"Micro-Document" for NSF Teacher Education Workshop, May 7-8, 1999

David E. Meltzer
Physics Education Group, Department of Physics and Astronomy
Iowa State University

(1) In order to ensure that all students master national science and mathematics standards, what qualities should effective K-12 teachers in the 21st Century possess?

In order to achieve this very ambitious goal, all students will need to have access on a regular and continuing basis to at least ***some*** teachers who combine several different essential qualities. These teachers will need a significant amount of content knowledge in the various areas of science – well beyond the level of the concepts that they are expected to teach. This is essential because, to be capable of carrying out "inquiry-based" instruction, a teacher must have considerable depth and breadth of knowledge. The teacher must be able to thoroughly comprehend typical learning difficulties encountered by students, must be able to respond to students' questions and confusion with well-thought-out, fruitful lines of questioning, and must be capable of leading students beyond their inevitable initial misunderstandings. Teachers will need a great deal of practice in carrying out guided-inquiry-based instruction; it is not something that one learns out of a text. Above all, teachers will need to have genuine enthusiasm for learning and teaching the concepts of science. Nothing will abort the educational process more rapidly than for students to be "taught" science and math by teachers who hate those subjects.

(2) What are the elements of and the barriers to an ideal program that produces and supports such a teacher? How are you or others you know overcoming these barriers?

It should go without saying (but in practice does not) that to teach science effectively, teachers-in-training will need to spend a very substantial amount of time learning science concepts in a guided-inquiry setting. ***In addition,*** they will need to practice their teaching skills under expert guidance, at least for some initial period. I believe that there is a great deal of disconnection from reality in much of the current discussion on teacher preparation for science and math teaching. Research from many groups has demonstrated one thing very convincingly: only intensive, time-consuming instruction (more than one semester in duration) has any hope of guiding most elementary-education students beyond well-known and widespread learning difficulties with basic physical science concepts. It is simply delusory to believe that significant progress toward the goals of the national science standards is possible within the current framework of teacher education, which for the most part comprises short-term exposure to many disparate subjects. The gap between what teachers at the elementary and middle-school level are "expected" to teach, and the actual knowledge that most of them possess, is vastly greater than often is imagined. A more realistic intermediate goal may well be to entrust most pre-secondary science instruction to science "specialists," who will receive substantial additional training and practice in the field.

(3) How can you or others know and document that you or they are producing a teacher that does indeed possess these qualities?

Ultimately, the only way to document this is to observe the teacher at work in a classroom with students. That should be part of any program that trains teachers to teach science. How effectively does the teacher guide student discussion and student activities? Is the teacher able to respond intelligently to student questions, by in turn asking the student the kind of question that will allow them to construct the targeted concept for themselves? Can the teacher test the student's knowledge by posing a problem in a novel, yet related context? Together, these form the ***sine qua non*** of effective science instruction. Short of field observation, those of us engaged in teacher education must intensively seek to assess student learning in depth. By posing problems in a wide variety of contexts, using multiple forms of representation (e.g., verbal, mathematical, diagrammatic, graphical, pictorial, physical, etc.), student learning may be more effectively assessed. By asking students to explain their reasoning – both in writing, and verbally – instructors will gain enormous insight into the students' actual depth of understanding. It should be considered an ***indispensable*** phase of assessment to probe and document students' thinking by analyzing their detailed written and verbal explanations of scientific concepts and principles.

(4) What more is needed to catalyze the changes outlined? Who can supply these needs? In what ways?

More confrontation with reality is certainly needed. Everyone involved in teacher education needs to address the assessment issue as seriously as possible. What are the goals of your instruction? How can you test whether those goals have been achieved? What means have you used to probe student understanding in depth? Have you observed your students as they attempt to explain the concepts they are expected to teach? Do you have some basis for anticipating their probable performance in the classroom? These questions should ***always*** be on the agenda.