Student, Graduate, and Faculty Perspectives on Fledgling Content-Based Doctoral Programs in Science and Mathematics Education

Producing a Professoriate as Well Trained to Teach as to Research

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Faculty at the University of Northern Colorado have developed doctoral programs designed to give science and mathematics graduates breadth of content-knowledge and pedagogical training, as well as science and education research opportunities. They developed these programs in response to calls for better training of the professoriate *to teach*. This case study of various participants' perspectives illuminates the trials and successes of these new programs, and offers insight for strengthening similar programs.

Many recent studies have called for reform in the way instructors teach undergraduates science and mathematics (Astin and Astin 1992; Krieger and Worthy 1990; MacNay 1993; Narum 1992). Leading the call for reform are national entities such as the National Science Foundation (NSF) (Danek, Calbert, and Chubin 1994) and the American Association for the Advancement of Science (Krieger et al. 1990).

The reform effort is catalyzed by such endeavors as NSF's Project Kaleidoscope, which attempts to facilitate reform by promoting dialogue and cooperation among educational funding agencies, educational policy makers, and science and mathematics educators (Narum 1992).

As the reform effort in undergraduate science and mathematics has included the promotion of change in the methods by which undergraduates are taught, several authors have noted the need for change in the preparation of those who will teach undergraduates. At present, some researchers view the preparation of college teachers to teach as incidental to their preparation for becoming a scholar (researcher) (Boyer 1989; Boyer 1990; LaPidus 1993).

Having assumed that research is the desired outcome of training for scholarship, and not recognizing that training for scholarship demands refinement and transmittal of that research so that others understand, many programs that train the future professoriate have not set teaching as a desired outcome of scholarly training (LaPidus 1993).

Bass (1993) defends the position that graduate programs should apply the "same standards" to the training of graduate students *as teachers* that they currently apply to their training *as*

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scholars (researchers). Boyer (1990) feels that when teaching is also defined as scholarship, teaching both educates and entices future scholars.

The qualitative analysis presented in this paper focuses on three fledgling doctor of philosophy degree programs in education at the University of Northern Colorado. The programs are housed in their content area departments. The doctor of philosophy degrees in biology education, mathematics education, and chemical education are housed in the biology, mathematics, and chemistry/biochemistry departments, respectively.

These programs were formed to better prepare future college teachers to teach undergraduate science and mathematics. All three programs, which began accepting students in or around 1988, require coursework in both content and pedagogy.

Both the biology and chemical education doctoral programs allow students to do either a pedagogy or a content dissertation, although requirements differ as to whether an individual has to have experience in pedagogical research experience (as the degree would imply) before graduation.

These programs became the focus of study to determine the effectiveness of the existing programs and to improve them. We hoped this study would also provide insight for faculty at other institutions considering the implementation of similar programs.

About the Programs

The goal of each program is to prepare graduates to conduct and supervise discipline-based pedagogical research and instruct in the content areas at the college or university level. The admission requirements and the doctoral degree requirements follow for each program.

For admission into the biological education doctoral program, 30 semester credit hours and a master's level content thesis is required (although the content thesis may be met as a deficiency in the program). The program requires 64 total semester credit hours for completion. Twenty to 21 hours are to be completed in graduate-level biology content, 11 to 19 hours are to be completed in pedagogy, and 23 to 33 hours are needed from a required core, including doctoral supervised teaching, science education research methods, statistics, and 12 dissertation hours for either a content or pedagogy research project.

The chemical education doctoral program admits students with an undergraduate major in chemistry. However, students entering with a bachelor's degree must complete 94 semester hours for the doctoral degree, while those entering with a master's degree with a chemistry major must only complete 64 semester hours.

The defined 64 hours for the doctoral degree includes 20 graduate chemistry content hours, 12 hours of pedagogy including five hours of doctoral supervised teaching, and 28 hours from a research core, including science education research methods, statistics, and dissertation hours (for either a content or a pedagogy project). In addition, original research of at least the master's level must be completed in both basic chemistry and chemical education before graduation.

Finally, for admission into the mathematics education doctoral program, a master's degree in mathematics or mathematics education or a bachelor's degree with undergraduate senior-level coursework in abstract algebra, linear algebra, point-set topology, and real or complex analysis is required. To receive the doctoral degree, the student must complete 67 semester hours total, including 26 hours of graduate mathematics content, 19 hours of pedagogy, 16 dissertation hours for either a content or pedagogical project, and six hours of electives.

Method

Six doctoral students (two from each program) participated in tape-recorded interviews concerning their experiences and knowledge of their respective doctoral programs. The interview data were transcribed and coded. Patterns in the data were sought out, which led to the administration of a follow-up survey given to a total of 20 doctoral students, including the same students who were interviewed.

For additional perspective, at least two faculty involved with the doctoral programs from each department as well as three educational psychology faculty completed the survey. The educational psychology faculty chosen were selected because they had served on committees of students in these programs or taught coursework required by these programs. Again, patterns were searched for in the survey data, and program bulletins, departmental review reports, and/or student handbooks from the departments were examined for triangulation.

Results

Following are major trends related to certain categories of questions that we discovered when analyzing the survey data:

1. Student rationales for entering the program:

▲ prepare for a primarily teaching position at a college or small university

2. Advantages, as seen by students, of having the program in the content area department:

▲ opportunity to observe content-specific pedagogy

▲ opportunity to enroll in pedagogy courses tailored to discipline

▲ broad content background would make them more competitive for jobs at colleges and small universities

3. Advantages, as seen by faculty, of having the program in the content area de-

partment:
▲ use of pedagogy/educational innovations within specific content area
▲ having trained pedagogists in the department

4. Disadvantages, as seen by students, of having the program in the content area department:
▲ less modelling of content-specific pedagogical skills than expected
▲ high course load in both content and pedagogy/education
▲ lack of faculty in content areas with training in pedagogy or pedagogical research
▲ isolation of pedagogy faculty within content area department
▲ not enough training to do high-quality research of teaching/learning in the content area
▲ current expectation of degree program too broad; possibly due to unclear job market for graduates

5. Disadvantages, as seen by faculty, of having the program in the content area department:
▲ faculty unwillingness to have their teaching practices openly discussed or critiqued
▲ double emphasis in content and pedagogy provides students with diluted knowledge base and spreads departmental resources thin
▲ high course load for students and high teaching load for faculty

6. Jobs obtained by graduates:
▲ many of the graduates, and all of the graduates from the biology education program, obtained jobs in content areas' departments at colleges or small universities. They teach content and methods courses to preservice teachers.

DISCUSSION

Trend 1 above *(the rationale for entering the programs)* shows that the goal of most students entering the programs is to teach. These programs are drawing students that the program designers wished to serve—those with the desire to teach.

It is interesting to note that a particular type of employment, rather than the desire to perform pedagogical research, was the predominant student rational to enter these Ph.D. programs, and that the desire to perform pedagogical research did not surface as a trend. Some students' disenchantment with previous content-research experiences and other students' lack of experience with pedagogical research may have contributed to the absence of this trend.

Trend 2 above *(advantages, as seen by students, of having the program in the content area department)* leads one to believe that the programs are integrating content and pedagogy in vital ways. However, Trend 4 *(disadvantages, as seen by students, of having the program in the content area department)* notes that there is more work to be done in integrating both pedagogy into the content coursework and pedagogy faculty into the content department.

Trend 2 and Trend 4 also present the amount of required coursework, aimed at preparing students in both content and pedagogy, as a double-edged sword in the students' minds—they feel that the breadth of coursework might make them competitive to assume a variety of assignments in a teaching position, but they also express fears that they may be viewed as not possessing in-depth knowledge to teach or to conduct research.

However, Trend 6 above *(jobs obtained by graduates)* shows that some employers have been content to hire graduates with this breadth of coursework. And, to date, students in and graduates from these programs have published peer-reviewed research articles in both content and pedagogical journals.

Trends 3 and 5 *(advantages and disadvantages, as seen by faculty, of having the program in the content area department)* echo the above sentiments of the students but also provide unique perspectives. Some faculty felt somewhat intimidated by having their own teaching critiqued when discussing content-based pedagogical methods, which is understandable since many of them have had no formal training to teach. Workshops that help all faculty improve their teaching methods in a supportive, nonthreatening atmosphere might help open faculty members' classrooms to become living laboratories of pedagogy instruction and pedagogy research.

Finally, Trend 5 also notes that while students seemed overburdened with coursework, the faculty seemed overburdened in offering that coursework. Upon further examination of future employment of the graduates, perhaps the coursework could be scaled back in content, pedagogy, or both. Until that time, perhaps the number of faculty members needed to offer these doctoral degrees should be reexamined.

Based on the types and quantities of coursework requirements in these degree programs, it is evident that much greater attention is being placed on training the professoriate to teach. Also, based on the jobs graduates are filling, employers seem eager to hire those with broad content background and pedagogical knowledge. It seems to be the case that those who earn these degrees do not get substantial content-based pedagogical training, although they are provided with adequate general pedagogical coursework and training. It is arguable that a majority of pedagogical skill is transferable between disciplines.

Some programs seem to lack emphasis in training students to do research on teaching/learning in the content areas, which the degree implies graduates of these programs know well. For instance, in the biological educa-

tion program, someone entering with a master's level content thesis could conduct a content dissertation and thus obtain the Ph.D. in biological education without having ever conducted a biological education research project.

Since all graduates take research design courses and complete some type of in-depth research project before graduation, the Ph.D. degree as opposed to the Ed.D. seems appropriate. However, there needs to be more emphasis on *research* related to teaching/learning in the content areas, not just an emphasis on *teaching* in the content areas, for the Ph.D. degrees in biology education, mathematics education, and chemical education to be appropriate.

Greater integration of pedagogical training into science and mathematics coursework could reduce the heavy course load in content and pedagogy. Perhaps more importantly, greater integration of faculty with expertise to provide pedagogical and pedagogical research training is needed. If teaching and research are to be viewed as equally important, then faculty who teach pedagogy and research must be more equally integrated and supported.

In conclusion, these programs were designed to produce a professoriate as well trained to teach as to research. While they are fledgling programs that can be improved upon, they serve as promising examples to other universities aiming to better prepare undergraduates in science and mathematics by providing graduate students in these disciplines with training in both pedagogy and the content of their discipline. This study provides insight to those universities in their quest to redefine scholarship. ❑

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