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Occasional Paper No. 4

Some Recent Developments in Teacher Education in Mathematics and Science

A Review and Commentary

Sheila Tobias

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About the Author

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Contents

Abstract

Teacher preparation in science and mathematics will be best served, says the author of this roundup, by improvements both in the pedagogy and content of the undergraduate science and mathematics courses required of future teachers and in the reform of required science and mathematics methods courses. In a review of the history and politics of teacher education, the author underscores the twin goals of achieving program coherence and higher standards. She compares the place of mathematics education in mathematics departments with that of science education in science departments and recommends the replacement of bare bones methods courses with those combining pedagogy and content. Included is a selective bibliography.

Introduction

Two conditions for maintaining the momentum of reform in science and mathematics education emerge from a review of recent experiments and reports. First, without close attention to teacher preparation, the momentum of K-12 reform in science and mathematics will be but short-lived. Second, without change in the pedagogy of the science and mathematics courses taught to future teachers as part of their subject-matter preparation, little that is formally presented in their teacher preparation courses will find its way into practice. The NSF-funded Collaboratives for Excellence in Teacher Preparation (See Appendix A) have been directed to deal with both issues, but reports from the field indicate that finding a way to integrate the needs of future teachers into standard undergraduate mathematics and science courses may be more difficult than has been anticipated. A compromise, in the form of "pedagogical content" courses or seminars, is herewith proposed as a short-term transition. One size may simply not fit all, as the author's tier analysis attempted to document (Tobias, 1990). Yet, there are many more preprofessionals-among them future elementary and middle school teachers-who need and deserve a solid grounding in mathematics and science than are currently being served (See Appendix B for a list of additional resources).

Mainstreaming in a Sea of Variability

If one were to seek a constant theme in the various waves of reform that have characterized teacher education in the past several decades, that theme would be mainstreaming, that is, moving teacher training from its ancillary place in higher education to a more central location in standard baccalaureate programs. Mainstreaming also offered teacher educators a way out of their isolation. First, in the 1960s, state teachers colleges (grown out of nineteenth-century normal schools) were reconstituted as comprehensive state universities, providing a wider assortment of preprofessional students with the full range of bachelor degree programs. Then, starting in the 1970s, efforts were underway to replace (or supplement) the elementary or middle-school education major with traditional majors, shifting pedagogical training to a fifth year or master's degree program.

Finally, beginning in the 1980s, future teachers, even those planning to teach at the elementary and middle-school levels, were being pressured to enroll in standard mathematics and science courses, which, in turn, are supposed to accommodate their needs. (Secondary science and mathematics teachers complete standard traditional majors in their disciplines.) Typical is the 1989 decree by the then-president of the University of Arizona who, with one sweep, eliminated all tailor-made courses (for nurses, for teachers, for architects, for music majors) in the sciences on the grounds that there should be no "second-class citizens" in science.*

Mainstreaming has an inordinate appeal. In the face of enormous variability among schools of education, state credentialling agencies, and local standards, mainstreaming suggests greater

* The immediate consequences in Arizona were a decision by the School of Education no longer to ***require*** a physical science course of its elementary teachers in training and the disappearance of all but a few of the nursing and future teachers from physics. (Personal communication to the author.)

coherence, uniformity, and ultimately higher quality. Certainly all three are desirable. But at least in mathematics and science, teacher preparation remains, in the words of former NSF Division Director Robert Watson, “everyone’s second priority.” Perhaps it is because of the local autonomy and diversity of its universe. Perhaps because of tradition. But the facts are as follows.

Local Autonomy and Diversity

Of the 1,250 colleges and universities that prepare future teachers, 700 are regularly audited by the National Council for the Accreditation of Teacher Education (NCATE), the nation’s main teacher-education accrediting agency, which has contractual relationships with 36 states. While NCATE accredits programs, the 50 states credential teachers. Conditions in the nation’s 16,000 school districts where these future teachers will take up employment further determine teacher practice. With responsibility thus divided, there is much room for variance in course requirements, the academic quality of preservice students, professional training and expertise of faculty, and the degree to which the outline and findings of the reform movement are making their way into the training of tomorrow’s teachers. Given that the majority of future teachers enroll locally in public and private institutions in their home states and then seek employment again near home, teacher preparation, despite NCATE, remains essentially a local affair with substantial variation around the country.

Contributing to the variation are two developments in recruitment of future mathematics and science teachers: (1) the emergence of the postbaccalaureate professional, who may have majored in science, mathematics, or engineering but now wants to obtain a teaching credential; (2) the postsecondary students who might become teachers and who begin their undergraduate education in community colleges, where there are no teacher educators or education courses in place.

Community colleges offer less than one-quarter of all courses in higher education. Their traditional role in the preparation of educators has been at the level of teacher aide, early childhood/preschool, and supplementary services such as day care management. Florida, where community colleges are recognized “as an essential partner with the universities in the training and education of many of the future teachers” (Florida Department of Education, 1989, p. 33), might offer a fruitful study of how effective these institutions can be in providing other than occupationally oriented programs in initial postsecondary education.

Divided Responsibility

At least as significant in the putative lack of coherence is the divided responsibility for teacher education that results largely from its dual nature. Part of the responsibility for educating future teachers lies with faculty whose primary interest is in their discipline, and part lies with faculty who represent the values, needs, and priorities of the teaching profession. Typically, content specialists, such as professors of mathematics, science, and engineering, are out of touch with primary and secondary classrooms. But then so, too, are education research faculty, who teach the generic education foundations and educational psychology courses, out of touch with advances in science and mathematics. Caught between are future teachers who must get a bachelor’s degree and at the same time must meet expectations of their state credentialling agency. Recent efforts to impose collaboration among these various bodies tend to tilt in one direction or the other. Mistrust dissipates to some extent, according to anecdotal evidence, when the parties are joined in some shared effort (as in the NSF Teacher Collaboratives). But until these collaborations are institutionalized, supported from within, the missing coherence in teacher preparation in science, mathematics, and technology will remain elusive.

Teacher Preparation and Undergraduate Education

The recent shift of teacher preparation at the National Science Foundation from the Division of Elementary and Secondary Education to the Division of Undergraduate Education reflects the Foundation's desire to give teacher education more prominence. The relocation is also an acknowledgment of two truths: first, that preservice training may be more critical than inservice; second, that most of preservice teachers' course work, whether they are preparing to teach in elementary or secondary school, falls within "undergraduate education." Historically, fewer than 32 credits of future teachers' training, less than one year of the full undergraduate program, took place in departments or schools of education; in some programs by state mandate (see below), fewer even than that. And where a fifth year is coming to be required for teacher certification, as in the California system, an even larger portion of undergraduate course work will take place outside of "teacher education."

By locating teacher preparation in the Division of Undergraduate Education, NSF is also sending a signal to college and university science and mathematics departments that they are co-responsible for the education of future teachers. If so, considerable work lies ahead because, except in the comprehensive state universities (many of which, as stated before, are former teachers colleges), science faculty have traditionally directed their teaching (in descending order) toward their majors, toward students whose majors are closely allied with their discipline (by way of "service" courses), and toward general education courses for nonspecialists. (Mathematics education is an exception. See below.) Tailor-made courses for future *elementary* teachers have had a place in some science departments, but elsewhere: they have been abandoned (as at the University of Arizona). Thus, tailor-made courses even for future secondary teachers in biology, chemistry, and physics, in their respective departments--courses that would supplement, not replace, courses in the major—may become rarer still. Although there are exceptions, science departments in the nation's research universities are not yet motivated to hire self-educated teaching specialists or persons holding doctorates in science education unless there is pressure from a Dean or an outside agency to do so. There are many exceptions, but they tend to be in the comprehensive universities. An example from Florida State University is described in Appendix C.

Mathematics education has a longer and more solid place in college and university mathematics departments than science education has in science departments, for two possible reasons: First, there is but one mathematics and many sciences. The mathematics educator can count on a sizable cohort of future teachers in a course in mathematics education, in contrast to the numbers who might enroll in chemistry education, biology education, physics education or geology education courses if they were offered; second, mathematics has been for decades an integral part of the secondary as well as the elementary and middle school curriculum, not just an add-on or an elective. Should states, however, shift their secondary-teaching credential from specific disciplines to a more generic “integrated science” credential (as is under discussion in Minnesota and elsewhere), the needs of secondary teachers-in-training will diverge even more from the traditional science programs in their universities. The future secondary teacher will need some background in all of the sciences, while many of his or her classmates majoring in science will not even have course work in some.

So while there is considerable effort underway toward mainstreaming science education at the full range of colleges and universities, that movement may be overtaken by outside events. Just when science faculties, because of underenrollment and other pressures, may become more willing to serve future elementary and secondary teachers, statewide credentialling decisions may make it more awkward for them to do so.

The Impact of Past Teacher Education Reforms

Most surprising to outside observers is the relative lack: of attention on the part of systemic science education reformers to teacher preparation. Evidence for this comes from midterm assessments of several of the NSF-supported Statewide Systemic Initiatives (SSIs). Initially, of the 21 SSI programs funded, 12 planned to make teacher preparation in science a major focus, and another 12 (with some overlap) planned to focus on teacher preparation in mathematics. But in a midterm review of the programs, budget allocations revealed that only 5 of the 21 spent more than 10 percent of their funding on preservice teacher education, and all but 3 spent more than 10 percent on teacher inservicing (Shields, Corcoran, & Zucker, 1994). Even in the much touted Arkansas statewide school reform initiated by then-Governor Clinton in 1980, teacher preparation got short shrift. Clinton’s program for Arkansas encompassed longer years of mandatory attendance, more course offerings, and higher salaries for teachers (tied to merit), but Clinton’s program gave no attention to teacher preparation.

When teacher education did come under review, as in the governor-mandated reforms in the states of Mississippi, New Jersey, and Texas during that same period, “reform” meant setting limits on the number of course credits in “education” and “methods” that future teachers could count toward a credential. Even in the case of Governor Kean’s 1986 reforms in New Jersey, “reform” meant approving ways that future teachers could “test out” of traditional teacher education altogether. The Mississippi Education Reform Act, 1982, followed by the passage by Mississippi’s legislature of Standard 10, limits elementary teachers to 21 credit hours and secondary teachers to 15 credit hours (plus student teaching); Texas law limits teacher education credit hours to 18, including student teaching. The desire to put a cap on teacher education courses is believed by some to have grown out of *A Nation at Risk* (National Commission on Excellence in Education (1983), because of the authors’ indictment of courses in “educational methods [taught] at the expense of courses in the subjects (Schnur & Golby, 1995).

Directions for Change

If teacher preparation in mathematics and science were to become an arena for sustained improvement, what would the changes look like? And where might one go for research and direction? In March 1996, the Mathematical Science Education Board (MSEB) identified five issues critical to improving the preparation of teachers of K-12 mathematics (1996).

- The content of college mathematics courses taken by future teachers should reflect the changes in emphases and content of the emerging school curriculum; teachers need deeper mathematical understanding to promote mathematical sense-making, problem solving, reasoning and justification—in short, to do more than acquire facts and memorize rules
- Methods courses should better blend pedagogy and content, because how teachers come to know mathematics is as important as the mathematics they know
- How teachers learn about teaching mathematics should be expanded to include videos of actual classrooms, vignettes, scenarios, case studies, and sample student work; also teacher reflection and writing about practice, including "action research"
- In a reform climate those who teach future teachers have to be prepared to teach mathematics in ways they themselves were not taught
- Coherence within divergent structures has to be found

As for teacher preparation in science, certain changes show up on everyone's reform list: (1) better undergraduate science courses to which future teachers would be attracted and from which they would directly benefit professionally; (2) the appointment of trained science educators either in science departments, or in departments of education, or both; (3) higher academic performance requirements in accepting students into teacher education programs; (4) more and better collaboration among the science faculty, the education faculty, and those who supervise the student teaching experience. But how would changes as significant as these fold into current movements for reform? Or, to say it differently, to which new teaching/learning reform models should teacher education programs conform?

However incomplete its implementation, mathematics education has one major model of reform: the National Council of Teachers of Mathematics (NCTM) standards (1989, 1991). Adoption of the NCTM model is not wholesale, although nearly 40 states have developed standards based in part on the NCTM standards. In addition, John Saxon's model (e.g., 1981, 1989) is widely accepted. But in science education, there are at least three approaches to reforming science and mathematics education in the K-12 arena and numerous state frameworks that borrow liberally from all three. The American Association for the Advancement of Science's (AAAS) Project 2061 (1990), in its initial orientation, sought to link science with its applications in society. The National Science Teachers' Association's (NSTA, 1994) Scope, Sequence, and Coordination (SSC) model promotes a spiral curriculum, with biology, chemistry, and earth science-physics revisited several times over the course of six years at increasingly higher levels of abstraction. Then there *are* the new *National Science Education Standards* (NRC, 1996) that identify specific goals for student learning at various grade levels.

In addition to these standards and models are state frameworks, some of which reflect pedagogical innovations such as hands-on science, science-by-inquiry, and collaborative learning at all grade levels and incorporate unconventional assessments; others don't. In recent years, these competing approaches have converged somewhat, but the results are standards so broad that implementation may produce as much variability as before.

The standard for teaching/learning reform, say a number of science educators and observers, is not a single model but an agreed-upon set of goals. To 'borrow their language, future teachers should be able to teach the material in their discipline so that it is learnable. That is, their own learning should be made to be self-reflective. Whatever their other goals, those who prepare future teachers-whether in science or in methods courses-should be able to help their students develop this self-reflectivity. (See "Teaching Pedagogical Content" below.) Further, future teachers of science should know something about the history of educational reform, most particularly about what is going on in their field. They should be familiar with the findings of cognitive science about teaching and learning, the nature of the new science standards (whether or not they have yet been adopted in their home state), new models of assessment, and where to go for information about science education research (Bourexis, 1996; Hewson, 1995).

Such topics, says David Jenness (Personal communication), contributor to a book on middle school teacher preparation in mathematics and science, are not addressed in "content" courses, since only a minority of students in these courses have teaching as a professional goal. Nor are they addressed in "methods" courses that focus, rather, on the practical: how to teach a particular unit at a particular grade level.

These are some of the concerns of the National Science Teachers Association. Steve Gilbert of Indiana University is a science educator, designated folio coordinator by NSTA, with the specific responsibility of looking over the "folios" of teacher-education programs' science component, in conjunction with NCATE accreditation. Gilbert is bothered by the absence of hard data in judging the effectiveness of teacher-preparation programs over the long term and by the lack of grade-level specificity of some of the new pedagogies in science education reform. "Hands-on" science will vary from elementary and middle school to high school, thinks Gilbert. "Constructivist" learning and teaching, while an important corrective, may not be a panacea. And "authentic assessment" may simply be impractical in large classes. Clearly, teacher collaboratives, which bring practitioners into the debate, are crucial for modifying innovations as appropriate to grade level and, above all, for helping teachers to fine tune their practice.

The NSTA regularly publishes a ***Handbook of Research on Science Teaching and Learning*** that was last updated in 1994. Now, because of the various new frameworks, the Handbook is being redesigned. Previously, the NSTA's "standards" called for something like 32 credits in biology for the secondary teacher credential in biology. The new NSTA standards will allow for more flexibility and local control, so that a teacher preparation program can better conform to the state framework. But this in turn will make reciprocity of credentials between states more difficult unless the new National Standards are truly national.

Teaching Pedagogical Content

One way to meet the objection of those who do not want "second-class citizens" in science is to create an entirely new model for the "methods course." Some few institutions have taken this route by introducing special courses in science for preservice teachers, courses no less rigorous and content-rich than the standard course in the discipline. The model calls for "pedagogical content" seminars meant to accompany standard introductory science or mathematics courses. In some instances the seminar stands alone, but whichever model is used, the courses are designed specifically to meet the needs of future teachers.

Pedagogical content knowledge was first practiced at Indiana University in the Mathematics-Methods Program directed by John LeBlanc (1976a, 1976b). That program developed a course for preservice teachers that was taught in the mathematics department; the course was devoted to teaching pedagogy with mathematics. Later, Lee Shulman, then a member of the Faculty of Education at Stanford University, now president of the Carnegie Foundation for the Advancement of Teaching, further developed the idea, sometimes called pedagogy of substance. Shulman's intention, according to his writings, was to integrate pedagogical training within the context of the subject matter (Shulman, 1986, 1987, 1989). Shulman appeared to be saying that students planning to teach should be made more self-conscious both about their learning styles and about their professors' teaching strategies, which the professor rarely makes explicit, as well as about what makes a particular subject "difficult," meaning hard to teach and hard to learn.

Where the "pedagogical content seminar" has been introduced as an add-on to a single course or courses, it is co-taught by the science instructor in the primary (or parent) course and by a teacher educator. During the seminar, instructor and students alike examine the process of teaching and learning in the context of the course being taken. Any student enrolled in the designated three- or four-credit courses may elect to participate in the accompanying one-credit seminar. But no credit for the pedagogy seminar is given unless the student also registers for the primary course with which the seminar is associated. At Millersville State University in Pennsylvania, a faculty member in chemistry described the pedagogical content seminar this way:

> The pedagogy seminar constitutes an exploration of a single question: how does the successful teacher transform expertise in subject matter into a form that students can comprehend? This ability, which has recently been characterized as "pedagogical content knowledge," involves (1) assessing student interest and understanding; (2) anticipating student difficulties and/or misconceptions; (3)construction of coherent explanations with examples, analogies, and metaphors; and (4) organizing course content clearly and from multiple perspectives. (Millersville State University, n.d.)

Clearly, teacher educators at Millersville are trying to stimulate the "self-reflectivity" among students that others have talked about. In addition to reflecting specifically on how to teach course content, students in the pedagogical seminar study a list of readings in the field of teaching and learning mathematics and science. Outside lecturers, including working teachers, may be invited to share their views of how to teach the subject matter at hand. What is unique about the design is the deepening of students' understanding of the content of the primary course by way of exploring its pedagogical challenges.

At the University of Arizona, physicist John McCullen independently invented a parallel course in physics, meant to provide just the kind of pedagogical content knowledge future teachers need to have when they teach basic physical science principles. The seminar was to be offered concurrently with the introductory college physics course. He gave the seminar a new number and carefully selected readings and topics-even wrote a short text on his own-and waited for enrollees. In addition to teaching and learning topics that would emerge naturally out of their introductory physics course, McCullen intended to have his future teachers look especially closely at the research on student "misconceptions" in mechanics. But when too few students enrolled to pilot the experiment, the course was canceled, and in time, its creator lost enthusiasm for it.

McCullen's experience reminds us that, however creative in theory, any new course configuration is vulnerable to institutional rigidities and requirements that can impede implementation. Certainly, questions of student enrollment, how student credits will be counted, and how faculty time will be charged are going to be relevant. Nonetheless, the pedagogical seminar may be one solution to the challenge of mainstreaming future teachers in science while acceding to their special needs and goals.

Cognitively Guided Instruction

Another way to integrate pedagogy and content is to study in depth one's future students. Such an approach is embedded in a promising innovation in the area of preservice elementary mathematics education. The program now in place at the University of North Carolina at Greensboro rests on the premise that the introduction to mathematics methods should emphasize the ***thinking of children*** rather than the ***behavior of teachers.*** Long before their formal student-teaching experience begins, UNC Greensboro mathematics educational instructors George Bright and Nancy Vacc engage their preservice teachers in exposure to children's learning and thinking about basic arithmetic (1994).

Once accepted into the teacher-education program, students at UNC Greensboro, in cohorts of 25, are immediately placed in one of two cooperating local elementary schools, where they will spend 1.5 days per week for three semesters, during which they will observe, talk with children, listen to children, and assist with classroom instruction.. In addition to establishing a relationship with the school where they will eventually student teach (itself an important innovation), the preservice students are supposed to study actively how children learn mathematics-in conjunction with the Fennema-Carpenter theory of "cognitively guided instruction"-the subject of the mathematics methods course they are taking at the same time (1995).

In their mathematics methods courses, "cognitively guided instruction" provides a template of problem types (11 for addition/subtraction, 3 for multiplication/division) not typically featured in mathematics textbooks, but difficult and important for children to encounter. Students bring to the class the insights gained from interacting in their assigned schools with children's mathematical thinking-not their own thinking, and not that necessarily of the pedagogical literature; for this is the focus of the course. Occasionally their mathematics methods instructors accompany them to their schools or teach demonstration lessons to children to add to their own repertoire of observations and knowledge of children's thinking.

Exposing preservice students to the thinking of children early in their training is one of the special features of the program at UNC Greensboro. Traditionally, the intensive in-school experience comes later, once preservice teachers begin their student teaching. But at UNC Greensboro, students are already in the schools where they will eventually student teach, a full three semesters before their student teaching begins; and in the fall semester of their senior year-the semester before their student teaching-they are working in the classroom with the teacher whom they will replace in January.

The twin tasks of watching and listening to children in the context of a mature theory of teaching and learning is a direction in which-think Bright, Vacc and others who are using children as "textbook" and "lab''-mathematics methods training should evolve.

Conclusion

Thus, mainstreaming has brought progress, but problems as well. To the extent that future elementary and middle school teachers are obliged to study science and mathematics in traditional courses, the science faculty is under pressure (1) to reform those courses to reflect "best practice" in pedagogy and (2) to fit them specifically to the needs of future teachers. The first component of this reform effort is laudable and long overdue. Surely for all students, even those preparing for careers in research, science teaching should reflect the latest findings in learning theory and be exemplary in pedagogy as well as content. But the second component is more problematical. The needs of future teachers, both elementary and secondary, especially where they constitute only a small minority in a science: course or program, may not be fully met even by exemplary courses. The forward-looking science dean or department chair may find that mounting pedagogical seminars will encourage alliances among scientists, mathematicians, and teacher educators, moving preservice education beyond mainstreaming and in the direction of true integration.

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Appendix A

NSF Collaboratives for Excellence in Teacher Preparation

The principle behind the NSF Collaboratives is that science, mathematics, and, where appropriate, engineering faculty must play a role in improving the mathematics, technology, and science courses that prospective teachers take as part of their undergraduate curriculum. They should be mindful that the manner in which the courses are presented-their own personal pedagogical style and approach-will have a critical influence on the quality of future teachers' own teaching. Hence "collaborative" means joint planning and implementation of new courses and curricula by science/mathematics/technology faculty in collaboration with teacher educators, and teachers in the K-12 community. Since 1993, ten collaboratives have been funded, each involving a consortium of teaching degree-granting institutions, one or more local school districts, and the local community colleges. Contact persons for all Collaboratives are listed in the FY 1995 and FY 1996 Teacher Education Collaborative Awards, prepared by the NSF Division of Undergraduate Education, 4201 Wilson Boulevard, Arlington, VA 22230.

Other comprehensive projects with partial focus on teacher preparation funded by NSF:

Systemic Change in the Undergraduate Chemistry Curriculum Initiative - Beloit College, University of California at Berkeley, University of Wisconsin-Madison, and a CUNY City College, and University of California at Los Angeles.

Mathematical Sciences and Their Applications Throughout the Curriculum Initiative - Dartmouth College, University of Pennsylvania, Rensselaer Polytechnic Institute, University of Delaware, Siena College.

ATE Centers - Chemeketa Community College in conjunction with Trenton State College.

Washington Center Calculus Reform Dissemination Project, located at Evergreen State College, Washington, has included teacher preparation in its focus since 199 1.

Appendix B

Further Reading

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The Salish I Research Project was founded to examine retrospectively the effectiveness of teacher preparation in science and mathematics on new teachers in their first year of employment. One hundred eighty-one graduates of ten institutions were followed through their first year of teaching to identify strengths and weaknesses in their preservice preparation. As stated in an issue of Salish I *Communique'*, (in Bourexis, P., 1996 3(1) p. 5) eventually the project wants to establish the "links between student learning outcomes, new teacher performance, and their teacher preparation programs."

Among the materials available from Salish I is a Measurement Package consisting of a variety of survey instruments, some of them very creative, employed to assess new teachers' competency and confidence on the job. Also available are a series of *Communiqués* tracking the project through its first two years. Among the early findings are the following:

Their science/mathematics methods courses were viewed by new teachers as the most helpful courses in the preparatory series for making their transition from university student to teacher.

It takes a second and third year for new teachers to implement many of the skills and behaviors learned in their preservice program.

Many new teachers see their former high school teachers as role models more than their college faculty-either in science/mathematics or in education.
The majority of new science/mathematics teachers report that they would have liked even more field-based experiences than were required in their program.

Too often the university faculty forgets (or is not aware of) the great diversity of student populations faced by secondary school teachers.

Most new science teachers chose teaching as a second or third career choice.

Many new teachers see their advanced preparation in science and mathematics as "too specific" for their use in teaching; and that their university science and mathematics professors have no understanding of the secondary school classroom.

Many new teachers are given primary responsibility for developing new curricula; i.e., to be teachers in reforms.

Yet, few new teachers are aware of the broader definition of science content as identified and elaborated in the new National Science Education Standards.

And many new teachers remain convinced that repetition is the way to promote better learning.

Darling-Hammond, L., Hudson, L., & Kirby, S. (1989). ***Redesigning teacher education: Opening the door-for new recruits to science and mathematics teaching.*** Santa Monica, CA: RAND.

Harkins, S., & Michelsohn, A. M. (1995). ***The preparation of elementary school teachers in science reporting on 142 preservice programs.*** Andover, MA: The Network.

Horizon Research. (1993). ***A profile of science and mathematics education in the United States 1993.*** Chapel Hill, NC: Author.

In 1993, Horizon Research undertook a national survey of science and mathematics education targeting 6,000 teachers in grades l-l 2 already working in 1,250 schools. Teachers' preparatory training in education and subject matter courses was one dimension of the study, which found few middle and high school science and mathematics teachers with undergraduate or graduate majors in their fields, but many of those teaching science in middle and high schools having taken six or more courses in their science disciplines. Some indication of inadequate preparation came from the finding that half or more teachers of mathematics and science were unfamiliar with the use of computers as an integral part of instruction. Most serious of all, though teachers were found to be familiar with the new NCTM standards (in the case of mathematics) and with some of the newer notions about teaching science, they were not yet willing to abandon the idea that (in mathematics instruction) students must master arithmetic computation before going on to algebra; that (in science instruction) mastery of basic scientific terms and formulas must come before learning underlying concepts and principles; and in both subject areas that the textbook can be used as a resource rather than a lesson plan.

The investigators asked 700 teachers and teacher candidates to perform certain tasks (plan a lesson given a particular classroom situation, evaluate some textbook selections, evaluate student work), and solve certain problems in the subject matter being taught. The findings indicate that when mathematics and mathematics pedagogy are ***not*** the explicit focus of teacher education, teacher confidence in mathematics, attitudes toward the subject and deepened understanding were not significantly improved.

Labaree, D. F., & Pallas, A. M. (1996). Dire straits: the narrow vision of the Holmes Group, ***Educational Researcher,*** *25*(4), ***25-28.***

Millar, S. B., & Alexander, B. B. (1996). ***Teacherpreparation in science, mathematics, engineering, and technology: Review and analysis of the NSF Workshop, November 6-8, 1994.*** Madison: University of Wisconsin-Madison, National Institute for Science Education.

National Science Foundation (1992). Science and mathematics teachers. In *Indicators of Science and Mathematics Education 1992* (pp. 86-112). Arlington, VA.

National Center for Research on Teacher Education. (1991). *Final report.* East Lansing: Michigan State University, Author.

This report of 11 teacher-education programs focused on two academic areas, mathematics and writing, but sought to cover a range of types of educational institutions, from a highly selective liberal arts college (Dartmouth) to an open-enrollment university (Norfolk State). Its aim was to measure relationships between 1) knowledge of a particular principle, with 2) a teaching situation of a particular type and 3) a teaching decision of a particular nature. The researchers found that teaching decisions while context-sensitive are also based on broad principles. Available from NCRTE, 116 Erickson Hall, E. Lansing, MI 48824-1034.

National Council for the Accreditation of Teacher Education. (1960). *Guidelines for teacher preparation in science math for secondary teachers.* Washington, DC: American Association for the Advancement of Science.

Project 206 1. (1990). ***Blueprint** for teacher education.* 'Washington, DC: American Association for the Advancement of Science.

Raizen, S. A., & Michelsohn, A. M. (Eds.). (1994).*The future **of** science in elementary schools.* San Francisco: Jossey Bass.

Weiss, I., & Raphael, J. (1996) *Characteristics **of** presidential awardees: How do they compare with science and mathematics teachers nationally?* Chapel Hill, NC: Horizon Research.

Survey of 6,000 awardees' teacher preparation indicated that as a group, they are "more likely than others to have extensive course work in science and mathematics." Seventy-two percent of the secondary science awardees, had majored in one of the sciences, compared to 54 percent nationally; and 55 percent of the mathematics awardees, compared to 39 percent nationally had majored in mathematics. Of the elementary teachers, (in 1990 elementary teachers were added to the presidential awards group) 36 percent of elementary mathematics awardees, compared to only 7 percent of elementary teachers nationally, had either an undergraduate or graduate major or minor in mathematics or mathematics education.

Appendix C

FSU Science Methods Courses for Preservice Teachers

At Florida State University at Tallahassee, on a five-year NSF grant, both the introductory science courses taught in their respective departments and the science methods courses required of elementary and middle-school/high-school preservice teachers were substantially revised to reflect new findings in science education research. The department-based courses were enlarged to include a section tailor-made for future teachers and involving such innovations as journal-keeping, "hands-on/minds-on" activities, student research projects, and exposure to interactive computers. The methods courses were enlarged to include field activities, students teaching other students in their methods classes, and interaction with working teachers in two counties in northern Florida. The new Professional Practice Schools established in those counties made possible new levels of cooperation among faculty and graduate students at FSU, preservice teachers at FSU, and working teachers in the designated schools.

What emerges from the final report of this project is the importance of involving science professors in the design of new science course curricula for future teachers that can both meet the value of building a "professional practice community" i.n the region and provide continuous feedback in both directions. Grant money was used to design the new course curricula. Thus, it appears that the revised courses will remain. For further information, contact Kenneth Tobin, education, or Penny Gilmer, chemistry, Florida State University, Tallahassee, Florida.

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