CHALLENGES FOR SCIENCE AND MATHEMATICS FACULTY

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The increased science and mathematics teacher licensure requirements for K-8 teachers are clearly necessary to prepare teachers to appropriately teach the new Virginia SOLs [1]. The expectations of a program equivalent to 12 hours of science and 12 hours of mathematics for the PreK-6 endorsement and the 21 hours each of math and science to teach middle school math and science must be chosen very carefully indeed if future teachers are to be prepared to teach the specific SOL content, as well as "practical applications and the use of appropriate technology". Most Virginia colleges and universities are not currently offering the appropriate courses nor the courses taught in the appropriate manner to meet new licensure requirements. Both interdisciplinary courses and interdisciplinary degree programs may be required.

It is clear from Patty Pitts' remarks on teacher licensure [2] that math and science faculty have our work cut out for us. One message I would like to give you is that what's best for a small community college is not necessarily what is best for an urban university, and what is best for an urban university is not necessarily what's best for a small private college, and so forth. Every one of our colleges and its resources is different. However, physical science is physical science, and we physicists basically teach the same material--we just do it different ways. All of us much teach the competencies as described in the teacher licensure requirements, and our graduating students must go forth and teach the math and science standards as espoused both at the state and national levels.

Ertle Thompson, the senior professor of science education at the University of Virginia (UVa), has probably produced more graduates of science education than anyone else in the state. He tells me that 25 years ago the math and science content courses for preservice teachers taught at the University of Virginia were better than they are today. Professor Thompson says that senior professors, chairpersons, and even Deans taught education students. What has happened? I can only speculate, but at UVa the 5-year BA/MA program for education students started about 20 years ago. There are no longer undergraduate education students, nor undergraduate education degrees. Those students became assimilated into our College of Arts & Sciences and now have the same math and science requirements

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as all college students. After the 5-year program was instituted, there was no need for special math and science courses for education students, so the special courses were dropped. If prospective teachers are not math and science majors, they take the same math and science courses as all other non-technical majors. These courses are usually the lowest level, easiest courses offered in math and science; they almost never have labs.

In my own department we have a separate introductory physics course for our prospective majors. We also have separate introductory courses for engineering majors, other science majors, pre-med students, and even architectural students, not to mention those special courses to teach the masses. We do a great job teaching the non-science students, but those courses are not appropriate for preservice teachers. In my opinion, preservice teachers should be one of the most important service clientele we teach. But until this past semester, we did not have a dedicated, hands-on, inquiry based course in physical science taught in a cooperative learning environment using technology such as graphing calculators and probes.

Now let's look at the challenges faced by math and science departments. First, for preK-6 we need to look at the Virginia Standards of Learning (SOLs) that every teacher must know. Let's look at a couple of SOLs.

In grade 5, we find

5.6 The student will investigate and understand characteristics of the ocean environment. Key concepts include

- geological characteristics (continental shelf, slope, rise);
- physical characteristics (depth, salinity, major currents);
- biological characteristics (ecosystems); and
- public policy decisions related to the ocean environment (assessment of marine organism populations, pollution prevention).

In grade 4, we find

4.4 The student will investigate and understand basic plant anatomy and life processes. Key concepts include

- the structure of typical plants (leaves, stems, roots, and flowers);
- processes and structures involved with reproduction (pollination, stamen, pistil, sepal,

embryo, spore, and seed);
- photosynthesis (chlorophyll, carbon dioxide); and
- dormancy.

The reason I list these two standards is that as a physicist, I would be reluctant to even agree to teach an interdisciplinary class that included these subjects as our objectives. I would need specialists in both ocean systems and life science to teach this material. Similarly, I could list a physical science standard that these specialists would have difficulty teaching. Yet, we require our K-6 teachers to master this material! It is not trivial, and research and experience shows the answer is not to have students read the material in a textbook and fill out worksheets. I look at these SOLs, and I see experiments to do on sedimentation, salinity, photosynthesis, and a field trip into the local schoolyard, woods, and fields.

The same thing is true in math. Let's look at a math SOL.

5.17 The student will collect, organize, and display a set of numerical data in a variety of forms, given a problem situation, using bar graphs, stem-and-leaf plots, and line graphs.

I took a lot of math in high school and college, but I don't know what a stem-and-leaf plot is. Most of us know that college students have considerable difficulty making graphs and plots. How are we going to teach all the math material in just 12 credit hours? I am not sure, but I know we can't do it in fewer credit hours. At UVa we are developing three new math courses, three new science courses, and two capstone courses for our K-8 preservice education students:

Three new basic math courses:
- geometry and measurement
- numbers and number measurements
- data and chance

Three new basic science courses:
- physical science
- life science
- earth/space science

Two new interdisciplinary capstone courses:

- one semester course in which students perform mini-projects in collaborative working groups. Possible projects include forensics, sound, global positioning satellites, modeling, and material science.
- one semester course in which students do a research project in a collaborative working group under the direction of a faculty mentor in arts & sciences, education, engineering, medicine, or nursing.

Four of these new courses have already been taught and others are under development. The capstone courses will be interdisciplinary in nature, and will be team-taught. We still need to work out the details of course credit, faculty teaching loads, and course mnemonics. Our eight courses should prepare the pre-service teacher to be able to do research with their school children, empower the new teachers to be lifelong learners, and prepare the new teacher to be a Teacher of Science.

We are not sure this will work. Every now and then we think we might need to have 4 credit hour courses, instead of 3 credit hours. We will try it and see how it works. Again I emphasize what works at UVa may not work anywhere else. But there will be similarities among all the math and science courses. One of the things we hope to accomplish at this conference is for all of us to learn about courses in our discipline at other colleges. In this regard, the community colleges and major research universities are on the same footing, because we are talking about introductory courses for freshmen and sophomores. It is well documented (see, for example, [3]) that community colleges teach general courses to a significant fraction of preservice teachers.

We have two National Science Foundation grants at UVa to help us develop the courses and institute them. We have a lot remaining to do, including convincing the university and our colleagues that this is what we should be doing. I should mention that these courses are separate from the methods and technology courses that preservice teachers must also take. Other than perhaps using probes with graphing calculators, we do not teach technology in the content courses, although we do use it. Students must be exposed to technology in all these courses. In my physical science course, we use Excel to analyze and plot data routinely. The students like it. We use probes with both graphing calculators and computer based systems to take and record data.

Before leaving the preK-6 preservice situation and turning to middle school, I want to mention how important it is for math and science faculty to work closely with our education colleagues. We are blessed at UVa to have a close working relationship. The elementary education group gives us a standing invitation to attend their meetings, and the math and science education faculty is invited to our meetings. The education faculty have their own challenges, not the least of which is how they are going to fit the new increased teacher licensure requirements into their curriculum.

I discuss the middle school situation with some trepidation. It is well documented [4] that a high percentage of middle school teachers teach outside their field of study. We do not have a separate grade 6-8 teacher preparation program at UVa, and our education faculty does not know if they will. It looks tough.

Remember that the middle school teacher licensure requirements require endorsements in two of the following four areas: math, science, language arts, social studies. The requirements require the equivalent of 21 hours in each endorsement in addition to required courses in the other two concentrations. It appears to many of us that there are simply too many course requirements to receive a degree. Let me briefly look at one possibility for a teacher who wants to be endorsed in math and science in middle school. The student must have 21 hours of math and 21 hours of science. In addition the student must also have 12 hours of English, 15 hours in history and social science, their education courses, and about 36 hours in their major courses. How can this be done? It probably cannot, unless the student majors in math or science.

But a student who majors in math or science will probably be endorsed to teach secondary school as well, and experience has shown that most of those students will opt to teach in secondary, not middle, school. A significant number of students majoring in math and science and initially planning on being teachers are deciding to enter other careers that pay more money and are less stressful!

We believe the answer to middle school teacher preparation will lie in interdisciplinary degree programs, and that is a major part of this conference. However, at UVa all our interdisciplinary programs are honors programs, and a GPA of 3.4 is required. We believe

we have a major effort ahead of us to institute an interdisciplinary degree program at UVa. The interdisciplinary degree will not be limited to math and science, because language arts and social studies students have the same difficulty. We submitted a teaching initiative proposal last year to the university to study this problem, and this conference is our culminating event. In the next months we will begin serious discussions about an interdisciplinary degree, and we are very interested in what we hear at this conference.

I have a concern that the Arts & Sciences professors are going to think that we are trying to institute an easy degree for education students. Of course, that is very far from the truth. We believe that such a degree will be popular with pre-law, journalism, and pre-MBA students, for example.

I would now like to make some personal observations about what I think must happen for us to produce better-prepared math and science teachers and for our K-8 students to be better prepared.

1) My experience is that many math and science professors are not even aware of the problem here at UVa. Those with children in school sometimes worry about it, but don't have time to really get involved.
2) We have to convince our colleagues that teaching preservice teachers should be one of our very highest priorities.
3) Excellent teaching for those concentrating on educating preservice teachers must become a suitable criterion for tenure promotion. Research and outreach in math and science education must be considered along with teaching and service. We must convince our colleagues, chairs, and deans of these criteria. And as Jerry Benson, Dean of Education at JMU, reminded us at our conference steering committee meeting, we must convince our Vice Presidents, Provosts, and Presidents as well.
4) I don't think we can compromise on the 12 hours each of math and science for preK-6 preservice teachers. I realize the requirements now have an exception that states the equivalent of these courses is acceptable, but I don't see how that will be possible. We think we need more than 12 credit hours, not less. On the other hand, I understand the difficulty education schools have in getting all the required courses in the curriculum.
5) The Virginia Department of Education will have to recertify all 37 teacher preparation programs in Virginia. All of us need to offer to help with this effort. I served on a

committee last year to help set up criteria for program approval. It was interesting. As a result of that effort, I think I will be able to help the Curry School of Education with their program approval. And I look forward to helping with site visits at other colleges. I hope you become involved, because it is an important responsibility.

6) I would like to see more math and science education professors in Virginia. Most of you have other responsibilities besides math and science. There are probably less than ten professors of each discipline that only do math or science education. I would like to see more math and science professors in Arts & Sciences concentrate on this effort. There are even fewer of us, and there are more in math than in science.
7) The teaching profession needs to rise in stature. Salaries must increase dramatically to make teaching competitive with business.
8) Teaching can be very satisfying, but the workplace must improve.
9) We will hear later from Julius Sigler about the demographics of the teaching profession. We have a tremendous crisis, and a week does not pass when we don't hear of it on TV or read about it in the papers.

A recent report issued by the U.S. Department of Education called *A Back to School Report on the Baby Boom Echo: America's Schools are Overcrowded and Wearing Out* [5] indicates that we will need 2.2 million teachers in the next 10 years, and that during the next 10 years, over 60% of the nation's K-12 teachers will retire or quit. Where are all these new teachers coming from? Our education schools need to grow, and we must do a better job of educating the teachers.

I am guardedly optimistic about our chances. During the past few weeks my optimism has grown as I have heard from so many of you. We think it is absolutely amazing that so many of our colleagues throughout Virginia have come to this conference with a common challenge--to improve the education of our future K-8 teachers. I expect to gain several insights, especially about interdisciplinary degrees, because that is becoming an issue we must face here at UVa. I know mostly about physical science courses, and if I could help you, I would be glad to share my experiences. I hope we can share with each other our successes and failures. Our children's future depends on it. ■

References

[1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

[2] "Editor's Note", *The Journal of Mathematics and Science: Collaborative Explorations* **2**(2) (1999) i-ii.

[3] Steering Committee Report to the National Science Foundation, "Investing in Tomorrow's Teachers: The Integral Role of the Two-Year College in the Science and Mathematics Preparation of Prospective Teachers", *The Journal of Mathematics and Science: Collaborative Explorations* **1**(2) (1998) 115-135.

[4] J. A. Sigler, "A Preliminary Analysis of the Supply and Demand for Middle School Mathematics and Science Teachers in Virginia", *The Journal of Mathematics and Science: Collaborative Explorations* **2**(2) (1999) 53-64.

[5] *A Back to School Report on the Baby Boom Echo: America's Schools are Overcrowded and Wearing Out,* U. S. Department of Education, September 1998.