Excerpts from Blueprints On-Line:
Ch 9 Teacher Education

These are just highlights; the complete chapter is at
http://www.project2061.org/publications/bfr/online/Teacher/text.htm

Includes important points about the nature and issues for science education, particularly with respect to general pre-service methods, best types of professional development, and involvement of scientists with pre-service science education.

Teacher education plays an important role in science education reform. Some reformers say that changing teacher education is the first step to dramatic change in science education. But sweeping reform of the teacher education system requires the same level of effort as reforming other components, such as standards, curriculum, and assessment. Equipping teachers to bring about science literacy for all is an intellectual and practical challenge of great societal importance. But sweeping reform of the teacher education system requires the same tremendous level of effort as reforming other components, such as standards, curriculum, and assessment.

Immediately below, recommendations are made for restructuring undergraduate education in four areas: preparing teachers in subject matter, preparing them for diverse students, preparing them to teach, and recruiting science teachers. These recommendations are followed by suggestions for improving 1) teaching by college faculty and 2) the continuing education of science teachers. Finally, we propose guiding principles and suggestions for the professional education of teachers. Although this chapter focuses on teacher education, the importance of continuing education for administrators should also be recognized. Administrators will surely have to change their roles if they are to lead schools like those envisioned by reformers in science education.

Needed Changes in Undergraduate Teacher Education

Preparing Prospective Teachers in Science

Addressing students' personal conceptions of scientific phenomena is one of the challenges in science teaching. It requires excellent knowledge of science, along with deep understanding of science learning. In response to everyday experiences with natural phenomena, children—including future teachers—construct their own theories and explanations to interpret the world around them. Some of these constructions have limited usefulness in and can interfere with learning about scientific phenomena. For example, many people come to believe that the seasons result from Earth's changing distance from the sun. Because ideas like these account for personal observations and often explain local phenomena, they are difficult to change. And because traditional test questions can be answered using these ideas, often science teachers in both K-12 and higher education do not detect them. The result is that even some college science majors continue to believe, for example, the incorrect reason for the seasons' changing. To be effective, most science teachers need a deeper and more generalized understanding of complex and often counterintuitive scientific principles than they currently have.

It is essential that all science teachers are literate enough in science to implement the goals presented in *Benchmarks* and *Standards*. The intensive study of a discipline increases the likelihood that future teachers will be able to understand science at a deep, conceptual level and to reflect on important ideas, theories, and applications. **For this reason, most educators agree that all high school science teachers—and probably middle grades teachers as well—should have a major in science.**

Most science and mathematics in the elementary grades is taught by generalists who majored in elementary education. **Although it is impractical and perhaps inadvisable to suggest that all science and mathematics instruction at the elementary school level be taught by specialists, all elementary school teachers should have a deep understanding of some discipline, along with preparation in science content. Experts disagree about just what science content preparation is most appropriate for elementary teachers. The answer may depend on whether elementary schools are organized departmentally or as self-contained classrooms, and on the role of K-6 science or mathematics specialists in the school.** Colleges and universities can work closely with schools to develop programs in science and mathematics education that meet the subject matter needs of their graduates. For example, an urban or suburban area may opt for a program that allows for K-12 majors or specializations in science; a rural area may require broader science knowledge.

Preparing Prospective Teachers for Diverse Students

Today's science teachers work with increasingly diverse student populations and are challenged by student attitudes and behaviors—cheating, questioning authority, and apathy—that reflect larger societal problems. Teacher education that simply presents science teachers with summary characteristics of different groups without establishing their relevance to effective teaching often has the effect of intensifying, rather than reducing, hidden prejudices and stereotypes (Kozol, 1991). Therefore, prospective science teachers should be introduced to literature that helps them understand the different issues faced in science classes by females, minorities, children with disabilities, and low-income students.

Preparing Prospective Teachers to Teach

Science-teacher education must engage students in discussions about substantive issues of teaching and learning closely connected with the everyday work of teaching. This work should take place in K-12 schools where the best science teaching practice is in place. These experiences should not be concentrated at the end of the program in a full-time student teaching assignment.

To sustain these programs, faculty in schools of education and science must remain in close contact—through extended research, observation, or regular teaching—with the realities of the schools and classrooms where their students are teaching. Education faculty must also remain current on national professional standards for teacher education programs.

Field Experience. First-hand experiences in schools, teaching and mentoring experiences, and fieldwork with scientists must come early in the teacher education program. These experiences prepare prospective teachers for the content of their education courses and serve as living laboratories for formal course work. Field experiences that allow experienced teachers to share the full picture of teaching with novices make these "hidden acts" of teaching more visible to prospective teachers.

Teaching Practice. Teachers often do not see the relationship between the events they experience in their own classrooms and the generalizations about teaching and learning they are taught in universities. Many teachers report that they learned little of value about teaching until they began to teach.

Schools should encourage team teaching and view individual teachers as specialists in various areas, including science. Organizing daily schedules to provide time during the school day for team planning and professional development is critical. **At least one teacher on each team with strong science preparation can lead science study and lesson planning groups, demonstrate lessons, and provide special resources.** These activities promote a belief in the value of increasing teamwork and professional interaction among teachers (Abell, 1990). In this environment, teachers can engage in continuous learning about science and mathematics. In the "team specialist" model, every teacher would have expertise in at least one area, a liberal arts education, and a subject matter major. **The team approach is an important departure from many current elementary generalist programs that assume a little science knowledge for teachers is better than no knowledge at all, and from many secondary programs that are highly departmentalized.**

Recruiting New Teachers

Because all levels of the educational system in the United States are decentralized, it is almost impossible to gather hard evidence on trends in the supply of new science teachers. However, some general patterns are clear. **Physics teachers are generally in short supply, while the number of life sciences teachers sometimes exceeds available jobs. Too few students of color choose majors in science or mathematics education. Elementary teachers are abundantly available, but too few of them have strong subject matter preparation in science and mathematics. Uncertainties in school funding, a negative work environment, and generally low salaries often inhibit the most successful science majors from choosing science teaching as a career.**

To strengthen and broaden the pool of science teachers, universities need to aggressively recruit and support able, high-achieving minority students to become teachers of science, mathematics, and technology. **Science professionals and others with strong scientific backgrounds can also be recruited into teaching if universities adjust their programs to match the capabilities and experience these individuals bring, and if feasible and innovative career change opportunities are available.**

To broaden science learning opportunities within and beyond the classroom, members of the scientific community can be recruited to participate in K-12 education as observers, guest speakers, tutors, and consultants. Scientists will need to become aware of the needs of teachers and students, but in the long run, their participation can enrich college and university classrooms and help K-12 teachers and scientists better understand each other.

Needed Changes in College and University Teaching

Even science majors in college often have serious deficiencies in fundamental ideas of science. It is no wonder that many science teachers enter classrooms without the kind of understanding called for by *Benchmarks* and *Standards* (Gallagher & Treagust, 1994; McDermott, 1990). **Teaching in undergraduate science courses should change more systematically to emphasize central ideas and underlying themes that help students, including prospective teachers, to apply scientific principles in solving real problems**. College curricula should also illustrate the relationships between science, mathematics, technology, and society. Integration does not need to occur in every course and throughout the curriculum, but it cannot be left for students to attain on their own.

Teachers rely far more on the teaching styles they have experienced as learners than on the theory or even the practical knowledge they encounter in teacher education programs (Grossman, 1991).

Because lecture-based science and mathematics teaching is common in colleges and universities, higher education should heed this reality. Future secondary teachers who are successful science majors experience lecture approaches in college, leading them to believe that lectures are effective for all students. Teacher educators must be concerned with preparing future teachers to implement reform by exposing them in their own formal science learning to teaching styles that support reform.

Teaching and learning for understanding take time, desire, and ability. Faculty and students—especially in large introductory science classes—feel the "content crunch" of covering material in a limited amount of time. **Science education for future elementary teachers is often limited to these introductory courses**, giving them little opportunity to interact with faculty, write about and discuss science concepts, or engage in hands-on activities that would help develop science knowledge and understanding. As a result, **they sometimes begin their teaching careers with negative attitudes toward science and without the skills to implement learning goals** such as those outlined in *Benchmarks* and *Standards*.

Because most K-12 science teachers do not conduct research, they must learn to read scientific journals and other sources of new scientific knowledge, and to interpret and evaluate data. Colleges can also use teaching methods that involve interactive participation, group work, and inquiry—especially in introductory courses taken by future elementary and secondary teachers. Finally, **colleges can integrate the study of science with the study of and preparation for teaching** to build on the widely held knowledge that the true understanding of a subject comes from teaching it.

Promising Approaches

While examples of excellent college teaching exist, serious shortcomings in science and mathematics teaching remain at many colleges and universities. University culture rewards faculty for research and provides little incentive to broaden their often limited repertoire of teaching and assessment methods. Several changes can focus attention on undergraduate teaching and learning: **departments can help promote good teaching by holding faculty seminars and discussions on ways to improve teaching and assessment, by making the quality of a faculty member's teaching an influential factor in deciding on tenure and promotion, by developing the teaching competence of graduate students who teach much of the undergraduate coursework in many large universities, and by rewarding innovations in university teaching.**

Universities need to find ways to bring the extensive body of research on teaching, learning, and assessment in science and mathematics to the forefront in discussions of higher education. In addition, **students should be allowed to become active learners, have first-hand experience with making connections between their own ideas and the knowledge they develop in courses, and participate in classes where faculty model a teaching style that is conducive to active learning**. Even large lecture classes can be organized to promote active learning (Bonwell & Eison, 1991). When universities increase the number of science courses that allow students to become active learners, they increase the likelihood that future teachers and scientists will experience the excitement and satisfaction of designing inquiries and collecting and analyzing data to explore those inquiries.

Needed Changes in Professional Development

Perhaps the most important reason for continuing professional education for science, mathematics, and technology teachers is that it allows them to recognize the special expertise related to their work. Specialized knowledge becomes a source of authority for setting policies and making curricular decisions.

A second reason is that pre-service education is simply not long enough or intense enough for teachers to master all the skill areas they need. Third, as knowledge in the fields of both science and teaching continues to expand, and as our society and its demands continue to change, teachers themselves must grow and develop. Finally, when teachers engage in long-term professional development, they build relationships with a wider community of peers, which improves teaching quality.

A central problem with the current system of incentives for professional development is that teachers are rewarded for completing college credits or a degree rather than for mastering a subject and how best to teach it. Master's degree programs in education offer in-depth study but lack science content and strong ties to individual instructional practice.

Professional development workshops lasting one or two days do little to improve teachers' understanding of their subject matter. Teachers are taught in "make it, take it" sessions how to conduct a particular set of activities or lessons, or they are taught to work with a curriculum package that has been adopted by the school or the district.

Neither of these approaches is satisfactory. Schools must be changed to reflect a view of teachers as intellectuals rather than technicians (Giroux, 1988). **To support science instruction with activities tied to specific standards and benchmarks, professional development work must address more directly the curricular issues of sequence and connection with benchmarks and standards.** The chances for successful reform will be enhanced by a focus on standards-based professional development that builds the scientific and instructional knowledge necessary for real curricular and instructional change.

Principles for Change in Teachers' Professional Development

Our understanding of how teachers learn and of the opportunities for development suggest the following principles to guide the redesign of teachers' continuing education:

- **Higher education and professional associations should strengthen their connections to professional development, providing greater coherence.**
- An emphasis on science learning tied to local school context should replace the focus on general teaching skills.
- **Activities should provide the curricular and practical skills for teachers to weave standards and benchmarks into an instructional sequence.**
- Cadres of teachers should assume leadership responsibilities.
- Activities should promote learning for all school professionals, including administrators.

These principles imply a rethinking of the way teachers' time is organized, the way current staff development funds are used, and the level of staff development support that is necessary to implement and sustain reform.

By strengthening links with higher education and professional associations, teachers can begin to bring some coherence to the currently disjointed system of professional development. At the same time, these organizations are flexible enough for teachers to avoid creating a highly centralized system of professional development that is unresponsive to local needs. **Teachers increase their use of research knowledge if they have sustained interaction with researchers** (Huberman, 1983). This interaction also gives researchers a chance to present their work in ways that fit local circumstances. Similarly, professional associations and teachers' unions have the infrastructure in place to help teachers share knowledge with each other, although little is known now about the effects of membership in these organizations on teachers' development.

Teachers may also need specialized help in learning methods for integrating science curriculum and connecting it with technology. Although science learning should be tailored to the needs of each unique classroom or even each unique individual, it is clearly unrealistic for teachers to devise new activities for each topic. Teachers will need opportunities to learn the skills to integrate learning activities that support connected learning.

Recommendations

The recommendations below begin to suggest a new vision of reform and the necessary steps to implement that vision. Groups of faculty and administrators, professional organizations, government agencies and others need to find strategies appropriate to their own settings. Using the following ideas as guiding principles will help the process.

- ***Convey a broad vision of scientific literacy.***
- ***Emphasize the profession of teaching.***
  The education programs should develop the attitudes, knowledge, and understanding that enable teachers to apply theories and principles in devising strategies and classroom activities that are responsive to the needs and backgrounds of particular students. This kind of teaching—called reasoned, principled, or reflective practice—is a defining characteristic of professional teachers. **New standards and curricula require teachers to have a deep understanding of their subjects** rather than to be technicians adept only at delivering prepared educational products produced by curriculum specialists and other "experts" outside the classroom. To this end, teacher education must be redefined as a career-long endeavor. Teacher preparation programs should work with school districts to create schools in which critical inquiry and discussion are defined as part of the routine organization of the work of teaching.
- ***Enable teachers to teach science to all Americans.***
- ***Improve university instruction.***
  Colleges and universities should draw the faculty's attention to available research in teaching, learning, and assessment that can be used to develop more effective undergraduate teaching. Undergraduate institutions should encourage and support faculty who strive to improve their courses and should hold seminars and discussions on ways to improve teaching. In addition, these institutions should work to develop more explicit guidelines about what constitutes effective teaching and incorporate these guidelines into policies on promotion and tenure. **The large universities should focus on helping graduate students develop their teaching competence and developing alternatives to the large lecture courses that dominate undergraduate education in science**.
- ***Enhance teacher learning.***

- ***Improve teacher recruitment.***

- ***Commit to long-term reform.***
  Because higher education plays a crucial role in shaping future teachers, **professional organizations in the sciences and education can take the lead in supporting publications, seminars, and other forms of professional development for administrators in higher education. Administrators in both higher education and K-12 education are keys to the success of any reform and should be included in professional development.**

Administrators and faculty in higher education should also recognize that broad support for continued science research will come with increased public understanding and appreciation of science. Therefore, higher education will benefit by working with elementary and secondary educators to implement reform.

Serious reform requires long-term commitment. Experienced educators have seen previous reforms come and go without enduring, significant change. If they are to be recruited for reform, teachers must be persuaded that efforts will be maintained over decades, not just years. Successful reform acknowledges the difficulty of the change process and pushes forward at all levels, building coalitions and developing a cadre of leaders that will continue the press for change.

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