33%</td>
<td>33%</td>
<td>33%</td>
</tr>
</tbody>
</table>
Program Continuation

The Modeling Instruction program and the Master of Natural Science degree with concentration in physics are institutionalized at Arizona State University but continuation of the professional development services continue to be impacted by fewer funding opportunities. In summer 2010 120 teachers participated in the Modeling Instruction program, choosing from five different Modeling Workshops, an astronomy course, and a Leadership Workshop.

In summer 2011 a full set of eight summer courses will be offered with funding relying on out-of-state enrollee’s tuition to pay instructor wages (as usual) and counting on the 50 tuition exemptions from the College of Natural Sciences. Some funding will be available from a local electric utility and donations are solicited from local companies. The summer schedule can be accessed at http://modeling.asu.edu/MNS/MNS.html.

Summers 2008 and 2009 Courses, Enrollment and Assessments

The grant funded 110 Arizona teachers (total course participation 150) in summer 2008, 90 Arizona teachers (course participation 120) in summer 2009 and 86 ABOR-ITQ funded Arizona teachers (course participation 109) in spring-summer 2010.

Dr. Jackson shared her observations with respect to the data in the following table which she provided. What I see from this is: a) the increase of 50% in ASU tuition from 2008 to 2010 decreased the number of out-of-state participants (and these are the teachers who pay tuition, which pays wages of instructors, thereby subsidizing the ITQ grant - a win-win situation!). b) The more grant funding, the more courses we can offer, and the more teachers who participate. Thus we held the highest number of courses in 2008; and that corresponded to the highest participation. However, the imminent demise of ITQ grant funds prevented us from offering more courses in 2010, yet participation continued to be high in each course.

Table: Summers 2008, 2009, 2010 course information for teachers supported by the ABOR ITQ grant

<table>
<thead>
<tr>
<th>Summer</th>
<th>ASU Course</th>
<th>Modeling</th>
<th>Participants</th>
<th>Assessment Names of Pre/Post Teacher &amp; Student Inventories</th>
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</thead>
<tbody>
<tr>
<td>2008</td>
<td>Methods of Teaching Physics I (PHS 530)</td>
<td>Yes</td>
<td>21 [43]</td>
<td>Force Concept Inventory (FCI)</td>
</tr>
<tr>
<td>2008</td>
<td>Methods of Teaching Physics II (PHS 531)</td>
<td>Yes</td>
<td>17 [25]</td>
<td>Conceptual Survey of Electricity &amp; Magnetism (CSEM)</td>
</tr>
<tr>
<td>2008</td>
<td>Methods of Physical Science Teaching I (PHS 534)</td>
<td>Yes</td>
<td>23 [25]</td>
<td>Physical Science Concepts Inventory (PSCI), Mathematics Concept Inventory (MathCI)</td>
</tr>
</tbody>
</table>

1 A teacher who moved out of Arizona (to Belgium) for the 2009-10 school year is not included in this chart.

PHS598: Leadership Workshop, is taken by a few Arizona teachers each summer at their own expense, but is not supported by this grant. [Numbers in brackets are total number of participants; all except Arizona K-12 inservice teachers participate at no cost to this grant, and instructors’ wages are at no cost to this grant.]
<table>
<thead>
<tr>
<th>Summer</th>
<th>ASU Course</th>
<th>Modeling</th>
<th>Participants</th>
<th>Assessment Names of Pre/Post Teacher &amp; Student Inventories</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Modeling Instruction in High School Chemistry I (CHM 594) 1st semester</td>
<td>Yes</td>
<td>19 [31]</td>
<td>Inventory (BECI)</td>
</tr>
<tr>
<td>2008</td>
<td>Integrated Physics and Chemistry (PHS 540)</td>
<td>No</td>
<td>10 [12]</td>
<td>-</td>
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<tr>
<td>2008</td>
<td>Integrated Mathematics and Physics (PHS542)</td>
<td>Yes</td>
<td>15 [22]</td>
<td>Mathematics Concept Inventory (MathCI)</td>
</tr>
<tr>
<td>2008</td>
<td>Light and Electron Optics (PHS 564)</td>
<td>No</td>
<td>11 [14]</td>
<td>-</td>
</tr>
<tr>
<td>2009</td>
<td>Methods of Teaching Physics I (PHS 530)</td>
<td>Yes</td>
<td>17 [27]</td>
<td>Force Concept Inventory (FCI) Mechanics Baseline Test (MBT)</td>
</tr>
<tr>
<td>2009</td>
<td>Methods of Physical Science Teaching I (PHS 534)</td>
<td>Yes</td>
<td>14 [15]</td>
<td>Physical Science Concept Inventory (PSCI), Mathematics Concept Inventory (MathCI)</td>
</tr>
<tr>
<td>2009</td>
<td>Electricity for Middle/Secondary Teachers (PHS 594)</td>
<td>Yes</td>
<td>14 [24]</td>
<td>DIRECT (Diagnostic Electric Circuits Test), Mechanics Baseline Test (MBT) only as a posttest</td>
</tr>
<tr>
<td>2009</td>
<td>Modeling Workshop in Mechanical Waves (PHS 594)</td>
<td>Yes</td>
<td>10 [11]</td>
<td>Waves Assessment adapted from one developed by the University of Maine</td>
</tr>
<tr>
<td>2009</td>
<td>Modeling Instruction in High School Chemistry II (CHM 594) 2nd semester</td>
<td>Yes</td>
<td>13 [17]</td>
<td>None. Teachers developed the Assessment of Basic Chemistry Concepts (ABCC)</td>
</tr>
<tr>
<td>2009</td>
<td>Modeling Instruction in High School Chemistry I (CHM 594) 1st semester</td>
<td>Yes</td>
<td>19 [26]</td>
<td>1st draft: Assessment of Basic Chemistry Concepts (ABCC)</td>
</tr>
<tr>
<td>2009</td>
<td>Spacetime Physics (PHS 570)</td>
<td>No</td>
<td>8 [13]</td>
<td>-</td>
</tr>
<tr>
<td>2010 spring</td>
<td>Methods of Physical Science Teaching I (PHS 534)</td>
<td>Yes</td>
<td>10 [19]</td>
<td>Physical Science Concept Inventory (PSCI), Mathematics Concept Inventory (MathCI)</td>
</tr>
<tr>
<td>2010</td>
<td>Methods of Teaching Physics I (PHS 530)</td>
<td>Yes</td>
<td>11 [24]</td>
<td>Force Concept Inventory (FCI)</td>
</tr>
<tr>
<td>2010</td>
<td>Methods of Teaching Physics II (PHS 531)</td>
<td>Yes</td>
<td>17 [28]</td>
<td>Conceptual Survey of Electricity &amp; Magnetism (CSEM)</td>
</tr>
<tr>
<td>2010</td>
<td>Physical Science with Math Modeling Workshop II (PHS 594)</td>
<td>Yes</td>
<td>27 [31]</td>
<td>Matter Concept Inventory (MCI)</td>
</tr>
</tbody>
</table>
Objective 1: Annually 75 Arizona teachers (majority in high-need districts) participating in June and July Modeling Workshops and other content courses will improve their physics, chemistry, physical science and/or mathematics content knowledge as demonstrated by concept inventories.

- Arizona teacher enrollment in ABOR ITQ workshops and courses far exceeded the goal (75 teachers); it totaled 288: 2008 (109 teachers), 2009 (93 teachers) and 2010 (86 teachers).
- In 2008 and 2009, 39% of the ITQ teachers taught in Title 1 schools. In 2010, 52% of the ITQ teachers were from Title 1 schools.
- Teachers from rural schools comprised 6% of the ITQ participants in 2008, 11% in 2009 and 12% in 2010.
- 47 (43%) of the summer 2008 Arizona teachers were not highly qualified in one or more sciences or math that they taught or expected to be assigned in the next three years. Three of the 47 teachers passed the AEPA test in physics in the year after summer 2008.
- 19% of summer 2009 and 30% of summer 2010 teachers were not highly qualified (NCLB) in a science to which they expected to be assigned.
- Teachers participating in this project were from 39 LEAs in 2008, 32 LEAs in 2009 and 35 LEAs in 2010.
- This project served teachers from 89 schools in 2008, 70 schools in 2009 and 60 schools in 2010.
- In 2008 this project served teachers from 5 parochial schools and 12 charter schools. Teachers from 9 charter schools and 4 parochial schools participated in 2009, and in 2010 there were teachers in the project from 2 parochial schools and 7 charter schools.
- College credits earned by teachers in this project were: 318 credits (2008), 214 credits (2009) and 198 credits (2010).
- In summer 2009 there were six participants from five new high-risk LEAs: Camp Verde UD, Chinle UD, Glendale ESD, San Carlos UD (2 teachers) and Santa Cruz UD.
- Teachers demonstrated increases in science content knowledge as demonstrated by gains from pretest to
posttest on the Force Concept Inventory, Mechanics Baseline Test, Chemical Concepts Inventory, Physical Science Concept Inventory, Mathematics Concept Inventory, Assessment of Basic Chemistry Concepts, Conceptual Survey in Electricity and Magnetism, Simplified Force Concept Inventory, Matter Concept Inventory, Diagnostic Electric Circuits Test, and the Conceptual Survey in Electricity and Magnetism.

PRE/POST TESTING RESULTS FOR SUMMER 2008 TEACHERS

Charts of pre/post test results for Arizona teachers who participated in this project's Modeling Instruction professional development in 2008 are displayed in Appendix C. The five tests were designed, administered, data analyzed and charts created by the ASU Modeling Instruction Office (Dr. Jane Jackson and Dr. Sharon Osborn Popp). The maximum possible score on each of the five tests was 100. Descriptive statistics for each of these assessments are displayed in descending order of pretest to posttest gain in the following table. The largest mean gain from pretest to posttest was on the Force Concept Inventory.

Table: Pretest and posttest results on five assessments for summer 2008 teachers

<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>Pretest mean</th>
<th>Posttest Mean</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force Concept Inventory</td>
<td>18</td>
<td>74</td>
<td>86</td>
<td>12</td>
</tr>
<tr>
<td>Mechanics Baseline Test</td>
<td>19</td>
<td>58</td>
<td>69</td>
<td>11</td>
</tr>
<tr>
<td>Chemical Concepts Inventory</td>
<td>22</td>
<td>71</td>
<td>78</td>
<td>7</td>
</tr>
<tr>
<td>Physical Science Concept Inventory</td>
<td>18</td>
<td>78</td>
<td>84</td>
<td>6</td>
</tr>
<tr>
<td>Mathematics Concept Inventory</td>
<td>19</td>
<td>83</td>
<td>86</td>
<td>3</td>
</tr>
</tbody>
</table>

PRE/POST TESTING RESULTS FOR SUMMER 2009 AND SUMMER 2010 TEACHERS

Charts of pre/post test results for Arizona teacher-participants in summer 2009 and summer 2010 Modeling Instruction workshops were provided by the ASU Modeling Instruction Office (Dr. Jane Jackson and Dr. Sharon Osborn Popp). These charts are displayed in this section.

Pre and post assessment results on 9 assessments were reported for 168 teachers who participated in the project's workshops in the summer of 2009 (with one chart displaying 2007 and 2009 combined) and/or the summer of 2010. The Mechanics Baseline Test pretest and posttest mean scores were higher for summer 2008 teachers than for summer 2009 teachers. The gains in mean scores from pre to post were nearly identical: 11 points (from 58 to 69) for summer 2008 teachers and 12 points (from 50 to 62) for summer 2009 teachers.

Force Concept Inventory pretest and posttest mean scores were also higher for summer 2008 teachers than for summer 2009 teachers. The gains in mean scores were similar to those on the Mechanics Baseline Test: From pre to post 12 points (from 74 to 86) for summer 2008 teachers and 11 points (from 66 to 77) for summer 2009 teachers.
The correlation between *Mechanics Baseline Test* scores and *Force Concept Inventory* was computed by Dr. Sharon-Popp ($R^2 = 0.81$). This is a high correlation ($R = 0.90$). Additional analysis of these test scores by Dr. Jackson is included in Appendix D.

*Physical Science Concept Inventory* pretest and posttest mean scores were slightly higher in summer 2008 (78 and 84, respectively) compared to summer 2009 (76 and 80, respectively). The increase in mean scores from pre to post was also greater in 2008 (6) than in 2009 (4).

*Mathematics Concept Inventory* pretest and posttest mean scores were considerably higher in summer 2008 (83 and 86, respectively) compared to summer 2009 (78 and 84, respectively). The increase in means scores from pre to post was greater in 2009 (6) than in 2008 (3).

Pretest and posttest mean scores for nine assessments are displayed in the following table. The greatest pre to post gain (28) among these nine assessments was on the *Conceptual Survey in Electricity and Magnetism*.

Table: Pretest and posttest teacher assessment results for summers 2009 and 2010 with one combined 2007 and 2009

<table>
<thead>
<tr>
<th>Assessment</th>
<th>N</th>
<th>Pretest mean</th>
<th>Posttest Mean</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Force Concept Inventory</em> (2009 and 2010 combined)</td>
<td>20</td>
<td>66</td>
<td>77</td>
<td>11</td>
</tr>
<tr>
<td><em>Mechanics Baseline Test</em> (2009 and 2010 combined)</td>
<td>24</td>
<td>50</td>
<td>62</td>
<td>12</td>
</tr>
<tr>
<td><em>Conceptual Survey in Electricity and Magnetism</em> (2010)</td>
<td>15</td>
<td>49</td>
<td>77</td>
<td>28</td>
</tr>
<tr>
<td><em>Simplified Force Concept Inventory</em> (2010)</td>
<td>23</td>
<td>48</td>
<td>51</td>
<td>3</td>
</tr>
<tr>
<td><em>Math Concept Inventory</em> (2009)</td>
<td>13</td>
<td>78</td>
<td>84</td>
<td>6</td>
</tr>
<tr>
<td><em>Physical Science Concept Inventory</em> (2009)</td>
<td>13</td>
<td>76</td>
<td>80</td>
<td>4</td>
</tr>
<tr>
<td><em>Matter Concept Inventory</em> (2010)</td>
<td>19</td>
<td>85</td>
<td>86</td>
<td>1</td>
</tr>
<tr>
<td><em>DIRECT: Diagnostic Electric Circuits Test</em> (2007 and 2009 combined)</td>
<td>20</td>
<td>66</td>
<td>80</td>
<td>14</td>
</tr>
</tbody>
</table>
The following chart displays results for 15 Arizona physics teachers in the 2nd Modeling Workshop: PHS 531 (microscopic models of electricity & magnetism). The posttest mean score (77%) was substantially greater than the pretest mean score (49%). This chart was provided by Dr. Jackson.

Dr. Jackson provided her analysis of the 21 Arizona teachers (15 women, 6 men) in CHM 594: Modeling Instruction in High School Chemistry in June 2010 who took the Assessment of Basic Chemistry Concepts.
(ABCC) pretest and posttest. (Six other teachers completed the course; three teachers from Arizona, two teachers from Singapore, and a master teacher from Illinois.)

On Friday afternoon, July 2, 2010, the day that CHM 594 ended, the two course instructors and I reviewed the course. According to my notes, both instructors expressed frustration, saying that "the majority of the class participants are biology teachers and don't know chemistry content." They had never had such a weak class, they told me.

2010-11 is the first year that Arizona's new requirement that all high school students take at least three years of science affects high school juniors. Chemistry is usually taken by juniors.

Of the 21 teachers who took the ABCC, five had never taught chemistry. Three of them expected to be assigned to teach a section of chemistry; they took the course to prepare.

Ten teachers were not Highly Qualified before taking the course. Six of them became HQ in the half year after taking the course, either by earning credit for CHM 594 or by passing the AEPA chemistry test. Another, a biology teacher, intends to become HQ in chemistry eventually. The remaining three do not plan to become HQ in chemistry, although two of them expected to be assigned to teach chemistry in 2010-11 (one due to downsizing in the economic downturn; the other due to expected increased enrollment at their school.) The third who doesn't intend to become HQ is a 9th grade physical science teacher and a Modeling Workshop leader who took CHM 594 to deepen her understanding of chemistry.

In addition to the 21 teachers who took the ABCC pre- and posttest, three more Arizona teachers participated: a) an out-of-field chemistry teacher repeated the course; her posttest score improved considerably, putting her in the top quarter of the class. b) An out-of-field chemistry teacher quit the course in week 2, so he didn't take the posttest. c) A rural general science high school teacher who claimed that she would be assigned to chemistry had a weak chemistry background and seemed lost in the course, according to the instructors. Her ABCC posttest appeared to the statistician to be an insincere response; i.e., she guessed. Her school moved her to the middle school in 2010-11. She used CHM 594 to become HQ in secondary general science, thus qualifying her to teach general science in grades 7 to 12.

![Assessment of Basic Chemistry Concepts (ABCC) Pretest and Posttest Percentage Scores of Teachers Summer 2010](image)
RESULTS OF THE “HIGHLY QUALIFIED” TEACHER SURVEY

Participants of the ITQ grants from 2006 to 2009 responded to a survey administered by Dr. Jackson in December 2010. A total of 44 teachers became highly qualified, and an additional 16 teachers are still progressing toward becoming highly qualified. Comments, with identifying information removed, are reproduced in Appendix E. Selected comments (with minor editing) are displayed below. The over-arching theme is that teachers increased their subject matter content knowledge and experienced modeling pedagogy which they took back to their classrooms resulting in more effective instruction and improved student learning.

- The leaders, fellow teachers, and curriculum of the three modeling workshops I participated in gave me the highest quality instruction for science teaching I have ever been a part of; this includes my teacher certification courses, my student teaching, my year of teaching middle school, and my two years of teaching high school.

- I am already highly qualified in chemistry, but my district is leaning towards going with a chemistry modeling curriculum. In that case, I am going to need chemistry modeling classes in order to be considered an effective teacher and to receive adequate evaluations.

- University classes are priced out of my league, now. I am unable to advance my knowledge and skill level without grants . . . . The ABOR grant is so important to science teachers. I feel like no one is helping us. Everyone recognizes the importance of children getting a good education, but few recognize the importance of supporting teachers in helping them to become highly qualified.

- It is discouraging to find so much information in the news about how there is this big push for science teachers, yet when I went to school (2008) it was a lonely uphill battle. Even now, I looked up mentorship programs for science teachers and all I have found so far is mentoring for teachers in training or teachers seeking alternative certification. What about support, both emotional and financial, for a 2.5-year science teacher? I still feel very alone in my profession. I attend science conventions, and for those few days it's great, but day-to-day I am still alone struggling with my students.

- Attending Modeling workshops not only was a great way to become highly qualified as there was depth in the physics content, but it also helped focus on physics instruction and teachers. A teacher can be very fluent in content, but if the teacher does not have the ability to teach and help students learn physics, it really does not matter what the depth of content the teacher has. The modeling program helps with both content and the methods of instruction in high school physics teaching. I feel as though I was enriched in both areas and I had been teaching science for 13 years before I attended a modeling workshop.

- This [modeling] is the way I wish all inquiry and science methods courses were taught. I wish I had this course 30 years ago, too. It would have benefited thousands of students by now.

- These classes change the way you teach. It takes teacher-centered classes and turns them into student-centered. It changes cookbook labs to student-centered labs that require critical thinking. Overall, the ASU course helped me raise the overall level of understanding for my chemistry students.

- Can't say enough good about modeling. These workshops have improved my teaching more than all the other professional development courses I’ve taken combined. Our entire physics, chemistry and investigative science departments are now teaching modeling curricula and our science enrollment has skyrocketed. We have many more students taking science classes, both core curricula and AP level, and many of our students take more than one science class a semester.
The ASU Modeling program is without question the best program for science teachers I have ever seen. The modeling methodology and the techniques I have learned improved my test scores on standardized tests by significantly large quantities. In one case I can even boast of 80% improvement on the Terra Nova tests the year after I attended my first modeling instruction workshop summer session.

Dr Jackson’s grant has given me the chance to become highly qualified and it has given me a toolbox of science best practices that is much more valuable than any other traditional kind of class being offered in the country.

I thought you would like to know this: last week we were visited by the Undersecretary of Education. The team visited my classroom and sure enough we were white boarding, plus it just so happened I had the instructional modeling handout handy I by the way, this was not planned; however, the team stayed in my room for a full 20 minutes and was very impressed with what we were doing. I got lots of questions and a lot of very interesting looks. I think they really liked what we were doing and I made sure to let them know it’s all from ASU. Your program got some big-time kudos from the visiting team.

Classes taken at ASU were the only way for me to get the education I needed to become highly qualified in physics and earn my master’s degree. No other program I have seen is specifically designed with teachers in mind.

The ASU courses were INVALUABLE for multiple reasons: deepening comprehension of course content, practical ideas to transfer to my classroom with my students, camaraderie established that has carried through to the present and provides a support system that is often lacking on campuses where there is often only one physics teacher. I absolutely loved all courses I took and am so grateful to have been funded through them.

ASU summer coursework provides valuable training to secondary education science teachers. The modeling classes have raised the standard of teaching across the state, which translates into student success. Isn’t that why all of us do what we do?

HIGHLY QUALIFIED STATUS AND CREDITS EARNED.

The following information was provided by Dr. Jackson on February 22, 2011.

The number of teachers who were not highly qualified (HQ) that became HQ as a result of grant-funded activities in each of the grant time periods (July 1 to June 30): 2006-07 (27), 2007-08 (11), 2008-09 (6) and 2009-10 (10). A total of 54 teachers became highly qualified as a result of ABOR ITQ grant-funded activities.

The number of college-level credits teachers and administrators earned as a result of grant-funded activities from 2006 through 2009 were provided:

- July 1, 2006-June 30, 2007: 260
- July 1, 2007-June 30, 2008: 315
- July 1, 2008-June 30, 2009: 265

Objective 2 Summative Information

Objective 2: Teachers who participate in June and July Modeling Workshops and other courses will improve STEM instructional strategies including effective classroom discourse management and content organization.

ASU ITQ #ITQ08-01 ASU (Final External Evaluation Report)
At the end of the school year after their summer participation, 80-92% of physics and chemistry teachers and 72-75% of physical science teachers reported that the Modeling Workshops enhanced their teaching pedagogy.

Physics teachers implemented the “Particle Moving with Constant Velocity” unit at the highest level.

Chemistry teachers implemented more modeling units at higher levels than did physics and physical science teachers.

Physical Science teachers implemented the modeling unit, “Force, Newton’s Laws” at higher levels in both 2008-09 and 2009-10 than other units. A close second in implementation was the unit, “Modeling physical properties of matter: density”.

Socratic questioning and cooperative groups were implemented at higher levels by participating teachers than were circle-white-boarding, white-boarding and modeling discourse.

Higher percentages of 2009-10 than 2008-09 physics, chemistry and physical science teachers reported substantially higher levels of coordination of their science courses with science and mathematics colleagues so that the courses enhanced each other. The intent of this collaboration is to improve student learning.

Objective 3 Summative Information

Objective 3: Students in classrooms of participating teachers who implement Modeling Instruction will demonstrate pre/post content gains.

Although some teachers administered both pre and post tests to their students most teachers administered a pretest but not a posttest. Even so, matched pre and post test data were collected, analyzed and summarized for 685 students.

The Simplified Force Concept Inventory was administered pre and post in 2008-09 and 2009-10 to 337 matched students. Mean scores increased substantially from pre (26) to post (50).

The Assessment of Basic Chemistry Concepts was administered both pre and post to 348 matched students in 2009-10. The pretest mean score was 36 and the posttest mean score was 48, an average gain of 12 points.

The following chart of student results on the Simplified Force Concept Inventory was provided by Dr. Sharon Osborn Popp, with the note: Preliminary research on 337 students from grades 11 and 12 with the FCI and SFCI indicates comparability between scores on the FCI and SFCI (i.e., the simplified language of the SFCI does not provide an unfair advantage, but may be an appropriate accommodation for younger students and/or students with limited English proficiency). These 337 students were taught by 12 teachers. The mean pretest score was 26 and the mean posttest score was 50.

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ASU ITQ #ITQ08-01 ASU (Final External Evaluation Report)
The Assessment of Basic Chemistry Concepts (ABCC) was summarized for 348 students taught by seven teachers. The mean pretest score was 36 and the mean posttest score was 48. This was an average gain of 12 percentage points. The following chart was provided by Dr. Jackson.
Mentoring in 2008-09 and 2009-10

Larry Dukerich and Roseanne Magarelli were hired as Modeling Instruction Mentors during fall semester 2009. Ms. Magarelli mentored physical science teachers and Mr. Dukerich mentored chemistry teachers. Mr. Dukerich reported that his visits with chemistry teachers increased his awareness of the problem that many chemistry teachers face with districts mandating that teachers follow the same instruction sequence. This pacing requirement, he felt, "reduces teachers to automata, mindlessly following a one-size-fits-none approach. I have no desire to require that all teachers implement modeling instruction in their classrooms. However, I would hope that directors of curriculum would remain open to the idea that some diversity is good for the profession, for without testing alternative approaches, the science curriculum will become stultified. (Some would argue that this has already occurred.)" Mr. Dukerich quoted the NSES physical science content standard and the article, "The Chemistry Classroom" (Herron, D., Journal of Chemical Education, 1996) in support of utilization of flexible, meaningful discussion and modeling to enhance learning.

During fall 2009 Mr. Dukerich mentored sixteen teachers and Ms. Magarelli mentored four teachers. Both Dr. Jackson and Mr. Dukerich extended the mentoring offer to modeling teachers both via email and in person at a follow-up session. Those teachers who expressed an interest in having Mr. Dukerich observe them and offer feedback were the ones mentored. Schools and the number of teachers at each school that were mentored were: McClintock HS (1), Desert Ridge HS (3), Camelback HS (1), Mesquite HS (1), Chandler HS (2), Highland HS (2), Red Mountain HS (3), Hamilton HS (3), Stapley Junior HS (1), Carson Junior HS (1), Phoenix Christian HS (1), and Alhambra HS (1).

Mentoring included classroom visits followed by either phone conversations or follow-up visits in which teachers were provided feedback. The summers when the 16 teachers took their first Chemistry or Physics Modeling Workshop ranged from 1995 to 2009: 1995 (1), 2004 (1), 2005 (1), 2006 (1), 2008 (2) and 2009 (7). Two of the teachers had not taken a Modeling Workshop.

In addition to mentoring Mr. Dukerich supported modeling activities by attending a chemistry workshop at Mesquite High School where he met with the Desert Ridge High School principal, Dan Coombs, and Jayson Phillips, the secondary science resource person for Chandler to talk about Modeling Instruction. Mr. Dukerich also spent time working with Earl Barrett (also supported fall semester by this ITQ grant) to plan meetings and help prepare policy documents to give to school district officials in support of Modeling Instruction. Thirteen teachers responded to the survey about the mentoring provided by Mr. Dukerich. The possible responses were rarely, sometimes, usually and almost always. There were no "rarely" responses. The following chart displays percentages of frequency of assistance provided by the Modeling Instruction (MI) Mentor.

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3 "There is always room for improvement."
All the low-performing charter schools in metro Phoenix (i.e., within commuting distance of South Mountain HS) were invited to partner with this ITQ project. The majority didn't have teachers who were interested or able to participate, so the ASU's Modeling Program partnered with all the charter schools in which teachers volunteered to participate. The following is a summary of feedback from teachers mentored by Ms. Magarelli, who mentored teachers at the charter schools.

Teachers were extremely enthusiastic about the mentoring process as a tool for professional growth and development generally and as a way to support implementation of modeling. They offered high praise for Ms. Magarelli personally.

Specific benefits of the process identified by participants in the 2008-09 program year included:
- Provided constructive ideas to improve teaching and classroom management.
- Provided feedback in constructive, positive, non-judgmental way that led to increased confidence, improvements in practice and more enjoyment in the teaching process.
- Specific and meaningful help in incorporating modeling pedagogy and in creating and adapting lessons into a modeling instruction approach.
- Communicated the importance of focusing on the needs of students.
- Source of encouragement, support, collegiality that allowed participants to be open in expressing concerns and issues and that built persistence to help them stay the course.

Teacher-respondent descriptions of Ms. Magarelli's approach and style included: positive, encouraging, affirming, collegial, very professional, good communicator, "spirit of joy and encouragement." One respondent mentioned a desire to participate in brainstorming sessions with other teachers who teach the same material. This respondent also expressed concerned about the "time crunch" and never having "enough time to get things done."
Specific benefits of the process identified by the 2009-2010 cohort included:

- Learned how to identify opportunities to improve teaching; how to self-evaluate.
- Received specific and helpful feedback about instruction.
- Accessed links of support about general teaching practices and troubleshooting tips for problem students.
- Had time to try new ideas and then to evaluate progress.
- Identified new ways to improve classroom practices.
- Established routines and procedures that contributed to effective teaching and learning.
- Reinforced the importance of focusing on the needs of students.
- Assisted in creating and adapting lessons into a modeling instruction approach.
- Shared professional experiences and wisdom in a collegial manner.

Teacher-respondent descriptions of Ms. Magarelli's approach and style included: joy to work with, take charge person, inviting, affirming, passionate, positive, encouraging, magic, and contagious excitement.

**Strengthening Modeling Instruction in AZ**

**INFORMATION ABOUT THE 2009-10 SATURDAY FOLLOW-UP WORKSHOPS**

There were 12 follow-up Saturday Workshops during the 2009-10 academic year. All teachers who ever enrolled in a modeling workshop or course were invited to attend the Saturday follow-up meetings. Participating teachers were expected to complete two hours of homework in addition to attending the four-hour workshops. The 2009-10 schedule of Saturday follow-up workshops included four workshops for each field of study with physical science and math integrated as one topic area.

<table>
<thead>
<tr>
<th>Physical Science and Math</th>
<th>Chemistry</th>
<th>Physics</th>
</tr>
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<tbody>
<tr>
<td>September 19, 2009</td>
<td>August 29, 2009</td>
<td>August 29, 2009</td>
</tr>
<tr>
<td>November 14, 2009</td>
<td>September 26, 2009</td>
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<td>February 20, 2010</td>
<td>November 7, 2009</td>
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<td>April 17, 2010</td>
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<td>January 23, 2010</td>
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</tbody>
</table>

In June 2010, Dr. Jackson asked the Saturday workshop facilitators why attendance was so low during the 2009-10 school year. One of the facilitators wrote: In chemistry, the two facilitators set up their Saturday workshop dates in July when their workshop was meeting. Later they learned that one of the dates did not work for the hosts at the school. ñWe kept trying to negotiate dates and school sites and finally had our fourth meeting in April (2010).ñ He added:

We had many east side teachers that flat out said they would not travel to the west side for a meeting (we had scheduled 4 different spots to be fair to all). Lack of free supplies may have been a deterrent but no one had said as much, as they didn't know any better for the most part - not all have heard that we used to have more money in the past for teachers to receive. We definitely talked about the low attendance - the ones present benefited and gave us good evaluations, but we believe teachers are under much more stress with the increasing school and district demands on their time, worry about layoffs and just being busier than ever before. I can certainly relate to that. I announced things over and over (but they just didn't attend).
Dr. Jackson wrote to the External Evaluator:
Fewer chemistry and physics teachers attended the four Saturday workshops than in prior years. In physical science, the attendance remained about the same as in prior years, but it has always been low. What seems most likely to me is, as the Facilitator wrote, "Teachers are under much more stress with the increasing school and district demands on their time, worry about layoffs and just being busier than ever before." I have learned that class sizes increased last year; and teachers report that their pay was reduced, thus forcing some to look for additional part-time work.

A teacher wrote to Dr. Jackson after participating in the April 2010 Saturday workshop:
The density follow-up modeling workshop was great. I marvel at the depth of understanding that comes from such simple equipment. Science equipment can be very expensive and teach only one concept, but Pat and Lee work wonders with glass bottles, plastic tubs, and cans. Just wow!

PARTICIPANTS’ EVALUATION OF THE 2009-10 SATURDAY WORKSHOPS

The 2010-11 Saturday Workshop Evaluation Form included four open-response items and six fixed choice items with a scale of 1 to 4:
4 = Closely aligned with my needs (Met my needs)
3 = Mostly adequate; needs minor changes
2 = Partially adequate; needs improvement
1 = Inadequate; not suited to my needs

The evaluation form was completed by participants of five workshops. There were 39 responses for all five workshops, pooled.

Mean ratings for all five sessions pooled (39 responses) are displayed in the following line chart. All mean ratings were greater than 3.60. The Saturday sessions (workshops) met the needs of participating teachers at a high level, the Saturday session content was interesting and useful, instruction was clear and engaging and participants received appropriate assistance and support during the sessions.

ASU ITQ #ITQ08-01 ASU (Final External Evaluation Report)
Participants' evaluation feedback is presented in the remainder of this section. Bar charts displaying distributions of ratings are included immediately after summaries of responses to the open-response items.

**PHS 534/594 (Three Workshop Sessions)**

**September 19, 2009 – 5 participants**
- Ideas for Improvement
  - More time (4 responses)
  - Time on task sometimes is diverted due to some off-topic conversations
- Ways participants will use skills and resources from this training in preparing for teaching
  - Will develop an alternative lesson for conversion factors
  - Will be more deliberate in my teaching
  - Will revise my lessons
  - Increased awareness of my own teaching and increased understanding of topics
- Ways participants will use skills and resources from this training in the classroom with students
  - Teach the metric system
  - Create my own lessons in other content like Life Science
- Other comments:
  - Really enjoy the workshops
  - So much work, so little time!
  - Love what you're doing! Thanks

![Bar Chart](chart.png)

**November 14, 2009 – 5 participants**
- Ideas for Improvement
  - Maybe provide examples of practicum instructions?
  - Some review from summer, but then, not everyone was in that class
- Ways participants will use skills and resources from this training in preparing for teaching
  - Breaking skills down into tasks
  - Have a sequence of how the measurement skills will be developed and strengthened
  - Excellent reminded me of the importance of the practicum
  - Substitute in for earlier lesson in my own curriculum/lesson plans
- Ways participants will use skills and resources from this training in the classroom with students

ASU ITQ #ITQ08-01 ASU (Final External Evaluation Report)
Plan detailed order of steps.
I will use the measurement activities during my astronomy unit.
Do more practicums with my class and review previous models.
Will duplicate/mimic and add to. I need to research data on memory sticks for other worksheets.

Other comments:
Better than the last one.
I currently have just begun to teach some of what we have done.
The entire process is geared towards a year of physical science but many of us have 9 weeks, only, to cover all this so I have the feeling I am shortchanging the development process since I cut things short.
As always - a great training!
Well planned.

February 20, 2010 – 8 participants
Ideas for Improvement
We need snacks!
More time
I was a little confused as to what would actually be said/presented to the students. I understand this may need to be adjusted according to needs of class. What were the actual learning objectives?
Stay on task; use time more effectively.

Ways participants will use skills and resources from this training in preparing for teaching
Will adapt existing lessons to include modeling
More focus on inquiry, group presentations and white boards
Will share the information with the 8th grade chemistry teachers at my school together maybe we can develop some lessons for our school.

Ways participants will use skills and resources from this training in the classroom with students
Will encourage discovery; student centered classroom
Perfect for my current unit. I will have my students use the Power Point to create a timeline and present as each scientist.
Blocks for compounds and Power Points
Socratic questioning

Other comments:
The session was very helpful, I focused again on modeling and not so much direct instruction.

Great follow-up.

Needed a reminder to bring flash drive.

Great program.

Good to have things posted.

---

**Two Sessions of Chemistry**

**November 2009 Session at Centennial High School – 12 participants**

- **Ideas for Improvement**
  - Second half was too much like the summer class.
  - A little more time for completing worksheets.
  - Discuss more complicated examples – Teach the Teachers.

- **Ways participants will use skills and resources from this training in preparing for teaching**
  - I will share with non-modelers in district.
  - Will alter instruction to help improve understanding of the concept.
  - Incorporating the history into unit 4.
  - ‘I needed all of this to help with units 9 and 10.’

- **Ways participants will use skills and resources from this training in the classroom with students**
  - Worksheets and explanations – putting words in my mouth.
  - To help students better understand atomic theory and bonding.
  - Will use Legos to help with the understanding of valence power and bonding; will use terms combining power and valence electronics to help with understanding the difference.
  - Will use Legos in other subjects e.g., Biology & Physical Science.

- **Other comments:**
  - It was good.
  - We covered enough material to explain each area covered.
  - Will share with other chemistry teachers in district.
  - Never wasted any of my time.

ASU ITQ #ITQ08-01 ASU (Final External Evaluation Report)
April 17, 2010 Session – 9 participants

- Ideas for Improvement
  - Computer access (2 respondents)
  - Equipment woes
  - Spend more time on what is after Unit 8

- Ways participants will use skills and resources from this training in preparing for teaching
  - In chemistry class
  - To reset/remind modeling techniques
  - Having students do daily reflections and a separate notebooks for journaling and notes
  - Will share the information with colleagues
  - Will meet with other teachers to plan Unit 10.

- Ways participants will use skills and resources from this training in the classroom with students
  - To assist students in learning
  - Liked the (Mercury) crystal program (2 respondents)
  - The Mercury program was interesting and could be useful
  - Anxious to use the Mercury software in both chemistry and earth science. Looks really neat!
  - The ideas for journal writing/reflections; modeling = active learning; final exam score replaces lowest test score during the semester
  - Will implement journals

- Other comments:
  - I appreciate the input from everyone who has been teaching for more years than I have.
  - Thank you for a great year of Saturday meetings!
  - Thank you for offering this session.
  - RTOP review was helpful
  - Terrific session
  - Great workshop † great to interact with other modelers. Finishing up the year energized!!
  - As always † excellent
Earl Barrett, a retired expert physics and chemistry teacher from Dobson High School, was hired as a short-term consultant to establish a self-sustaining mechanism in PUHSD for education and communication among school principals, assistant principals and teachers who use modeling instruction. By mutual consent of PUHSD administrators, Russ Shaffer, Phoenix Union High School District Science Specialist, led a series of educational sessions for principals and assistant principals in the district on December 11 (2008), January 12 and January 27 (2009). The purpose of the training meetings was to show administrators what modeling looked like so when they evaluate teachers they are more aware of what the best practices are in Modeling Instruction. Through this project’s work with the school district, administrators were encouraged to help teachers incorporate these practices, specifically, to do labs, utilize modeling best practices and use technology. During these training meetings Mr. Shaffer went through a modeling cycle doing the mass-volume lab activity. Participating administrators did the mass and volume measuring, made a graph of M vs. V results on their whiteboards and discussed the meaning of their graphs of brass and Al cylinders. Mr. Shaffer summarized:

*Each session was two hours and we went through a modeling cycle (in accelerated form obviously) doing the mass-volume lab activity. I had the administrators be students and they did all the work in student mode. They had to be quickly taught about what mass and volume were and how to measure/calculate them as high school was a long time ago for most of them. I was the teacher for the sessions and would often make ‘teacher mode’ comments to them about modeling vs. traditional, things we want our kids to do and say, things we want our teachers to do and say, ask them to compare things, and all that. I gave them some information about best practices at the end and had them give me some oral feedback.*

Schools and the number of administrators (14 total) that participated in the modeling administrator meetings were: Metrotech (4), Cyber (1), Bostrom (1), Suns-Diamondback Academy (1), Fairfax (4), Maryvale (3). Although multiple attempts were made to schedule these trainings at the other 10 schools, Mr. Shaffer did not succeed at getting the needed commitments.

In January 2009, Mr. Barrett organized a series of three informational meetings at Mesa School District with two school district science coordinators and science department chairmen in all
junior and senior high schools. Meetings were led by Mr. Barrett, Jane Jackson, Larry Dukerich, and Roseanne Magarelli

FALL 2009 MEETINGS WITH THREE SCHOOL DISTRICTS

Earl Barrett, a retired expert physics and chemistry teacher from Dobson High School, was hired as a short-term consultant during fall semester 2009 to establish a self-sustaining mechanism in Gilbert and Chandler school districts for education and communication among school principals, assistant principals, physics teachers and chemistry teachers who use modeling instruction. Mr. Barrett surveyed all the physics teachers in the two districts in November and December 2009. He also surveyed all the physics and chemistry teachers in Deer Valley SD and met with school administrators (the meeting was called by Debra Webb, Director of Curriculum). Deer Valley is a northern suburb of Phoenix. Deer Valley USD is the fourth largest school district in AZ. Of its five high schools, physics modelers teach in four of them, and two chemistry modelers.

All physics and chemistry students in Deer Valley school district are required to take an end-of-semester test but the test does not follow Modeling Instruction topics. As a result, teachers were being forced to teach to the test instead of teaching to the sequence in Modeling Instruction. In Deer Valley USD, Gilbert USD, and Chandler USD, end-of-semester district-wide tests are used in chemistry and physics. In physics there is no problem with use of Modeling Instruction. However, the modeling chemistry storyline is not aligned with traditional textbooks, so chemistry modelers must adapt the sequence so that their students will pass the end-of-semester test. The students don't learn as much, of course, because the concept flow is weakened.

All physics and chemistry teachers in the school districts who had taken an ASU Modeling Workshop were invited by email from Earl Barrett to answer these questions. Their responses were compiled and summarized by Earl Barrett. The findings were consistent with evidence of Modeling Instruction successes and challenges during the years of ABOR ITQ funding.

- There was universal satisfaction with the quality of training provided in the summer workshops. Factors such as time on-task and the efficient use of white boarding have taken time for each teacher to adjust to their own style.

- The amount of equipment and supplies varies with each school and discipline. The more modelers there are, the greater need there will be for equipment and computer hardware. Lack of equipment has not deterred teachers from using the pedagogy and that speaks to their ability to share and work collaboratively.

- There is a strong level of support between the principal and the local administrative staff evident from the responses. There seems to be a disconnect particularly in chemistry with the district administration in terms of the kind of testing being used to evaluate the modeling pedagogy. Modeling teachers have had to ignore the fact that their students have not studied the material they are tested on for the semester CRE. A change in sequence is not possible if they are to implement the Modeling pedagogy.

- There are mixed results concerning the effectiveness of the individual teacher evaluations, but there is no doubt about the district semester evaluations being inadequate for evaluating the effectiveness of those who employ modeling. What is striking is the absence of a dialogue between the modelers and the district with no plan to allow for a reasonable alternative.

- Between regular group meetings and ongoing mentoring the modeling teachers feel there has been adequate support.

ASU ITQ #ITQ08-01 ASU (Final External Evaluation Report)
Sample quotes from Gilbert USD teachers:

- I absolutely feel I received adequate training. The three-week workshops that are put on in the summer are excellent. I do feel, however, that modeling takes practice, and even with adequate training, it will take a year or two before someone is achieving high levels of teaching by using the modeling approach.
- Yes, our principal gave us the green light to make any adjustments that we need to teach the modeling method even though our end of semester final exam does not have the same type of questions that our students will be able to answer. Our current final exam covers the material by a sequence a traditional-based class would cover. We are currently putting together some information to provide our district leaders so they can begin to learn the benefit of modeling instruction and start the process of changing our end of semester final exams. We are gaining more modelers in Gilbert than ever before.

Mr. Barrett noted that teachers using modeling to reform pedagogy need the support and encouragement of the district administration, that the mid-year assessment of student performance did not align with the modeling sequence in chemistry and that this situation needs to be addressed. Mr. Barrett recommended a dialogue with modeling leaders dealing with this issue and the lack of equipment needed to fully employ Modeling Instruction.

The Deer Valley follow-up meeting included approximately 15 Deer Valley personnel including principals, science department chairmen, and a chemistry/physics teacher who uses Modeling Instruction.

Mr. Barrett wrote to Debra Webb, Director of Curriculum after the meeting:

That was an impressive group. They paid attention and offered relevant insight, especially the principals. The win/win would be for your master teachers to learn enough in a summer workshop to become role models for reform. The more I think about it the more I feel there needs to be a master teacher at each site that truly understands the benefits of Modeling Instruction and who can serve as a mentor to teachers who are ready to embrace a different way to instruct. The biggest gain for Deer Valley, other then training additional chemistry modelers, would be to train biology teachers in the first course of physical science. Knowing that the AIMS test is 50% science as inquiry, these teachers would be better prepared to incorporate inquiry and analysis skills into their curriculum.

I was also impressed that you were so open minded about looking at assessment as a process you could adjust to future changes in the way student assessment is designed. Remember, there is also school year follow up support for workshop participants if they request it. Thank you for bringing the right people together and I hope a solid future partnership can be built and sustained.

On March 24, 2010, Larry Dukerich also wrote about the successful features of the meeting:

I, too, was pleased with the receptivity of the people there. There was some healthy skepticism, but people were open-minded. I think that Debra Webb's remarks about finding common ground on the assessment in chemistry were encouraging. I believe we have to keep promoting the view of the one principal who said that so long as kids got to the same place at the end that it didn't matter what path they took to get there. We have to keep stressing that testing is designed to INFORM instruction, not to drive it.
Observations of 2008-09 Saturday Follow-up Workshops

Follow-up Saturday workshops provided teachers with an opportunity for ongoing professional development. This section includes information about selected workshops that were observed externally with detailed observation reports disseminated to the Project Director shortly after the workshop.

PHYSICS (AUGUST 23, 2008)

The agenda for this workshop included 1) sharing problems, achievements and implementation questions; 2) RTOP self-assessment training. After a brief welcome the 25 teachers split into groups of five matching up teachers with modeling skills with those who were novices. Groups were instructed to share experiences teaching physics using modeling, classroom management skills, how to address a variety of learning abilities, etc. Novice members were encouraged to develop three questions for more experienced members of the group. These were lessons learned that experienced physics teachers on mathematical models shared:

- Buy lots of white board markers!
- Keep a slow teaching pace to ensure understanding.
- Use reflective writing (e.g., personal journals and email) after assignments for deeper understanding.
- Let students take control of work and teaching each other.
- Feel free to modify assignments to tailor them to unique classroom abilities and learning mode.
- Complete lab and test/understand all instruments before students undertake lab.
- Use classroom technology to engage students (e.g., Power Point, smart boards, etc.)

Teachers’ interactions and discussions were open, friendly and engaging with time for all teachers to provide multiple view points. It appeared that the inexperienced teachers gained lesson plan ideas, logistics of implementing modeling instruction, and ideas pertaining to general day-to-day classroom management all of which were discussed at length from multiple view points. The discussions seemed to help novice and experienced teachers.

The Facilitator, Dr. Eugene Judson, gave a Power Point presentation about the RTOP in which he explained its origins, project goals, where funding came from, and the teaching criteria on which RTOP was based. He also explained how to assess lessons using RTOP’s rating system. Teachers watched a short (15-minute vignette) video of a fourth grade class doing a physics experiment in which students built circuits using batteries, wires and light bulbs. After watching the video a second time teachers rated the lesson using RTOP criteria and compared their scores to professional RTOP ratings. This process was repeated for another short vignette. Teachers were actively engaged in the training. Novice teachers especially seemed to gain from the discussions about instructional methods.

The workshop Facilitator was interviewed by the External Evaluator after the workshop. The Facilitator reported that from his vantage point the teachers were engaged in the RTOP training activities, although not all to the same extent. The teachers seemed generally receptive about learning how to utilize the RTOP assessments (short and long forms). The Facilitator added, ‚From the evaluation forms however, I’d say about 20% of the teachers did not view the RTOP training as a subject that was appropriate for a follow-up session to a modeling instruction workshop. Perhaps they were looking for more hints about implementation of the tools they learned during the summer.Š More information prior to the meeting about why the RTOP is an important tool would have helped teachers understand the relationship between Modeling Instruction and the RTOP.

ASU ITQ #ITQ08-01 ASU (Final External Evaluation Report)
The Charter School Mentor also observed this Saturday Follow-up Workshop so the External Evaluator interviewed her by email. She wrote:

I observed the session from 9:00-1:00 PM. The discussion centered on how the Modeling Instructors were incorporating this pedagogy into their Physical Science and Physics Curriculum. The veterans were white boarding their advice to new modelers and the new modelers were asking questions of the veteran modelers. The discussions were very informative and quality advice was shared.

The Facilitator presented the importance of modeling and presented the RTOP for the educators to first witness and then assess current modelers in the field through video clips. Groups were assembled and the participants shared their findings. The clips were replayed and the participants reviewed their scores. The final discussion included reviewing seasoned RTOP evaluators' reviews of the video clips.

Excellent workshop! The collegial process was both informative and provided a starting point for all modelers to assess themselves periodically.

My suggestion was to have the mentees pick an area of the RTOP to hone in on and practice and then to evaluate that section later in the semester.

The observation report included this comment by the External Evaluator: It would make sense for the RTOP to be introduced during the summer professional development sessions so that teachers understand that it is an important component of implementing modeling. Knowing that 20% of the teachers did not view the RTOP training as an appropriate subject for a follow-up session to a modeling workshop is a concern. It might be helpful to include training objectives as well as an agenda when contacting the teachers prior to the follow-up sessions and then have the session facilitators go through the learning objectives at the beginning of each follow-up session. It appears that teachers do not view the follow-up sessions and the summer sessions as a cohesive, integrated professional development model. The suggestion the Charter School Mentor made to have mentees pick an area of the RTOP to hone in on and practice seems to be a very good way to get teachers started on using the RTOP because the RTOP might feel a bit overwhelming to teachers who are using it for the first time. The fact that some of the teachers did not understand how the RTOP connects to their implementation of modeling instruction supports the importance of incorporating the RTOP into the modeling instruction summer workshops.

**PHYSICAL SCIENCE AND MATH (SEPTEMBER 27, 2008)**

This Saturday Follow-up workshop was held at South Mountain High School. Teachers from both private and public schools were in attendance. The disciplines represented by participants were Biology, Chemistry, Physics and Earth Science. Materials made available for teachers in both hard copy and digital format were: a copy of the State Standards, RTOP assessment materials, and graphing worksheets.

After a brief welcome, teachers split into groups of four or five to share personal stories and teaching anecdotes of pros and cons on teaching Unit 1 (Number sense, labels/units, conversion factors, basic modeling applications, significant figures, slope, metric measurement, white boarding, etc.). Teachers asked each other questions during the course of this activity about teaching methods, etc. Group results were discussed in front of the classroom with everybody in attendance. The advantages of using Modeling Instruction include reflective writing, students are empowered to learn, the curriculum is concept-driven, technology can be integrated into lessons and the vocabulary list helps students learn the terminology behind modeling. The challenges to Modeling Instruction are that students want to be told what to do (and they aren’t), activities are time consuming, the modeling program goes against the district curriculum map, and deficiencies in mathematics hamper student learning of science concepts.
The interactions and discussions between teachers and workshop facilitators went very well; everybody had a lot of meaningful input. It appeared to be very helpful for the inexperienced teachers to be able to ask the experienced teachers questions; lesson plan ideas, logistics of teaching models, and general day-to-day classroom management were discussed at length and from multiple viewpoints.

The workshop was very well organized and the leadership was highly experienced and prepared. Meeting expectations were made clear to the participants and having clearly stated expectations resulted in a focused, efficient workshop. Repeated references were made to skills gained during the summer workshop and how the summer workshop content pertains to current workshop activities, future lesson plans, classroom instruction, etc. The meeting provided an open, friendly environment for teacher interaction. Teachers shared experiences and techniques for implementing physics modeling in the classroom which was well received by all in attendance.

**PHYSICAL SCIENCE AND MATH (JANUARY 24, 2009)**

This workshop at South Mountain High School was observed by a member of the external evaluation team. The agenda was: 1) Adapting your curriculum to modeling style and 2) Socratic dialog. Nine middle school and high school teachers participated in the workshop. Disciplines represented by the teachers were biology, chemistry, physics, and earth sciences.

Teachers were provided a copy of RTOP assessment materials and a worksheet with the principles of modeling used in the classroom. After a brief welcome, teachers wrote their responses to the focus question: *What makes a lab suitable for implementing the principles of modeling?* The group presented and discussed their responses which included the importance of student interest in lab experiences for high engagement levels, up-to-date computational tools, needed background in order to comprehend theory behind scientific relationships, encouraging students to take learning risks in exploring the unknown, and teachers having enough time to plan and debrief lessons.

The interaction and discussion between teachers and workshop facilitators occurred in a supportive environment. Everybody had time to share their experiences. It appeared that inexperienced gained from this session by having the opportunity to ask more experienced teachers questions about suitable approaches to implementing models in their classrooms. Criteria for logistics of teaching models and supplies needed (e.g., data gathering technology, computers, analytical software, etc.) were discussed at length and from multiple viewpoints. This seemed to help experienced and novice teachers.

The facilitators then asked the teachers to reflect on two focus questions: *What are the principles of modeling? What are the challenges associated with teaching modeling laboratories?* The general themes of the teachers’ responses to the first question about the principles of modeling were:

- Teachers need in-depth knowledge of modeling concepts and knowledge of possible student misconceptions.
- Paradigm modeling lab (foundational lab) needs to establish base concepts, modeling procedure and presentation format. This lab can be referenced in future laboratories.
- Collaboration between students is essential to the modeling process.
- Visual representation is important for data analysis and concept reinforcement.
- Modeling assignments need to apply to a variety of formats (e.g., graphical, written, discussion based formats).
- Assignments need to force students to use modeling-type thinking.
- Models need to match real world observations.
Modeling content needs to be cohesive and needs to build over the course of the semester. Subject areas can be presented in a "story" format with an introduction, arc, and ending. Subjects can stress concept interconnectedness and the interdisciplinary nature of scientific inquiry.

State education standards are essential to the Socratic process.

These were the challenges that come with teaching modeling:

- The teacher needs to know the fundamental definition of "modeling".
- Dialogue between teachers is essential for success. Teachers can share experience, classroom success, etc. Teachers should follow the success of other teachers involved in similar activities.
- Teachers often have to balance students' past education when introducing new concepts. Not all students learn at the same speed.
- Labs need to be designed so that they satisfy multiple state standards in modeling session.
- Teachers need to start small and build concepts up.
- Interconnectedness of concepts should be emphasized.
- Student driven discussions can keep the class on track and provide for opportunities for identification of any concept misconceptions. Students' question can represent novel approaches and insight to modeling concepts.

Next teachers met in small groups according to subject expertise in order to collaborate on future lesson plans. These plans were developed using RTOP guidelines and points raised during the morning discussions. Lesson plans were to be partially completed at the workshop and then finished and sent to one of the Facilitators as a workshop product.

The workshop was very well organized and it was evident that the facilitators were highly experienced and well-prepared. Workshop expectations were made clear to all participants, which resulted in a focused, efficient workshop. Repeated references were made to skills gained in past meetings and how that content pertains to current workshop activities, future lesson plans, classroom instruction, etc. Teachers shared experiences and techniques for implementing science modeling in the classroom which was well received by all in attendance. The small size of the group allowed the two Facilitators to engage the teachers in a personal, in-depth manner. For example, while the teaching groups were collaborating on their lesson plan product, Lee Rodgers took each group aside for individualized coaching.

The External Evaluator interviewed the facilitators after the workshop. They both agreed that the workshop went very well and that they would not have done anything different. The learning highlights from their perspective were that teachers developed their skills in developing modeling lessons were explored, strengthened their lesson planning skills, explored creating a modeling lesson/lab that includes modeling principles and gained more precise understanding of a model.

Evaluator\(^4\) Note: There was confusion among the teachers in attendance about the exact definition of the term modeling. In order to address this, one Facilitator gave examples of models used across a variety of disciplines (e.g., ecosystem model, phase state model, Newtonian motion model, etc.).

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\(^4\) Evaluator\(^\) Note: There was confusion among the teachers in attendance about the exact definition of the term modeling. In order to address this, one Facilitator gave examples of models used across a variety of disciplines (e.g., ecosystem model, phase state model, Newtonian motion model, etc.).
Appendix A: Project Logic Model and Evaluation Plan

Clarifying Program Theory

I Basic Assumptions
   A. Resources: ASU faculty; ASU Modeling Program; Grant administrators (Robert and Jane); ASU laboratories and facilities; ABOR funding; previous research findings; Modeling assessments; teachers and principals from established and new partner school districts.
   B. Barriers: Teachers HQ but not highly effective; out-of-field teachers; low teacher salaries; geographic isolation of teachers in many high-need districts; poorly stocked school laboratories; poorly prepared students; unaffordable university tuition; high turnover of administrators and teachers

II Activities
   A. Products: Valid and reliable Modeling Instruction
   B. Services: Professional development consisting of workshops/classes with follow-up Saturday sessions during the school year.
   C. Infrastructure: Established Modeling Program with pre/post assessment results.

III Outputs: Mathematics and science teachers take 1 or 2 of 10 Modeling Workshops or other content courses; teachers participate in 4 all-day Saturday meetings in 3 subject areas; principal training sessions and meetings; students are pre/post tested

IV Outcomes
   A. Short-term Outcomes (learning): Principals report increased understanding of Modeling; teachers increased content knowledge; teachers learn instructional strategies and scientific use of classroom technology
   B. Intermediate Outcomes (action): Increased numbers of teachers in schools who use Modeling instruction;
   C. Long-term Outcomes (condition): More teachers attain HQ status; HQ teachers are more effective; participating teachers' students increase content understanding from pre to post; increased support for Modeling among principals

V Impact: Improved teaching of mathematics and science in Arizona junior and senior high schools with improved AIMS math and science scores

Theory of Change: Increased teacher mathematics and science content knowledge and use of modeling instruction as well as principal support of high quality proven (modeling) instruction will result in increased student understanding of mathematics and science content.
VI. External influences that:
   A. Support Project Activities: ABOR funding; national recognition of Modeling Program; highly qualified in science is not necessarily “highly effective” in teaching science; teachers need content preparation to teach advanced second-year science courses; national recognition in education and business of the need for increased student proficiency in the sciences; low AIMS scores in math and science focus the need for improved learning for all students in these subjects

   B. Limit Project Activities: Teacher turnover; teacher attrition; low Arizona salaries for teachers; administrator turnover; science not a high priority in many schools; poverty; teacher isolation in rural communities; many physics teachers didn’t major in physics; teachers need content preparation to teach advanced second-year science courses which is not provided nor funded by the DoEd; financial obstacles to teachers updating science content (many teachers cannot afford the $1600 per course tuition); high stakes tests because they promote rote memorization of facts; and lack of administrative support and parental support for inquiry science and for math-science coordination.

The Plan for Tracking Intended Resources, Activities, Outcomes and Impacts

<table>
<thead>
<tr>
<th>Resources</th>
<th>Activities</th>
<th>Outputs</th>
<th>Short and Long Term Outcomes</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers of STEM Teacher stipends ASU laboratories ASU classrooms Workshop facilitators ASU faculty ASU infrastructure High need SDs HQ data from SDs ABOR ITQ funds</td>
<td>Recruit teachers from high-need districts and schools, workshop facilitators, mentors and ASU faculty; offer Modeling Workshops &amp; content courses (rotated scheduling at ASU)</td>
<td>9 graduate courses (including new course Electricity for Middle/Secondary teachers) taught in summer 2009; 10 additional teachers will become HQ in targeted subject area; Total service delivery hours/course: 60 to 90</td>
<td>(1-3 yrs) Teachers become HQ, increase posttest content scores &amp; use RTOP to improve instructional practices. Teachers implement modeling instruction (4-6 yrs) Teachers become more effective as measured by student AIMS tests</td>
<td>The majority of Arizona math and science teachers in all schools will be highly qualified.</td>
</tr>
<tr>
<td>Modeling leaders ASU Physics Dept Classrooms of modeling workshop leaders ABOR ITQ funds</td>
<td>12 structured follow up Saturday workshops during 2009-10 school year; mentoring during fall semester by Larry Dukerich and Rosanne Magarelli</td>
<td>70% of teachers involved in summer PD will participate in the structured meetings</td>
<td>(1-3 yrs) Participating teachers will report higher level of modeling than non-participating teachers (4-6 yrs) some teachers will become modeling leaders</td>
<td>More teachers in science and math departments will use modeling instruction.</td>
</tr>
<tr>
<td>Teachers Students Modeling Survey ASU Modeling office ASU infrastructure ABOR ITQ funds</td>
<td>Teachers will implement Modeling Instruction in their classrooms</td>
<td>Modeling Implementation Survey will be administered to all participating teachers</td>
<td>(1-3 yrs) Students in teachers' classrooms will demonstrate pre/post gains in the appropriate Concept Inventory (4-6 yrs) Post test gains will increase substantially each year.</td>
<td>Improved student science and math content knowledge in AZ as demonstrated by increased science and math AIMS scores.</td>
</tr>
</tbody>
</table>

ASU ITQ #ITQ08-01 ASU (Final External Evaluation Report)
Objectives, Formative Measures and Performance Measures

**Objective 1:** 75 Arizona (majority in high-need districts) teachers participating in June and July 2009 Modeling Workshops and other content courses will improve their physics, chemistry, physical science and/or mathematics content knowledge as demonstrated by concept inventories.

Formative measures: Course surveys, teacher satisfaction

Performance measures: Pre/post assessment of teachers using concept inventories (e.g., FCI); number of teachers who were not HQ (pre) and number who become HQ (post).

**Objective 2:** Teachers who participate in June and July 2009 Modeling Workshops and other courses will improve STEM instructional strategies including effective classroom discourse management and content organization.

Formative measures: RTOP Self-Assessment to assess level of implementation, teacher satisfaction and self-assessed increase in knowledge and skills with Saturday follow-up workshops; names of participating teachers

Performance measures: Modeling Instruction Implementation Survey

**Objective 3:** Students in classrooms of participating teachers who implement Modeling Instruction will demonstrate pre/post content gains.

Formative measures: Modeling Instruction Implementation Survey

Performance measures: Appropriate Concept Inventories

**External Evaluation Plan**

The timeline of the evaluation plan had to be adjusted primarily because of the cutbacks in administrative offices at ASU. The updated evaluation plan is displayed here with the adjusted dates in parentheses. An example of this is that we thought the assessment data would be analyzed by Dr. Popp by the end of December, 2009 but Dr. Popp didn’t receive the data from the ASU center until the last week of March 2010

<table>
<thead>
<tr>
<th>Obj.</th>
<th>Formative Evaluation</th>
<th>Outcome Evaluation</th>
<th>Data, Measure, Instrument and/or Activity</th>
<th>Timeline and Responsibilities Target Date (with Adjustments)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td></td>
<td>Grades for ABOR ITQ supported teachers in Modeling workshops and courses</td>
<td>Jane Jackson and course instructors August 2009</td>
</tr>
<tr>
<td>1</td>
<td>X</td>
<td></td>
<td>List of ABOR ITQ supported teachers with contact information (email and phone) and names of summer 2009 courses; HQ status pre and post</td>
<td>Jane Jackson sends to Rose Shaw via email September 1, 2009</td>
</tr>
<tr>
<td>1</td>
<td>X</td>
<td>X</td>
<td>Additional demographic and mentoring information collected, all summarized and reported. Some information will be used in the outcome evaluation.</td>
<td>Rose Shaw collects meaningful information after agreement with Jane Jackson. Mentoring survey has been developed. October 15, 2009 (May 15, 2010)</td>
</tr>
<tr>
<td>1</td>
<td>X</td>
<td></td>
<td>Post grades for June 2010 courses</td>
<td>Jane Jackson and Instructors June 2010</td>
</tr>
<tr>
<td>Obj.</td>
<td>Formative Evaluation</td>
<td>Outcome Evaluation</td>
<td>Data, Measure, Instrument and/or Activity</td>
<td>Timeline and Responsibilities Target Date (with Adjustments)</td>
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</tr>
<tr>
<td>1</td>
<td></td>
<td>X</td>
<td>Pre/post (summer 2009) teacher content assessment scores</td>
<td>Jane Jackson sends scores to Rose Shaw for analysis/reporting May 1, 2010</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>X</td>
<td>Workshop satisfaction survey administered at all 12 Saturday follow-up workshops</td>
<td>Workshop facilitators and picked up by student worker Monthly</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>X</td>
<td>Summarized follow-up workshop surveys ongoing with longitudinal aggregation for outcome evaluation</td>
<td>Rose Shaw 2009-10 school year</td>
</tr>
<tr>
<td>2-3</td>
<td></td>
<td>X</td>
<td>Modeling Instruction Implementation surveys developed with editing cycles</td>
<td>Jane Jackson and Rose Shaw November 10, 2009</td>
</tr>
<tr>
<td>2-3</td>
<td></td>
<td>X</td>
<td>Modeling Instruction Implementation surveys posted on <a href="http://www.externalevaluator.com">www.externalevaluator.com</a></td>
<td>Rose Shaw December 1, 2009 (Adjusted: April 10, 2010 and Jane will administer as usual instead of by web because teachers prefer the process and method used previously.)</td>
</tr>
<tr>
<td>2-3</td>
<td></td>
<td>X</td>
<td>Modeling Instruction Implementation Surveys completed by participating teachers</td>
<td>Jane Jackson and Rose Shaw (Adjusted: Jane and her staff will do this as per previous years; Rose will process and summarize data.) Start: March 15, 2009 End: April 15, 2009</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>X</td>
<td>Development of Modeling Instruction Mentoring assessment instrument; administered to mentored teachers</td>
<td>Rose Shaw Developed: Sept and Oct 2009 Administered to teachers: Jan 2010 (Administered April 2010)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>X</td>
<td>RTOP teacher self-assessment and/or summaries of RTOP-informed narratives from the mentors (Larry Dukerich and Rosanne Magarelli)</td>
<td>Rose Shaw Start: August 10, 2009 Complete: December 24, 2009 (Adjusted completion: April 20, 2010)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>X</td>
<td>Analysis of student data from 2008-09</td>
<td>Sharon Osborn Popp December 2009 (Adjusted: June 30, 2010 because the data were just received by Dr. Popp during the last week of March 2010; cutbacks at ASU delayed this)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>X</td>
<td>Prepare, collect, and enter pretest and posttest student data for 2009-10</td>
<td>Sara Swinson June 2010</td>
</tr>
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</table>
Appendix B: 2009-10 Implementation Survey

2009-10 TEACHER FEEDBACK ABOUT ABOR ITQ

As part of the May ITQ Implementation Survey for 2009-2010, participants were asked an open-ended question: “What do you want ABOR and/or ITQ staff to know?” Dr. Jackson sent the survey via e-mail and compiled the responses. Janis Goldstein followed up by phone with participants who did not respond quickly to the e-mail survey. Janis’s background includes 38 years high school teaching experience and two ASU Chemistry Modeling Workshops.

Comments were organized into categories of respondents. Responses to the e-mail survey shown below were copyedited as needed. In all, 38 respondents provided qualitative input through the survey, 23 by e-mail and 15 by participating in phone interviews. Of this total, 13 were Physics teachers (four with degrees in Physics and eight out-of-field), 14 were Chemistry teachers, and 11 were Physical Science teachers (seven at the middle school/junior high level and four at the high school level).

2009-10 PHYSICS TEACHERS

- I really appreciate all of the teaching materials and teaching strategies (Socratic questioning, white-boarding, etc.) that I received in my workshop. It really helped guide me through my 1st year teaching.

- This year, my school (three teachers in eight sections of regular and three sections of honors physics) implemented CASTLE for studying electrical circuits. Even the average students from other times in the year could discuss the physics of an electrical circuit with more accuracy than AP students who had studied circuits without CASTLE.

- I like white-boarding as the best strategy to overcome the shyness of my students and increase their confidence in themselves. Thanks for every help!

- I had my most truly "modeling" day one day in my IB physics class. We were talking about what happens if you throw a ball up while moving up in an elevator. One group was presenting a whiteboard with a problem and the kids started saying those things we all want to hear like, "Well, the way I thought about it...." So we all sat down in a circle and kids drew out their ideas on whiteboards and really talked through their reasoning. By the end, the class had developed a solid idea of frame of reference and created a model of the behavior based on the frame of reference and how Newton's laws play into all of this.

- The modeling program is great for teachers, and students reap the benefits. Modeling opens up the opportunity for more students to experience physics in a meaningful way.

- I've had a lot of success with modeling at the general physics level. This is the first year I've taught at the AP level and I did have some trouble trying to merge the quick pace of AP with the modeling style.

- The Modeling curriculum was so effective that I actually had parents calling the school to complain that my teaching style and my Physics class, in general, was TOO rigorous.
• Sometimes, I feel like I need to go through the mechanics workshop again because now that I've taught it, I have discovered many of my own misconceptions and have a pile of little problems to clear up. I'm sure others feel the same way.

• I did not have any of the lab/computer equipment used in modeling workshops. I expect my modeling instruction to improve with more experience.

• Has not used the modeling units as much as he would like due to lack of equipment. This summer he will write grants and hopefully receive the money needed to fund the equipment.

• Modeling really helped to put content together with teaching. Modeling is the only class that does this.

• Finds teaching the math models difficult for his ninth grade students.

• Awesome, wonderful program. It helps students to really understand physics.

2009-10 CHEMISTRY TEACHERS

• Great curriculum. Our entire chemistry and physics departments are modeling and it's working really well.

• The modeling pedagogy is wonderful for both the materials it provides teachers, but also in the methods it inspires teacher. I find myself doing things differently in all my classes that emphasize students constructing models and true learning rather than learning equations, topics, algorithms, etc. My students end up becoming much better problem solvers. Thanks modeling!!!

• Every time I create a lesson plan or worksheet, I always consider the modeling cycle in its creation. My goal for next year is more practical labs.

• Major turnarounds for some students. Confidence led to 10 student internships in the Future Renewable Electrical Engineering Delivery and Management Program at ASU.

• Thanks for providing the opportunity to expand and grow to become a more effective educator to have a more student centered classroom.

• I need more guidance about classroom management with white-boarding/questioning and how to actually get students to participate.

• Strong Curriculum. I enjoyed watching the students learn Chemistry through their own learning experiences instead of me telling them the answers.

• It was much easier for my students to work homework problems after having used modeling concepts in class. I will continue to move in the direction of teaching chemistry using modeling techniques. Gilbert USD

• I did not teach chemistry this year, I taught Chm/Phy. I was able to implement modeling into my classroom, but only some of the worksheets and labs. It has changed the retention of knowledge
in my students by leaps and bounds. The final exam I have given every year for the last four years had the highest average ever.

- Modeling works because it is student centered and self-directed. Students are responsible for their own and others' learning. The teacher becomes a facilitator. Hopes to continue to have twice weekly meetings to sharpen teachers' skills in Socratic questioning and white-boarding.

- Whole-heartedly supports the modeling program. Completed 14 of the chemistry modeling units this year.

- Modeling helps students by causing them to think. Used circle white-boarding after every lab, demo, and activity.

- The modeling method of learning is interesting and meaningful for students. They learn to discover the information and build consensus. Enrollment increased as a result of using the modeling program. Loved the program.

**2009-10 PHYSICAL SCIENCE TEACHERS**

- I struggled a lot this year. I did more modeling than I have ever done before. Next year, I will try to find a balance between the enormous amount of time that modeling takes, and all of the standards that I am required to cover since my 8th graders are tested in AIMS Science and they need to do well.

- This year was a difficult year with a great deal of classroom management problems. The entire first semester, kids' schedules were being changed. There was no consistency. Kids jumped from one teacher to another. Mid semester, they threw 7th grade at me and I inherited many new kids. Everything that I had set up for white boarding and such was shot out the window. They tell us this will not happen next year so I hope to try to incorporate modeling more effectively. I feel that I was in "survival" mode for most of this year.

- I will need a lot more than taking a summer class in order to change the way I teach. It is a total paradigm shift and it will not happen amongst the other demands of "teaching." I understand the benefits and want to pursue the strategies further.

- Modeling class prepared me for teaching physical science with confidence. There were too many changes this year making it impossible for me to administer the pre and posttest.

- Would like to sit in on a class to make up sessions I missed last summer. I liked modeling.

- Wish I had more time to take other modeling classes. I liked the constructivist approach to learning that modeling offers. Modeling is GREAT. It unlocks how to think, gives relevance to the subject and changes the way one teaches.

- The Physical Science Modeling class is the best class for learning how to teach anything. It is great that it is taught in student mode with time for teacher questions. Pat and Lee are awesome! It is great that you provide an opportunity for sitting in on the class.
Modeling has helped me understand the why of what I do as a teacher. I am absolutely certain that Modeling will improve my students’ math scores. I definitely feel more confident in the understanding of the reasons for teaching Physical Science content with math.

I am impressed at how well this method works with groups of mixed ability. Many times the student with lower grades coming into the class performs at or above the other students. I think this is due to the hands on approach and the emphasis on thinking skills rather than rote memorization of facts.

I had to stop modeling instruction as taught this summer due to parent complaints to the principal. This NEW FORM OF TEACHING was above the level of their children’s. Basically, the parents were complaining that they couldn’t do the work for their students and the kids were failing because they had to do the learning themselves and didn’t like it. It was rather a frustrating experience. I still used the whiteboards as I could second semester and group work in labs when I could arrange it with the other instructors. Lab work was still great, just truncated and done as a culmination project, not a learning project.

I had classroom-limited space and no chemistry lab. The curriculum changed and I was behind when I used modeling. However, students enjoyed learning the modeling way.

2008-09 TEACHER FEEDBACK ABOUT ABOR ITQ

2008-09 PHYSICS AND PHYSICAL SCIENCE TEACHERS

A big issue for me is time. We are required to expose students to 9 months of standards into 7 months because of AIMS. Therefore, although modeling is fabulous and I need to streamline all activities to be able to fit everything in.

I took the Math and Physics course and the dots groupings and other tools helped throughout the course. I used the terms and concepts in Chemistry and physics in new areas and it helped with students who needed a different modeling tool for the math being done. I had to separate the physics and chemistry content into 2 courses that all 6th graders take 3 days per week. The difficulty was continuity since the kids schedule is not every day. Both classes were in the same room and switching from physics to chemistry to physics the same day was a challenge. The bits of equipment supplied through the grant have accumulated over the courses and class I’ve taken and I supplied most of the labs. I plan to get a tech grant of some probes and we have some volunteers in place that are supplementing materials. Spacing is a problem for materials and storing supplies. The school is popular with “nerdy” kids of professionals, but it is overcrowded and will be more crowded next year. It is a public charter school so we do not get the grants lower income schools get so we ask the parents to help with supplies and teacher compensation. I would also like to know other 6th or 7th grade teachers that face the unique challenges of presenting this material at a lower level, thought the kids have done very well mathematically and conceptually. Still I struggle with the questioning and tend to guide their thinking too much. I am working on making my questions more open-ended so that they can figure out the answers. I need more physics at their level like the upcoming castle class and I need to revise the physics curriculum to go more into work, momentum, energy and further areas of mechanics with pre-algebra kids. I need to take the modeling chemistry course for lab idea. I used the particle model concept my own way building from the kinetic molecular theory piece by piece looking at pure substances vs. mixtures and then atoms, parts of atoms, and building back with chemical bonding to study pure substances, mixtures, solutions, elements, and compounds.
• Would like to have access to all of the resources online.

• Modeling has made me a better teacher. I have taught 16 years in the public schools. Only in the last two years have been "highly qualified" in my own personal opinion. Modeling has helped me get there.

• Integration of both science and math have worked. Classes are set in a house format. 100 students circulate among the content teacher and as a house we implement our lesson plans to work together as a house place emphasis on working with our lower level students and try to give equally to the 100 students--I did have a lot on my plate for this school year extra activities I did not plan on doing--I was the team leader also representative for the teachers association for meet and confer with the school board and of course on the executive council---and finally having a green house built for the school---on the planning team to secure funding outside of school resources it has been a busy year.

• It has made my students much stronger in knowing the concepts that have been covered. More has been retained and learned. I would love to see more in the Earth & Life sciences using this method.

• Since taking the modeling course I have improved greatly. However, I have not been able to fully incorporate the modeling program into my classes because I am required to teach space science, earth science, and weather units in addition to the physical science material that I teach. I incorporate as much as I can, I use notebooks with the students like we did in the summer course, and I use the white boards when appropriate. These types of courses which allow teachers to learn from other teachers are very important to continue.

• During the class, I saw some things that I didn’t think applied, or I thought I would place in another part of my sequence. I have found that when I get to some places they don’t have the foundation because I haven’t done the pre-work (measurement, graphing pi activity, sufficient HW practice).

• Keep modeling going. I definitely want to take more modeling courses. I am in the middle of getting my teaching certificate.

• Courses helped me think about doing experiments that run longer and help students set up and design themselves and do things in real world. Circle-white-board new: Great idea.

• Everything went great. I really wish I could go the second part of the modeling class, but I will be out of town again.

2008-09 CHEMISTRY TEACHERS

• I really enjoy being part of the modeling instruction team. As a new teacher, it has helped me tremendously.

• We were a brand new school, with much lacking as far as equipment and technology. After the workshop last year I was able to purchase much of the equipment and technology needed, but has only recently come in. I really hope to dive more into the modeling curricula next year and therefore am hoping to retake the course as to effectively implement. Thank you for this fantastic opportunity.

ASU ITQ #ITQ08-01 ASU (Final External Evaluation Report)
• The modeling curriculum is refreshing and exciting. This is the first year I've used this curriculum. The students figure out much of the material in their cooperative groups conducting the experiments or during the white boarding. There are more "ah-ha" moments for the students. Students teach other students more often and the length of time they retain the information impresses me. I'm sold on the modeling technique and the way it has been designed. The classes we took this past summer, plus all the materials we were given and the continued support both through the list serve and workshops has been one of the best comprehensive approaches I've seen to supply teachers everything they needed to use the curriculum.

• Block scheduling 4X4 does not allow enough time to get through all 9 units.

• Great program. I'd LOVE to see a similar modeling workshop for Biology!

• Unit 4 is somewhat confusing for the students, as it is really unlike other units. Overall much of it is very successful!

• The modeling method of teaching has revolutionized both the way I teach and how I think about teaching. It has enhanced the Chemistry experience for my students, and I can't imagine even trying to teach Chemistry without utilizing this method. I see in my students a growing ability to problem solve and critically think. They have learned to observe and explain the world around them, and justify claims that they make. Modeling, in my opinion, is the best way to produce scientifically literate members of society.

• The modeling is amazing. It gives my students a much better understanding of the basic concepts in chemistry. Even topics they learned in previous classes they really didn't understand until it was approached through modeling. Example: Students know density as mass/volume. But could not draw or identify particle diagrams of objects having different densities until approached via modeling.

• I believe in the modeling instruction program, because of the way it makes chemistry meaningful. I do not see connection from unit to unit in the traditional method and therefore believe that modeling instruction is the only way to teach.

• I think there is a maximum class size that should be considered that makes this effective when you teach the class. So, when you teach a first year class and you are preparing them for the next level, if you don't teach them some of the info, they are at a disadvantage from other students who have that info.

• This is probably the most worthwhile professional development I've been involved in as a Science teacher. The goals of the program are to get students to think and learn in meaningful ways. I've had incredible success with meaningful learning using the modeling approach and materials. Please support Modeling Instruction! It will pay off in the future as students who have learned under modeling advance in their studies and careers.

• The students do not get an adequate understanding of charge or of solutions with the modeling material.

• The difficulty I've had in implementing the chemistry modeling materials is that they seem to be written for students at the upper end of math and science ability. Mine are "normal" kids who
need repetition, review of math skills, and are at times, intellectually lazy. I’ve needed to supplement the materials at times. Students are trained in other courses to study, take a test, flush that unit, and go onto the next. They don’t get the idea of the cumulative nature of chemistry. I try to draw an analogy to learning to conjugate verbs in Spanish (you will always need to know how to conjugate the verb ‘estar’ just like you will always need to know how to write chemistry formulas, balance equations, and convert mass to moles.

- Love the modeling stuff! Keep it up!
Appendix C: Pre/post test results for summer 2008 teachers

These results were presented in previous evaluation reports. They are included in this appendix because of their value in documenting the increases in content knowledge of teachers who participated in the ASU ABOR ITQ Modeling Instruction courses and workshops.

Mechanics Baseline Test
Force Concept Inventory
Mathematics Concept Inventory
Physical Science Concept Inventory
Chemical Concept Inventory
Appendix D: FCI and MBT Analysis by Dr. Jackson (February 2011)

I compiled a list of the 24 AZ teachers who took the FCI & MBT in summer 2009 or 2010 in PHS 530 (mechanics Modeling Workshop). I tabulated:

1) whether the teacher has a degree in physics education or is out-of-field,
2) whether the teacher had ever taught physics before taking the mechanics MW.

I found:

- Degrees: 3 in physics education (2 women, 1 man: a brand-new teacher!)
- 21 out-of-field (11 women, 10 men)

Physics teaching experience:
- 10 had some experience (4 women, 6 men)
- 14 had no experience (8 women, 6 men). Of these 14:
  - 5 (one woman, four men) expected to teach physics the following year
  - 6 intend to teach physics eventually (i.e., are preparing to become HQ) (5 women, 1 man)
  - 3 (all women) were broadening & deepening understanding for their field (chemistry, physical science)

Their ages were early 20s to 50s. Several are 2nd career teachers. I divided the 24 teachers into 3 groups of eight, based on their FCI pretest scores.

Three teachers got their college education in India and are teaching here on a Visa. All three teachers from India claim to have degrees in multiple subjects, including physics; two of the three teachers were in the bottom eight (i.e., in the lowest-scoring group of 8 teachers) on the FCI and MBT pretest and posttest.

All 8 of the lowest group of teachers on the FCI and MBT pretests are out-of-field; all but two had no physics teaching experience. Only two expected to teach physics in the next year (only one was actually assigned physics).

Of the highest one-third of teachers on the FCI pretest, 6 had physics teaching experience and 1 is a brand-new teacher who had just graduated with a degree in physics education. All 8 taught physics the following year.

However, only 4 of the 8 highest scorers on the MBT pretest had physics teaching experience. This fact, and their scores, indicates that 6 of the 10 teachers who had physics teaching experience had deficiencies in their problem-solving ability. Did those six improve? The four in the middle group YES; the two in the lower group: NO. (They should not be teaching physics. In fact, one of them is now teaching only chemistry and the other wrote recently that this is his last year teaching physics, since he is not Highly Qualified.)

Four of the five who expected to teach physics for the first time that fall actually taught it. One, a math major, gave up after one semester, writing that the technology was too hard to learn.

Thus it appears that the course gave three new out-of-field teachers and one brand-new physics education major a good start and six more teachers are preparing to teach physics long-term but need more physics courses. Long-term the number of physics teachers in the group almost doubled -- from 10 to 19 -- if all
of these six persist. The only way this will happen is if they continue to get markedly reduced tuition, because all of them have a long way to go to become Highly Qualified.
Appendix E: Comments from Teachers on the HQ Survey

The following are excerpts of comments by teachers who responded to the "Highly Qualified" survey requested by the Arizona Board of Regents ITQ Grants Manager in December 2010. The requested survey included summers 2006 to 2009.

These teachers took our courses in summer 2009 (and most teachers continued in 2010):

- The leaders, fellow teachers, and curriculum of my three modeling workshops (mechanics, waves, e&m) gave me the highest quality of instruction for science teaching I have ever been a part of; this includes my teacher certification courses, my student teaching, my year of teaching middle school, and my two years of teaching high school.

- I need 12 more credits. I would not have gotten that without the grant. I am changing from math (algebra 1) and would like to thank the grant for the opportunity it has provided to become HQ in Physics. Without the grant I would be unable to earn a master's or change subject. I could use thermal physics as well.

- Not yet [HQ], still need more courses. More chemistry!!!!

- I have not become highly qualified in physics yet, but the class I took in the summer of 2009 was only the first physics modeling class I have ever taken. My goal is to continue taking the modeling classes until I have taken all of them. I learned so much in the one class I took. I am very impressed with the quality of teachers and the amount of information covered in such a short amount of time.

- Technically, by the first definition [24 credits in physics], I am very close to being highly qualified after taking the one physics modeling class combined with the other physics classes I have taken, but in my school district, I must pass the AEPA to be considered highly qualified, and I don't feel confident enough yet to do that. That is why I need more summer physics modeling classes.

- I am already highly qualified in chemistry, but my district is leaning toward going with a chemistry modeling curriculum. In that case, I am going to need chemistry modeling classes in order to be considered an effective teacher and to receive adequate evaluations.

- University classes are priced out of my league, now. I am unable to advance my knowledge and skill level without grants. I haven't gotten a raise in four years and the price of university classes has quadrupled since I have gone back to school. I am also paying tuition for my son. Most of my colleagues are in the same boat. I so appreciated the ABOR grant. The class I took with the ABOR grant also helped me to earn recertification credits. I need 180 clock hours or four 3-credit hour classes every six years to recertify. The ABOR grant is so important to science teachers. I feel like no one is helping us. Everyone recognizes the importance of children getting a good education, but few recognize the importance of supporting teachers in helping them to become highly qualified. They are expected to do it on their own budget, on their own time, and on a low salary. In fact, I will be bringing home less money next year and educational expenses for my son are going up.

- No [not HQ], but should help towards it in the future.

- I did not become HQ due to the class, but it did make me more prepared for the AEPA chemistry test. I would like to add that the chemistry test is unfairly difficult for those of us who do not have a master's in chemistry and is challenging even for those who do. It would be unfair to have the expectation that this class could prepare me for it.
The program was extremely helpful. I was able to become HQ from a very specialized set of science classes and lacked much of the foundational coursework. This summer program and my studying helped me so that I am knowledgeable of what I teach. I plan to move up to high school in a couple of years - sooner if I was HQ.

I am National Board Certified in chemistry. I did not have to take the AEPA content area test. I also have been teaching prior to that test being available so I was grandfathered in for awhile until I became an NBCT.

Being HQ is only one way of measuring the preparedness of a teacher. The best way to prepare teachers is to enable them to follow their own ideas of what it means to be qualified.

My ASU course was valuable -- however, I did not complete it due to challenges with the instructors. Becoming HQ in a science field when it is not my primary field of study is very time intensive, and if there was an alternative way to become HQ, I would definitely look into it.

Added in January 2011:

I passed the AEPA Subject Knowledge Test in physics. Course offerings were very helpful to my instructional effectiveness and were easily accessible.

It is discouraging to find so much information in the news about how there is this big push for science teachers, yet when I went to school (2008) it was a lonely uphill battle. Even now, I look up mentorship programs for science teachers and all I have found so far is mentoring for teachers in training or teachers seeking alternative certification. What about support, both emotional and financial, for a 2.5-year science teacher? I still feel very alone in my profession. I attend science conventions, and for those few days it's great, but day to day I am still alone struggling with my students.

The methods of this course and courses like it break things down so the teacher has a more solid understanding of the content, which then allows the teacher to really see how to tackle the many possible misconceptions. It developed the Socratic questioning that brings a student from what they already know to what they have just discovered through connections. I love this course and it has made my class more productive.

The ASU class I took was tremendously valuable to me as a science teacher. I wish I had more time to take other classes. Maybe in the future . . . I'll eventually work on a master's in science ed.

This course was so very eye opening as to how to teach effectively, which is huge!

These teachers took our courses in 2008 (and some took our courses in later summers):

Attending Modeling workshops not only was a great way to become highly qualified as there was depth in the physics content, but it also helped focus on physics instruction and teachers. A teacher can be very fluent in content, but if the teacher does not have the ability to teach and help students learn physics, it really does not matter what the depth of content the teacher has. The modeling program helps
with both content and the methods of instruction in high school physics teaching. I feel as though I was enriched in both areas and I had been teaching science for 13 years before I attended a modeling workshop.

Yes—3 credit hours enabled the requirement to be HQ. I need to eventually find a program that would make it easy to get a master's degree—just don't have the time—there are online degrees but I prefer classroom instruction.

Would it be possible to develop online versions of courses after the initial Modeling courses? This [modeling] is the way I wish all inquiry and science methods courses were taught. I wish I had this course 30 years ago, too. It would have benefited thousands of students by now.

Im taking the test in February. The ASU summer workshops have been instrumental in both teaching content and pedagogy, and I have used all the materials consistently and very effectively since I have taken the workshops.

Improved my content knowledge. And as a result I am probably very close to being highly qualified in Chemistry. These courses prepared me to teach physical science, and if I am able to take more of these courses in the future I will be better prepared to teach a variety of science courses, not just biology.

I was trying to become HQ [in physics] but when a new teacher came that was more interested in teaching the class I stopped the process.

I already had 24 credit hours in chemistry from my undergraduate courses. The class was very beneficial to me, because I needed to update my knowledge of chemistry and learn how to teach it. My 24 hours at the U of A only included general chemistry, organic, biochemistry, and a chemistry safety class. This class prepared me for what I actually teach in the classroom.

Im HQ by rubric. Thank you for the opportunity for this VERY valuable class. It not only helped me as an instructor in chemistry, but it also helped my instructional techniques in other classes. This was a rigorous, but extremely beneficial class.

There was a terrific value to the course I took. It helped my 8th grade class so much in their physical science studies, and also helped improve the math scores, especially graph reading!

I was already highly qualified in math when I took the course and have not pursued further coursework. Somewhere down the road, I may choose to qualify in physics.

More beginner chemistry or physics classes are always helpful!

Would choose no other program to improve teaching strategies and content knowledge. There are still about 4 classes I want to someday take.

Added in January 2011:

These classes change the way you teach. It takes teacher centered classes and turns them into student centered. It changes cookbook labs to student-centered labs that require critical thinking. Overall, the ASU course helped me raise the overall level of understanding for my chemistry students. Without the grant I wouldn't have been able to afford the class.
The modeling courses I took were integral to becoming a better and more well-rounded teacher in chemistry. Students build a deeper understanding through learning using the modeling curriculum.

These courses have given me the tools to become a better teacher through modeling. I have used the material and strategies over and over again. Thank you for making it possible.

**These teachers took our courses in 2007 (and later):**

The modeling courses that I have had the opportunity to take have been invaluable to my teaching practice. Without your support and the help of the Modeling Instruction Program I would not be highly qualified at this point. It is my hope to finish the last coursework towards my master's program at ASU. Without your support I would not have been able to pursue this program.

This was by far the best preparation for teaching chemistry I could have received. Larry Dukerich and Guy Ashkenazi were experts in both the content and pedagogy of teaching chemistry to high school students. They made learning how to teach using chemistry modeling interesting, challenging, and ultimately very rewarding. I learned many important skills and techniques during this workshop and I recommend it to every chemistry teacher I meet.

I still am primarily a math teacher; however, this year I’m teaching an Introduction to Engineering course where I’m attempting to incorporate some physics learned in the modeling workshops, primarily waves and statics (force vectors).

The course in mechanics I took that summer helped tremendously in deepening my understanding of physics. It was invaluable to me, and future teachers would benefit greatly from having these courses available in the future!

The modeling class was great for obtaining my highly qualified certification and allowing me to become a better teacher. I valued the classes (as well as the instructors).

I have learned so much about science taking these courses. I am only able to take one course during the summer each year, but I am slowly working my way to being HQ in physics. Thank you for helping me do that. I would not be able to afford it otherwise. I know my students have benefited because of the knowledge that I have gained.

Can’t say enough good about modeling. These workshops have improved my teaching more than all the other professional development courses I’ve taken combined. Our entire physics, chemistry and investigative science departments are now teaching modeling curricula and our science enrollment has skyrocketed. We have many more students taking science classes, both core curricula and AP level, and many of our students take more than one science class a semester.

Would love to take modeling physics to aid my understanding of chemistry.
Added in January 2011:

The ASU Modeling program is without question the best program for science teachers I have ever seen. The modeling methodology and the techniques I have learned improved my test scores on standardized tests by significantly large quantities. In one case I can even boast 80% improvement on the terra nova tests the year after I attended my first modeling instruction workshop summer session. The numbers don’t lie: this program has made me a much more effective teacher and has given me tools that now my colleagues are starting to incorporate into their classes.

Being a high school science teacher with a family, it is very difficult to afford taking graduate level courses, much less finding the time to take them. Dr. Jackson’s grant has given me the chance to become highly qualified and it has given me a tool box of science best practices that is much more valuable than any other traditional kind of class being offered in the country.

The value of these courses cannot be given a price tag. When teachers are given the chance to become better in the classroom, the students are the ones who win. With test scores dropping nationwide and dropout rates continuing to rise, it’s amazing to me that more schools are not at least trying to do what ASU is accomplishing each summer. Without this program, there is no way I could ever afford the time or the money to continue becoming a better science teacher.

It’s my sincere hope there is funding again this summer for the program. There is nothing like it out there and it has become the basis for everything that I do in the classroom. I thought you would like to know this: last week we were visited by the undersecretary of education. The team visited my classroom and sure enough we were white boarding, plus it just so happened I had the instructional modeling handout handy by the way, this was not planned; however, the team stayed in my room for a full 20 minutes and was very impressed with what we were doing. I got lots of questions and a lot of very interesting looks. I think they really liked what we were doing and I made sure to let them know it’s all from ASU. Your program got some big-time kudos from the visiting team.

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Classes taken at ASU were the only way for me to get the education I needed to become highly qualified in physics and earn my master’s degree. No other program I have seen is specifically designed with teachers in mind.

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The courses at ASU were invaluable to me as a teacher in learning the best way to teach concepts to students, handle student discourse, and better learn content to help me grow in my professional knowledge.

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The courses that made me HQ in AZ did not transfer to Ohio where I recently moved. I guess it’s more of a state issue, but I can only teach 4-9 science in Ohio now.

These teachers took our courses in 2006 (and in later summers):

Thank you for your help in doing this!

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I would like more upper division and graduate hours in PHY and/or PHS so that I can be eligible to teach at the community college level, too (dual enrollment).

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Still need 2 courses during the summer of 2011 and then I will be finished with qualification [in physics].

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The ASU courses were INVALUABLE for multiple reasons: deepening comprehension of course content, practical ideas to transfer to my classroom with my students, camaraderie established that has carried through to the present and provides a support system that is often lacking on campuses where
there is often only one physics teacher. I absolutely loved all courses I took and am so grateful to have been funded through them.

I think that courses were great. The modeling design is a wonderful idea. I would love to see a modeling biology class be developed since that is the one class that all students in Arizona must take to graduate high school, and changing how that course is taught would be ideal.

While I was already HQ in physics and had significant classroom experience in chemistry, the ASU courses offered opportunities to review material long buried by time and to practice classroom presentation of that material using pedagogical techniques that are fresh and more clearly effective than traditional teaching methods.

**Added in January 2011:**

The modeling courses were the most helpful grad courses I had. As a new teacher, I interacted with more experienced teachers, reviewed content as well as pedagogical content! I encouraged several co-workers to take modeling and we see in the classroom that it helps kids learn to think and hopefully be more interested in chemistry and in science.

ASU summer coursework provides valuable training to secondary ed science teachers. The modeling classes have raised the standard of teaching across the state, which translates into student success. Isn't that why all of us do what we do?

Change in requirements for middle school teachers which went from 24 hours of science to 12 physical/12 life left many HQ teachers to not HQ status.

The ASU courses greatly helped my teaching in physics (and later physical science, earth science and chemistry). I recommend these course to all the teachers I know. It provides a deeper understanding for teacher and students. It also provides a much more interactive teaching style the students easily get used to.

My biggest problem in becoming HQ (besides time) is money. I haven't had the money for so many courses. As a rural teacher, they expect you to be highly qualified in all areas you teach, which is fine for an English teacher. Science teachers (where you are the only one) are expected to be highly qualified in physics, chemistry, biology, physical science or general science, and earth science! It isn't like a biology teacher changing over to teaching physics. I'd love to see more support and assistance for teachers like me, struggling to meet so many requirements.

I'd love to see earth science be available or even biology, but I think what is going on with physics and chemistry is really great already.

Based on the HQ criteria (24 credits) I am not there yet. I have only earned 15 credits in physics. I have a degree in chemistry but do not have one in physics. The modeling courses have greatly improved my content knowledge and the effectiveness of my teaching. I hope to take more courses to meet the requirements. In physics I have taken 3 modeling classes: 1999 w/ Dan MacIsaac; 2 at ASU, one modeling physics and one Castle [electricity].

The ASU Modeling program is fantastic and provides a valuable learning opportunity to teachers. Becoming a HQ teacher is beyond challenging and expensive, especially after you pay for a college degree in (for example) SCIENCE. The department of education (AZ) requires that you pay them simply to review your transcript and gives you the third degree on the courses you took. ASU’s program has been the bridge between the courses I took and the ADE. They worked with ADE and obtained letters of verification that the courses were considered by the ADE to be qualifying in certain areas. I really appreciate this.

ASU ITQ #ITQ08-01 ASU (Final External Evaluation Report)
Modeling chemistry is far superior to traditional approaches to teaching/learning chemistry!

I recently received my master's in education intervention and have taught elementary school for the last 4 years. Although I no longer teach science, the workshop improved my teaching style and knowledge of physics tremendously. It was certainly time well spent.