A Stronger Role for Science Departments in the Preparation of Future Chemistry Teachers

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A New Model

Within the next decade, an estimated total of 240,000 middle and high school mathematics and science teachers will be needed. Of this total, nearly 70% of the teachers will be newcomers to the profession (1). Alarming, the country's demand for science teachers is far outpacing the current supply. This teacher shortage is compounded by the fact that many teacher-preparation programs do not adequately prepare their graduates (1, 2). The reports of several national commissions, such as the National Commission on Teaching and America's Future (2) and the National Commission on Mathematics and Science Teaching for the 21st Century (1), have urged higher education institutions to restructure or develop new teacher-preparation programs that impart a deep understanding of the subject matter and student learning, teach and model effective teaching practices in the discipline, and foster the development of reflective practitioners (3).

Recent calls for reform of traditional practices in teacher education have also stressed the need for colleges of science to actively recruit students into science teaching and for science departments to become more accountable for the quality of our nation's teaching workforce (4–6). In this regard, it is not only necessary that science departments invest a considerable effort in redesigning their science courses to model effective teaching practices, science departments must also work to fully integrate the learning of science content and pedagogy.

In the fall of 1999, the University of Arizona's College of Science (CoS) took a bold step to answer these calls for reform by making the preparation of science teachers a high priority. A new program was developed and implemented to recruit and prepare undergraduate science majors to become secondary-level science teachers. This unique program is housed entirely within the CoS, with all pedagogy courses designed specifically for undergraduate science majors and taught by science education faculty members with full tenure-line appointments in their respective science departments.

The new program represents an innovative model for the preparation of science teachers. The program does not belong to any specific department in the CoS, but rather is conceived as a collegewide academic enterprise. The design, development, and implementation of the program have been the central responsibilities of four new tenure-track science faculty members with expertise in science and science education.

These specialists have been appointed to four departments within the CoS (Astronomy, Chemistry, Molecular and Cellular Biology, and Physics), and their primary responsibility is the preparation of secondary-school science teachers. The daily work of these science educators receives substantial support and input from the CoS and university administration, faculty, and staff, as well as collaborating mentor science teachers.

Traditionally, students interested in secondary-school science teaching at the University of Arizona (U of A), as in many universities, completed their science courses in the CoS and applied for admittance to the College of Education. Once in the College of Education, the students would complete several general education and psychology courses, one science methods course, and one subject-specific methods course. The flexibility of the new program's design allows students to become prospective science teachers by completing either the recently approved Bachelor of Science in Science Education program offered by the CoS or a traditional science degree program with an additional set of science education courses that will enable them to apply for teacher certification. The latter option is designed to encourage more students to become science teachers: students who otherwise would not have considered science teaching as a career if asked to switch degree programs or transfer to the College of Education. Additionally, students interested in pursuing graduate studies and a future teaching career at the college level may complete a minor in science education by taking a subset of the education courses offered within the new program.

The new program not only is more successful at encouraging high-quality students to become science teachers, it also is more effective in better preparing these students as science educators. Their success in this area is due to a number of unique characteristics that distinguish the program from more traditional models. One central feature is the universitywide collaboration including strong ties between science departments and the development of a solid relationship with the College of Education. Additionally, the program fully integrates and relies upon the expertise of master science teachers in the community. Finally, the new model offers the unique opportunity for students to learn to teach science in an environment where good teaching practices are modeled and where all education courses are focused on central issues related to the teaching and learning of science.
The Program

The new teacher-preparation program at the U of A offers all pedagogical and subject-matter courses within the CoS, thus enabling a more integrated experience for prospective science teachers and facilitating the definition and implementation of a common educational philosophy. The program seeks to provide undergraduate students with opportunities to develop the skills and knowledge necessary to teach science for understanding (7) and implement inquiry-centered, science-teaching practices (8–9) that promote scientific literacy among secondary-school science students.

The new program requires 30 semester credits of general education courses, 30 semester credits in CoS science education courses, and a minimum of 60 semester credits of science courses, divided among required courses in a major concentration area (biology, chemistry, earth sciences, and physics), electives in complementary scientific disciplines, and supporting mathematics courses. The science education courses have been explicitly designed according to research supporting mathematics courses. The science education courses can be grouped in three well-defined sets as shown in Table 1, each requiring different degrees of student involvement in highly-structured field experiences in a secondary-school classroom.

The sets of courses described in Table 1 address central ideas in teaching and learning science in a secondary-school setting, from traditional topics such as adolescent development, curriculum, planning, classroom management, and assessment to more contemporary issues such as the nature of science and technology, students' alternative conceptions in science, and diversity issues (15). All of these topics are discussed using the teaching of science as a common thread and framed by a set core of understandings that guide science education faculty in developing experiences to help prospective teachers become reflective practitioners (3), recognize the complex context in which teachers work, and practice teaching for understanding (7).

Most science education courses within the program require a minimum number of hours of fieldwork in a secondary-school classroom. The quantity of time that the students work in secondary-school classrooms increases as they progress through the three sets of courses described above. During the initial Introduction and Engagement phase, prospective teachers work under the supervision of mentor teachers completing observation and student-interaction tasks developed collaboratively by the teachers and the CoS education faculty. For courses in the Exploration and Practice phase, the students are required to work one period a day in a school classroom observing, coteaching, and teaching the same group of students over a seven-week period in close collaboration with a mentor teacher. Finally, during the Application phase (student-teaching experience), prospective teachers devote one semester working full-time in a secondary-level science classroom.

In the design and implementation of this new science teacher-preparation program, there has been a continuous emphasis on collaborative planning, teaching, assessment, and decision making. By forging close ties between the university science educators and local school teachers, the program has developed rich and meaningful learning experiences for the prospective teachers, both in the university and in secondary-school classrooms. In particular, experienced secondary-school science teachers working either full-time alongside the CoS education faculty or as mentor teachers in the secondary school have had a major influence on the program since its inauguration in the fall of 2000. They provide the faculty and students with important and valuable perspectives grounded in their vast experience teaching science at the secondary-school level.

Our program also depends on the collaboration and support of the faculty and administration of the U of A College

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Table 1. Description and Requirements of the Science Education Courses in the CoS at U of A

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>Description</th>
<th>Field Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Introduction and Engagement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teaching Science</td>
<td>3</td>
<td>Introduction to science teaching, and the history and nature of science and science education.</td>
<td>20</td>
</tr>
<tr>
<td>Adolescent Development and Learning in Science</td>
<td>3</td>
<td>Introduction to learning theories and student characteristics that influence science learning: intellectual development, prior knowledge, social context, diversity.</td>
<td>20</td>
</tr>
<tr>
<td>II. Exploration and Practice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science Instruction in the Secondary School</td>
<td>4</td>
<td>Focus on thinking about teachers' decisions that foster a productive learning environment in the science classroom.</td>
<td>40</td>
</tr>
<tr>
<td>Curriculum Decisions and Assessment in Science</td>
<td>4</td>
<td>Focus on practical aspects of planning, implementing, and assessing science lessons.</td>
<td>40</td>
</tr>
<tr>
<td>Subject Teaching Methods</td>
<td>3</td>
<td>Pedagogical content knowledge specific to the area of concentration (biology, chemistry, physics, or earth sciences).</td>
<td>—</td>
</tr>
<tr>
<td>III. Application</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student Teaching</td>
<td>12</td>
<td>Prospective teachers student teach in a secondary school during a school semester.</td>
<td>540&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Seminar</td>
<td>1</td>
<td>Reflection on teaching issues that arise from classroom experiences.</td>
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<sup>a</sup>A minimum of 540 hours is required.
of Education. The emergence of a new science teacher-preparation program, contained entirely within the CoS, initially created some uneasiness among some College of Education faculty members, particularly those in charge of teacher preparation. Historically, communication between the College of Education and the CoS has been sparse, thus hindering possible collaborations. However, in the last few years, the U of A administration and general faculty have been highly supportive of the University’s move to broaden the responsibility for teacher preparation across all colleges on our campus.

This remarkable agreement among different stakeholders has paved the way for substantial collaboration between the new program and the College of Education. Currently, two faculty members from the College of Education are actively involved in the evaluation projects associated with the new program in the CoS and one of them teaches a course within the program. In addition, the College of Education administration reviews, recommends, and forwards preservice teachers’ applications from the new program for teacher certification by the state.

Educating Chemistry Teachers

The prospective chemistry teachers in the new program are required to complete the same first two years of a typical bachelor’s degree in chemistry. This includes two semesters of both general and organic chemistry. Additionally, students must take one semester of analytical chemistry with laboratory, one semester of physical chemistry, a course on chemical safety, and 11 semester credit hours of upper-division chemistry electives. Students are required to choose elective courses that offer a set of diverse experiences: lab work, independent study, preceptorship, and research experience. Prospective chemistry teachers need to complete a minimum of 35 semester credit hours of chemistry, requiring no fewer than 300 lab hours. Supplementary science and mathematics courses include one year of calculus, one year of physics with laboratory, and 12 semester credit hours of any science outside of chemistry. These requirements closely resemble those recently proposed for the ACS-approved chemistry education option as outlined by the Committee on Professional Training of the American Chemical Society (16).

The structure of the program, in which all pedagogy courses are focused specifically on teaching science at the secondary-school level, allows us to devote considerable time to the discussion of important topics that are rarely addressed in more traditional teacher-preparation programs. Thus, prospective chemistry teachers are not only exposed to classical topics such as laboratory experimental design, stockroom procedures, safety and liability, waste disposal, and literature in chemical education, they also regularly participate in discussions about the nature of chemistry and science in general, inquiry-based teaching, alternative conceptions in chemistry, and the use of technology in the chemistry classroom.

The program’s focus on science teaching also creates multiple opportunities to develop the prospective teachers’ pedagogical content knowledge (17, 18)—that is, the knowledge of how to foster the understanding of specific scientific concepts and ideas through the different science education courses, and in the chemistry-teaching methods class in particular, students analyze, discuss, and create multiple ways to represent their scientific knowledge for instructional purposes. The students reflect on the various levels of representation commonly used in the chemistry classroom: macroscopic, microscopic, and symbolic. Students also analyze the role of modeling and language in learning chemistry, discuss the strengths and weaknesses of analogical thinking, and learn how to foster intellectual skills for problem solving (19). All these different topics are analyzed and discussed in the context of teaching chemistry in the secondary-school classroom, using a variety of authentic activities designed in collaboration with expert teachers (20).

The development and implementation of the CoS teacher-preparation program has had a positive impact on each of the different science departments involved in the program. For most of these departments, it is the first time that science educators have been hired as part of the regular faculty and their presence has sparked rich discussions about the department’s level of commitment to science education. The Department of Chemistry, in particular, has openly embraced the preparation and ongoing education of chemistry teachers as part of its central mission in an effort to strengthen the area of chemical education. The future success of any teacher-preparation program requires that the undergraduate chemistry course content and pedagogy be redesigned in such a way as to both incorporate the results of contemporary science education research as well as utilize interactive technologies. Prospective teachers need to develop a deeper understanding of the central ideas in their discipline and build a more integrated structure of their scientific knowledge. They also need to regularly experience effective strategies that are learner centered and that promote collaborative learning inside and outside the classroom. Part of the current efforts are thus focused on helping chemistry faculty model the kind of teaching approaches we want our future teachers to implement in the secondary-school classroom.

Promising Signs

In the second year of the CoS teacher-preparation program, there were indicators of success. During the first academic year, 27 science majors completed at least one of the new science education courses and, in the second year, the enrollment in the introductory course almost doubled. This explosion of student interest in the program far exceeded our expectations, especially when compared with the number of students pursuing a science-teaching degree in the past.

Three graduates from the program are already working as science teachers in the Tucson area. An intensive induction program supports these beginning teachers. Additionally, numerous faculty members have become public supporters of this ambitious educational enterprise and enthusiastically encourage science majors to enroll. The recognition across the university campus of the scope and potential impact of this new science teacher-preparation program has sparked similar initiatives in other departments, such as mathematics and humanities.

A teacher-preparation program like the one we have described in this article could not be developed without the strong support and commitment of fiscal and human resources by the host college and the university administration.
The support of public and private granting agencies is also invaluable to the process of building strong partnerships with mentor teachers, individuals schools, and school districts. However, the central need is for a radical change in the way science departments conceive their role in the preparation of future science teachers. All too often, university science departments participate only marginally in the preparation of prospective teachers; they do not actively encourage students to become science teachers nor do the science departments help those interested in a teaching career to integrate science and pedagogy. The educational challenges that we face demand that science departments assume a more proactive role in teacher education by helping develop new models of teacher preparation that create opportunities to learn how to teach in the context of thinking about science and the nature of science—models that encourage prospective teachers to reflect about teaching while recognizing the complexities of learning science.

Literature Cited

15. For more detailed information, visit the program Web site http://scied.mcb.arizona.edu/TPP_home.html (accessed Jul 2003).