

## EFFECT OF MODELING METHOD TRAINING ON PHYSICS TEACHER DEVELOPMENT IN CALIFORNIA'S CENTRAL VALLEY

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FCEPT is the Fresno Collaborative for the Excellence in the Preparation of Teachers and has continued with support from California State University, Fresno and its Science and Mathematics Education Center (SMEC). The program is aimed at recruiting and training outstanding math and science teachers for K-12 teaching positions in California's Central Valley. This multifaceted collaborative held summer physical science modeling workshops from 1999-2003, incorporating "modeling instruction" originally developed at Arizona State University. The results from four summers of interviews and assessments on modeling training indicate improved teacher comprehension of physics content as well as enthusiastic support from the participants in the modeling approach. Post-workshop interviews with teachers have indicated modeling instruction has greatly influenced their teaching styles and that they found their students more receptive and enthusiastic participants in their classrooms.

### **Background:**

This report summarizes the effort undertaken by SMEC (formerly FCEPT), details of which were published in the Journal of Physics Teacher Education Online [1]. FCEPT was a partnership between California State University, Fresno, Fresno City College (FCC) and the Fresno Unified School District (FUSD), funded by a four-year grant from the National Science Foundation starting in 1999. A recruitment pipeline has been established with surrounding community colleges and the experience and wisdom of other CETPs in California have been essential in the development of effective in-service and pre-service training activities. We have received industrial sponsorship through a GTE technology grant over the summers of 2000-01 for our Project Science students. The support helped demonstrate ways to more effectively teach science through mathematically-based tools such as graphing calculators, computers, sensors and interfaces. Sixteen other local, state and federal collaborators have helped to provide teacher training in content and through experiential learning. These collaborations are designed to satisfy one or more of the following project goals.

1. Recruitment of committed and academically successful pre-service science and mathematics teachers into the teacher preparation program for middle and secondary school science and mathematics.
2. Pre-service mentoring of students by university, college, and district science and math and education faculty.
3. Early field experiences for pre-service undergraduates in science and mathematics.
4. Development of a five-year academic program combining pedagogy with content.
5. Revision and field-testing of university/college science and/or math content and methods classes.
6. Employment of a "clinical model" for science and math methods classes whereby school district faculty and others are involved in the presentation of science or mathematics teaching methodology.
7. Implementation of a comprehensive content/pedagogy-based summer institute series for pre-service science and math teachers and in-service science and math teachers

8. An academic year special support program for final student teachers, teaching interns, and new teachers.
9. Implementation of a program that results in high hiring assurances from local district for FCEPT graduates.
10. Implementation of a partnership program that serves as a dissemination model for the nation and one that is fully institutionalized beyond the funding period.

### **Special Academic Year and Summer Programs/Institutes:**

The FCEPT summer science institutes provided our FCEPT science students and mentor science teachers with an opportunity to work together in a relationship and setting very different from the Teaching Assistant/Mentor Teacher role played during the academic year. The summer science institute also provided opportunities for college and university science faculty to field-test certain elements for delivery of content of regularly offered courses are being revised under the project. During the summer of 1999, FCEPT, merging resources with the Fresno Unified School District's Urban Systemic Initiative, offered two major institutes. The intensive 10 day-long Secondary Science Institute (with a follow-up field trip scheduled later in the summer) focused on integrating key cross-disciplinary science concepts incorporating energy dynamics and environmental topics as major points of connection. FCEPT has also enjoyed outstanding success in providing some very worthwhile enrichment workshops and institutes in science and math/education topics.

We have provided or are currently providing academic year workshops, monthly seminars, and summer programs dealing with entomology, environmental science, biotechnology, classroom management, lesson plan development, equity in science and math education, classroom organization, science and math standards, laboratory interface software and hardware, applications of technology in teaching science and mathematics, embedded literacy in science and mathematics, fractals and chaos, problem solving, web design in math teaching, and modeling physics. These workshops and institutes have been well enrolled and well received. These programs provide a means by which the university/college faculty and district science and math teachers can pilot teaching strategies. These are often later infused into regular academic year courses [2] taken by undergraduate and credential students in the pre-service program. Evaluations of these offerings have revealed a very high level of satisfaction on the part of the participants. CSUF, a designated minority serving institution, has had and continues maintain a participant pool that reflects the demographics of the university with approximately a 60% minority representation and a 50% female representation through its FCEPT program.

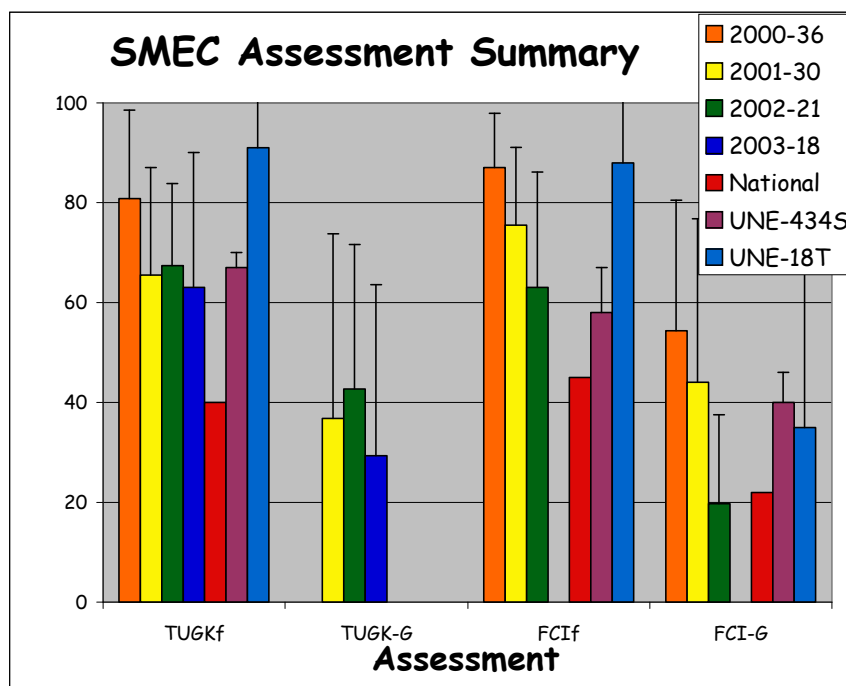
### **Modeling Physics - Institute Description:**

Modeling Physics Institute (MPI) is a learning approach that attempts to help students construct conceptual understanding by converting physical models into mental pictures. Modeling Institutes in Physics have been run every summer from 1999-2003. The approach was first discussed in a seminal paper by Wells, Hestenes and Swackhamer in 1995 [3,4]. Instead of the traditional coverage of seemingly disjointed topics, a few core models are used to describe a broad range of physical phenomena. The process involves the development of commonly understood operational definitions, a paradigm laboratory activity, a consensus model, application and refinement, and ultimately deployment. Furthermore the consensus description is expected to be expressed through multiple representations (graphical, verbal, diagrammatic, and mathematical) to reflect a range of learning styles. Assessment of student understanding is determined by formative measures, principally using "whiteboard" presentations, and through summative measures using deployment activities and research based assessments. The modeling materials have been presented in both two and three-week institutes. In 2001 modeling instruction was recognized by the United States Department of Education as an exemplary program in K-12 science education [5]. The workshop activities were characterized by:

- Data collection based on a guiding set of questions or models that needed explanation.
- Data collection and analysis using computer-based probes and software.
- White boarding (i.e., small group processing on dry erase marker whiteboards).
- Group presentation of results and conclusions.
- Class questions and discussion.
- Deployment questions (i.e., questions that dealt specifically with the lab content.)
- Socratic Questioning.
- Building knowledge from student understanding.
- Using evidence for conclusions.
- Explaining based on words and mathematical statements.
- Small group work.
- Whole group discussion.

### Assessment Results:

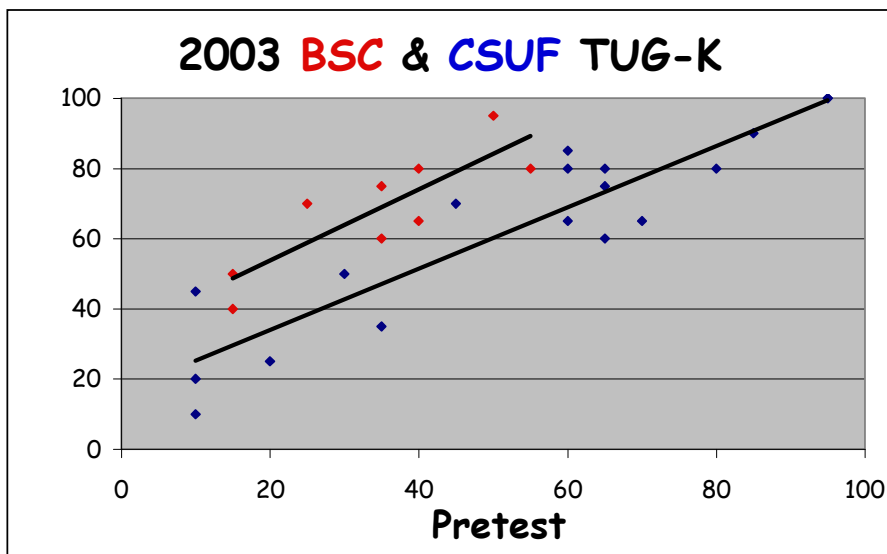
Several research-based assessments were used during the workshop to assess participant comprehension in the kinematics and mechanics. The "Test for Understanding Graphs in Kinematics" (TUG-K) [6] and the "Force Concept Inventory" (FCI) [7] were used throughout the four years of institutes (identified by "year-number of participants" in the histogram key below). Comparisons from the authors' (JV) undergraduate teaching and workshop results on the east coast are included in Figure 1 below.



**Figure 1:** Both the TUG-K and FCI final scores from all four years of workshops are significantly above the national average. With exception of one year, all the gains are well above the national average. In that moderate gain year the co-leader had attempted a new paradigm approach that had been successful in undergraduate classes, but appeared not to work well in the workshop environment. The results achieved in two to three weeks of workshops were equivalent to that achieved by a teacher workshop at the University of New England (UNE-18T) and the average of five years of assessments of general physics students at UNE (UNE-434S).

### Urgent Need for Continued Professional Development:

The most interesting comparison of results between the SMEC and east coast modeling workshops is illustrated in Figure 2 below. The results of pre-test versus post-test scores are presented from data collected during the last SMEC workshop and an author's workshop at Bridgewater State College in Bridgewater Massachusetts. The reproducible slope indicated that low initial scores predicted low final scores on the TUG-K and have been observed elsewhere [8]. **The problem is that these scores represent basic kinematics skills of in-service and pre-service teachers indicating that continued professional development opportunities are essential to raise participant expertise with content AND process.**



**Figure 2:** Post-test versus Pre-test TUG-K scores for 2003 SMEC and Bridgewater State College workshop participants. Low pre-test scores are frequently indicative of low final scores. **Only multi-year workshop participation appears to effectively deal with improvement of expertise and process.** One participant stated “I’ve participated in physics and chemistry workshops. This is my third workshop. Finally I feel I have a good grasp of how to implement the modeling cycle and create models in my discipline chemistry.” (SMEC 2003) Post workshop surveys of the participants over the years have given the following typical response to the questions below:

*How well were the workshop materials structured into models?*

“Well. During the course of this workshop, we started with some models and add to them, ‘tweaked’ them, to make them better.”

*In what ways, if any do you see models contributing to improvement of physics instructions?*

“Students recognize that models are fundamental part of science. Students see that problems can be solved easier if they first recognize the model the problem deals with.” (SMEC 2003)

*What changes, if any, has the workshop convinced you necessary to bring about in teaching practice?*

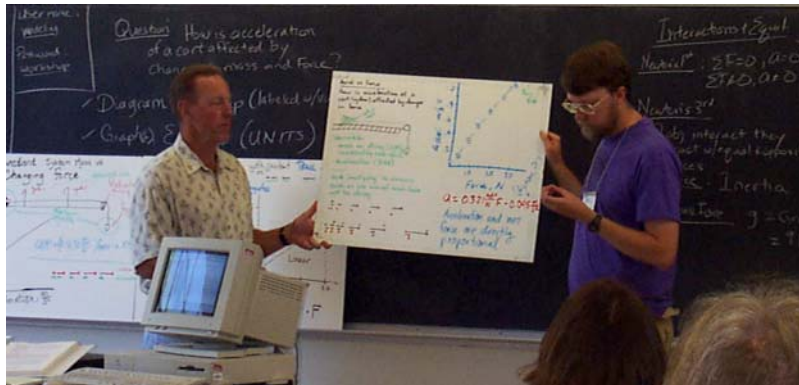
“To allow students the power of connecting ideas and teaching themselves. I don’t have to be their only information source, they can be ‘led’ to their own conclusions.”



**Figure 3:** 1999 SMEC Institute participants collecting data with interfaces and computers.

A workshop co-leader observed the following, illustrated in Figure 3.

“If you walked into a room you would see students engaged in activities, students would be looking at phenomena, asking questions, going through the scientific process and trying to answer those questions. They would be taking data, they would be interpreting the data, developing graphical and mathematical models from that data. They would be presenting their results to the class on white boards. Students would be asking students about what is on their white board. The teacher would not be the dominant source of knowledge, the students would be constructing knowledge, the teacher that is there would be there to hopefully prevent them from heading down dead ends, as a guide, as a facilitator. But they would be asking students questions, they would be involving dialogue about the material.”



**Figure 4:** 1999 SMEC Institute participants presenting models on whiteboards and questioned for understanding of physics concepts.

A participant observed the following, illustrated in Figure 4.

“I took Physics 2A (algebra-based college physics) this past semester so I just finished and I am taking the Modeling Physics course now. And in Physics 2A, we went so fast, we went over so many terms and I learned how to solve the problem, but I didn’t really understand the meaning... I got an A, just because a lot of the physics was math and I was able to solve the problems.

[In] the Modeling Physics ...I understand what the terms mean, what position means, using the operational definition, what I think a term means and then using a model to understand what the terms mean and how they are related in graphs... it has brought a whole understanding to everything that I have learned to this point in my physics class that I didn’t understand before.”

A participant observed the following about the challenging curriculum.

“...in my Physics 2A class, it was a bigger class, but the teacher wouldn’t really challenge us, he just lectured, he wouldn’t ask questions, he wouldn’t challenge what we know. And in this class [MP], the teacher is continually asking us questions, making us think and he is not telling us the answer, but he is making us think about it through this process. We are trying to figure it out, and I really liked that, it makes me think.”

But the single most valuable tool we provided our workshop participants involved exposure to whiteboards, as mentioned by the participant below.

“...I am definitely using the white boards, I will continue to use the white boards in my classroom. I think they are invaluable. It really does help the students to be able to communicate and to feel, the way I use them in my classroom, they feel safe, it is a safe environment. I also use bits and pieces of Socratic questioning. ...Also just the process of hands-on activities. I have always been a hands-on oriented teacher, but it just validates it even for higher level.”

### **Overall Impact of Modeling Science on Central Valley Teacher Participants:**

We have learned that several of our region’s veteran science teachers or preservice teachers now teaching under contract, are using the modeling approach rather extensively in their classrooms. The Socratic dialogue strategy combined with the use of white boards to encourage student discussion and to elicit student reflection is widely seen in classrooms. Our teachers have indicated to us that a significantly greater percentage of their students are engaged in the activities and discussions. They attribute this success to their use of the modeling approach. Several teachers have stated that they are able to successfully link the modeling approach to the California Standards. Additionally, some of our teachers have formed their own modeling networks and share their successes and challenges in using modeling in the classroom. This has proven to be a very positive, unanticipated development. Other teachers have stated that, overall, their classroom practice has been greatly influenced by their training in modeling. They report that they are far more student-centered, approach the teaching of science concepts from an inquiry basis, and engage a wider range of students in classroom discussions. Teachers also report that many of their students have shown increased skills in the interpretation of graphs and diagrams as a result of the application of modeling principles in their teaching. Finally, and we think importantly, many teachers are reporting that their students appear to be considerably more enthusiastic about their science classes as a result of modeling. All in all, the program is beginning to impact Central Valley of California schools and we hope that modeling turns more students on to science and to considering science majors (and possibly science teaching) as career choices.

### **Acknowledgments:**

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### **Bios:**

David Andrews is a Professor of Biology at California State University, Fresno and is currently the director of the Science and Mathematics Education Center. He was the head PI of the Fresno Collaborative for the Excellence in Preparation of Teachers and has received numerous grants to fund improvements in science education and teacher training in California's Central Valley.

Jaime Arvizu is the assistant director of the Science and Mathematics Education Center and associate director for the Fresno Collaborative for Excellence in the Preparation of Teachers.

James Vesenka is an Associate Professor of Physics at the University of New England. His research interests include physics pedagogy and undergraduate nanotechnology training. He has directed modeling instruction teacher training workshops in California and Maine each summer for the last five years.

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