Curricula Gridlock and Other Challenges in Teacher Preparation

Karen L. Johnston
North Carolina State University

Viewpoint

John Dewey had it right. Education is the cornerstone of democracy. The responsibility for the education of young people resides with all of us. With purposeful attention and deliberate actions, we will match and even surpass the great strides we have made and the successes we have enjoyed in science and education during the past 50 years.

When Congress passed the National Science Foundation Act and President Truman signed this into law on May 10, 1950, the science (and science education) enterprise in this country became linked to the public in a real, measurable and accountable manner through public tax dollars. Initiatives on behalf of the science education enterprise emerged from the public voice for science. That public voice spoke of a need to "provide a nation with an aristocracy of talent."[1] Bright students needed to be encouraged to attend college; and science, physics in particular, needed to find ways to identify those best suited for advanced studies. Almost 50 years later, that public voice, recognizing the successes of a strong, albeit very different, science community, suggests a more populist perspective for science education. Shaping the Future[2] recommends a new vision, one proposing that "all students have access to supportive, excellent undergraduate education in science, mathematics, engineering and technology, and that all students learn these subjects by direct experience with the methods and processes of inquiry." Shaping the Future recognizes that we have communities of researchers and practitioners committed to the science education enterprise who are capable of and committed to making science available to all students. Our task is no longer limited to identifying and educating talented students as the centerpiece of science education, though we must continue to do so, but offering **all** students an education in science.

The student remains our focus during this transition period, and the teacher is the most influential connection to the student. Therefore, our attention to the preparation of K–12 teachers is more necessary than it has been in the past 50 years. Physics departments cannot simply discharge their duty by providing an occasional workshop or relegating a lone faculty member committed to K–12 education matters to offer a few courses for teachers here and there. Our standards of what is acceptable educational practice, shaped by the merger of research in developmental psychology and cognitive science with students' conceptions of physics, have changed. We recognize that new curricular materials developed by physicists and based on research are more effective in helping students learn physics. In addition, we support a cadre of physicists, from university and precollege settings, who are able to translate our new knowledge into practice. Considering all of this, we have what we need to do a better job of preparing future teachers.

It is the right time for every physics department in two-year colleges and four-year colleges/universities to take deliberate actions to develop coherent programs that prepare K–12 teachers who understand science and are skilled at making science a part of every person's life. So, let's get to work.

Student Learning and Standards: The Touchstones for Change

Almost 30 years ago *Physics Today* boldly published an issue that highlighted children learning physics. With articles by Jean Piaget[3] on developmental patterns of reasoning and Robert Karplus[4] on children's conceptions of science principals, the early efforts of physicists doing physics education research were validated. Karplus suggested we had a lot to learn from our students and could do so by probing their view of the physical world. He invited physicists to engage in this all-important task of linking science and the practices of science to the educational enterprise more directly and to expand the audience of students having access to science education. By keeping science education visible through curriculum development projects, teacher institutes and projects that capitalized on research into learning and later, new technology tools, we have positioned the physics community to respond to the ever-changing landscape of education.

The future seems promising. AIP[5] reports increases in student enrollment in high school physics. New curriculum projects designed to offer physics to ninth graders signal that the 50 years of post-Sputnik science education initiatives have produced some successes, and we are compelled to expand our attention to students beyond the small subset of those who will become practicing physicists. Physics departments have established research groups engaged in physics education, and while the number of these groups is small, it is growing. The scholarly work created by physicist-educators is expanding. One such example provides a perspective of physics education research (PER) by blending carefully selected constructivist language within a scholarly framework. Redish[6] captures what is at the heart of the National Science Education Standards (NSES or Standards)[7] in a few principles and corollaries in language a physicist can appreciate.

The NSES document is influencing the way we think about science education through the inclusive language in which it is written. The Standards demand we put less emphasis on the tired arguments engaged in by academicians from two different "camps" regarding whether the "s" or the "e" should be the focus of science education for teachers. Instead, we are compelled to focus on students' learning and teachers' skills at affecting that learning. The Standards declare that science teaching is about understanding science. The Standards demand that professional development programs engage teachers throughout their career. From the Standards we can infer how to measure and evaluate the quality of our science programs for teachers and students.

The NSES are based on five assumptions that form the foundation of **science for all**. These assumptions are listed in Table 1.

Table 1. Five assumptions on which the NSES for science teaching are based.[8]

Assumption 1: The vision of science education described by the Standards requires changes throughout the entire system.
Assumption 2: What students learn is greatly influenced by how they are taught.
Assumption 3: The actions of teachers are deeply influenced by their perceptions of science as an enterprise and as a subject to be taught and learned.
Assumption 4: Student understanding is actively constructed through individual and social processes.
Assumption 5: Actions of teachers are deeply influenced by their understanding of and relationships with students.

The NSES model of professional development, buttressed by these five assumptions, occurs along a continuum from undergraduate studies throughout the professional career. [Studies undertaken by the National Institute for Science Education likewise support the concept of continuous professional learning experiences for teachers.[9]] In essence, the Standards instruct us that those who teach are *always becoming a teacher*.

The Standards and results from PER should not be unreflectively accepted, but should be deeply understood. They should change the way we view teacher preparation and the way we do our personal teaching. The Standards, coupled with the results from PER, serve as the two external guideposts for the development or improvement of professional development programs for teachers.

It is easy, however, to get caught up in discussions about the crisis related to the numbers of science teachers in the United States. It is these numbers and the projections of shortfalls that seem to provide the impetus for action. We fret about the pipeline. Are we preparing enough science teachers (output)? Do our programs prepare teachers in "the right way" (quality control)? How can we improve retention of teachers in the early career years (preventing leakage)? Are programs for crossover teachers doing the job (managing seepage)?

The pipeline is not the problem; the pipeline simply is. By turning our attention away from the numbers and toward the task of building and maintaining the infrastructure necessary to support the nurturing and developing of science teachers, we address the pipeline problem in a way that fits our professional role. University and departmental infrastructure provides content, coherence and stability for professional-development programs. When science faculty and administrators, education faculty and administrators, and K–12 teachers and school personnel work together, the efforts address the more important concerns of the teacher in the classroom and produce the desired outcomes, such as (1) developing meaningful coursework for pre- and in-service teachers, (2) continuing to do research in learning and disseminating the new knowledge, (3) developing scholarly collaborations between science and education faculty and (4) strengthening professional communities by linking all elements of the K–G science education enterprise.

When N is Small. . . the NC State Story

Two elements of the culture of North Carolina State University are the drivers for science-teacher professional development efforts in the Department of Physics: (1) the land-grant character of the university and associated mission of extension services (outreach) and (2) the absence of an elementary-education degree program. As a land grant Research I institution, the university is obliged to reach beyond the confines of the campus laboratories and classrooms to connect North Carolina citizens to the university and her work. In the last two decades, this extension mission has been embraced by the sciences, at first with individual faculty members undertaking outreach efforts on an ad-hoc basis and more recently through an interdisciplinary outreach center for the College of Physical and Mathematical Sciences.

The absence of an elementary-education program in the undergraduate curriculum results in a small number of preservice teachers enrolling in physics courses. The steady state number of those who plan to be science, mathematics, or technology (SMT) teachers in middle schools or secondary science education enrolled in introductory physics/astronomy courses in any academic year is less than 50. These two characteristics of the NC State culture are reflected in how we expend our efforts in K–12 teacher professional development. More effort and resources are directed toward in-service education, and the in-service efforts are consolidated with those of other departments in the College of Physical and Mathematical Sciences (PAMS) in a resource facility called The Science House[10] located on the Centennial Campus of the university.

Professional Development Programs: Inservice

By consolidating the outreach efforts of the mathematics and several science departments, David G. Haase, physicist and Director of The Science House, guides outreach efforts in science and mathematics from an interdisciplinary perspective. Programs for middle and high school teachers and their students are offered year-round and made possible by having a permanent facility and a permanent professional staff of faculty and teaching specialists. Reaching over 600 teachers and 20,000 students annually, The Science House is, in every sense, a partnership between the university and K–12 teachers. Permanent in-service facilities and professional staff seem to be the infrastructure needed to establish and maintain the scholarly collaborations between the science disciplines, the education faculty and the partner schools. Table 2 illuminates the range of activities at The Science House. A more detailed description of each program is found at The Science House Web site.[10]

Resource	Description	Programs
Teacher Toolbox	Workshops in SMT, equipment lending library-CBL and MBL	EMPOWER
Stuff for Students	Science research experiences, SMT experiences for student groups under-represented in SMT	IMHOTEP Academy, Expanding Your Horizons PAMS Summer Camps
Curriculum Closet	Hands-on activity books in chemistry/physics, physics curriculum activities aligned with NC standards	Physics on the RoadFun with Physics (vt)
Science Junction	Cyber-community for teachers, students and researchers with collaborative experiments	Links to: SERVIT, NC State research, SciTeach Forum, Lesson Plans linked to Standards
Hands on Happenings	Up-to-date calendar of local and national SMT activities	

Table 2. The Science House—A Learning Outreach Program.

The workshop-related programs for teachers provide not only hands-on experiences with equipment and technology tools, but also encourage and assist teachers in building resources of science-teaching equipment at their own schools.[11] Existing and new initiatives are aligned with the NSES and state standards.

Preservice Teacher Education: Curricular Gridlock and Licensure Dilemmas

The teacher preparation model at most institutions in North Carolina is a clinical model[12] where faculty members who teach in the schools (K–12) are involved in the professional development programs for aspiring teachers. This clinical faculty offers their expertise in methods courses, supervision of practicing teachers and mentoring of new teachers. At NC State University, veteran teachers serve as mentors for new teachers in the induction years. Other clinical experiences include teaching practice opportunities followed by guided reflection on the experiences and skill development that includes demonstration and practice followed by feedback. The NC State program is accredited by the National Council for Accreditation of Teachers (NCATE).

Preservice teachers in SMT are enrolled in degrees programs that fulfill state or NCATE requirements for licensure either at the middle-school level or secondary level. The Science Education (SED) program for grades 9–12 prepares prospective teachers for licensure in **comprehensive science**, meaning that the teacher has the credentials to teach any science taught at the high-school level. Licensure in comprehensive science requires prospective teachers to select a science concentration and to take at least two courses in each of the other three areas of science. For example, a physics concentration requires approximately 30 semester hours of physics and two courses each in chemistry, earth sciences and biology. None of the physics courses in which an SED student would enroll are specialized courses for preservice teachers, and many of the lower division courses would be properly characterized as traditional large lecture section courses. The upper division courses for SED students in a physics concentration are the courses regularly taken by physics majors. With never more than one or two SED students per semester and rarely a student who has selected a physics concentration, specialized courses in physics for SED students are not fiscally feasible.

Until recently, the undergraduate physics program at NC State was a rigorous Bachelor of Science (BS) degree program providing opportunities for research experiences. During the past five years, physics department adopted and had approved a more flexible Bachelor of Arts (BA) curriculum to complement the existing BS degree. The BA degree provides ways for students to express interest in other technical areas without sacrificing the rigor of the undergraduate physics program. Although we had no expressed demand for preparing high school physics teachers with a major in physics, we took this occasion to work with faculty from the Department of Mathematics, Science and Technology education to explore the possibilities. This exercise revealed how crowded teacher-preparation programs have become with requirements. For example, future teachers now must take courses in multicultural education, tutoring adolescents and teaching exceptional students. In addition, a workable program had to include two courses in each of the three other science areas since licensure was for comprehensive science. The physics departmental course and curriculum committee debated the merits of considering science education courses as **technical** electives and in the end were convinced that these courses, indeed, were the technical background of the teacher-preparation program. The final product is a dual degree (BA physics/BS science education) requiring four years plus one summer. While both departments streamlined the program, it offers little breathing room for the student.

NCATE recently issued a set of more rigorous performance-based standards requiring teacher candidates to have a major or the "substantial equivalent" of a major in their area of expertise.[13] Whether these new standards will increase interest and demand for our dual degree program in physics and science education remains to be seen.

The number of students enrolled in physics courses seeking **middle-school licensure in science**, averages around 10 students per semester. A student seeking middle-school licensure with a science concentration would take two semesters of physics, such as a one-semester conceptual physics course and one semester of introductory astronomy (in addition to science courses other than physics). Middle-school licensure with a concentration in both mathematics and science requires two semesters of college-level physics (in addition to other science courses). All of the degree/licensure programs require a minimum of 128 semester hours, with 16 of those hours reserved for the methods/student teaching experience. Do middle school science teachers need more physics or more specialized physics courses? Most likely. Unfortunately, to meet the demands of comprehensive science licensure, university-required general-education courses, education courses demanded by NCATE and the sampling of courses from four science areas, the curriculum has no room for more physics. The small number of SMT education students we encounter in our courses makes it unfeasible to offer for teachers the specialized courses that are demonstrably more effective than traditional introductory physics.[14]

Our most promising solution to the small N and gridlocked curricula problems for students in preservice education programs relies on insuring that introductory physics and astronomy courses are more closely aligned with instructional methodology promoted by NSES. The PER and development group in our department are engaged in initiatives to do just that. Under the leadership of Robert Beichner, the university is building a state-of-the-art interactive classroom that will integrate lecture and laboratory and accommodate the large sections of introductory physics. The classroom is designed for collaborative work by students, making it easy to move from low technology, hands-on experiences to more high-technology tools for addressing real-world problems. Recognizing that teachers influence the achievements of their students far more than any other observable variable, discussions have explored ways in which SMT education students (both middle and secondary) can be directed to the specific physics classes that are conducted in the interactive classroom. In addition, the department is taking the lead at the university to assemble an interdisciplinary group of SMT faculty to focus on teacher professional development.[15] The premise for this collaboration is that research will drive permanent changes in the courses we teach and improve the ways in which we prepare SMT teachers. External funding provides opportunities for change and can accelerate change, but it is faculty, students and university infrastructure that implement and make permanent those changes.

Advice: Begin with the End in Sight

The essential elements for developing effective teacher professional development programs are to: (1) involve all stakeholders in that effort, (2) buttress the program with the scholarship of learning and teaching and (3) build the institutional infrastructure that supports continual, incremental change.

Our collective wisdom and results of research tell us clearly that lecturing about physics does not develop understanding for most students. Lecturing about the importance of and how to do inquiry does not help teachers develop the understanding and skill to teach by inquiry. Walt Whitman says it well in “When I Heard the Learn’d Astronomer”[16]

When I heard the learn’d astronomer
When the proofs, the figures were ranged in columns before me,
When I was shown the charts and diagrams, to add, divide, and measure them
When I sitting hear the astronomer where he lectured with much applause in the lecture room
How soon unaccountable I became tired and sick,
Till rising and gliding out I wander’d off by myself,
In the mystical moist night-air and from time to time,
Look’d up in perfect silence at the stars.

If we want students to understand science one by one, then we must teach science in that way.

What are the ways and means to mend the fractured environments between K–12 institutions, institutions of higher education and professional communities? For program coherence, a professional development program at a university must have integrated preservice and in-service components that have been informed by research and the Standards. Faculty in both the education and science disciplines must work together respecting the expertise that each brings to the table. Administrators must be leaders of reform in the teacher professional development by supporting the requirements of these new faculty initiatives. Programs must have permanent space and other related resources. Faculty who devote their talents to teacher preparation and the related scholarship must be rewarded for their efforts. Teaching specialists from the K–12 classrooms must be invited into the university, on equal footing, to work as scholars with university faculty. Professional associations must develop on-going programs that engage pre- and in- service teachers in the larger professional communities. While the historical traditions and culture at the university must be respected, they need not interfere with or prohibit physics departments from actively pursuing a path that leads to science for all students.

Beginning with the end in sight means that each of the stakeholders must establish goals and identify benchmarks for reaching the goals. Continual program monitoring and evaluation protocols need to be established so that we make every attempt to measure our progress and gauge whether our actions are producing the desired effects. For example, can we demonstrate that our courses do improve student understanding of key physical concepts? Can we document that our pre- and in-service teachers are skilled in using the equipment and tools of technology as a result of our courses or workshops? Do our in-service efforts have an effect on teacher retention? Does active engagement in professional associations have an effect on teacher retention? Can we document that we teach our university physics classes by more interactive methods and what effect does this have on student learning and student attitude?

Holding our institutions, our departments and ourselves to high standards is what guides change and allows us to begin with the end in sight—science for all students. John Dewey had it right.

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