An Integrated Math and Science Course for Present and Future Teachers

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The problem of institutional and disciplinary barriers is especially pronounced in university courses that are offered to prepare teachers in upper elementary and middle grades. These teachers are either generalists (teaching their students all subjects) or partial specialists, teaching, for example, mathematics and science (including such different domains as elements of physics, astronomy, chemistry, and biology), while also being responsible for the school's computer lab. There is no integration of content among the courses in mathematics and science that they take during their undergraduate, and sometimes graduate, years. Mathematics, physics, and chemistry are taught in the Math, Physics, and Chemistry Department, respectively. These interdisciplinary barriers lead to knowledge that is often fragmented, and teachers are usually unable to integrate knowledge from one domain into another. A second barrier, for undergraduates planning to be teachers, is that their experiences teaching in classrooms occur during their senior year field experiences in the College of Education. Content courses are taken earlier, in other departments, without any connection to classroom practice. So there is no bridge between their content knowledge and classroom experiences. In the NMSU Department of Mathematical Sciences we are trying to alleviate these problems by offering a sequence of courses designated jointly for elementary and middle school practicing and future teachers (graduates and undergraduates in the same class). The courses are interdisciplinary; they contain a large science component and are infused with technology (calculators and computers). We have an agreement with the Las Cruces School District that undergraduates can attend teachers' classrooms, observe, and also teach under supervision. Thus what they learn in the university class becomes directly connected to their teaching practice. I will summarize the content of one of the courses, Math and science with technology, and discuss organizational and logistic problems involved in offering this type of course.

1. Introduction. Different strokes for different folks.

We have different student "customers" at the university, and we design courses to meet their needs. The three main types of courses are those for majors, those for non-specialists (general education service courses), and those for teachers.

If you teach college courses for students majoring in your domain, you think of each course as part of a bigger plan. A particular course for a major is just one stepping stone in the plan. And the scope of such a course can be rather narrow and well defined. Also, the student population in the course is relatively uniform in terms of background, interests, etc.

When you offer a general course for non-specialists (e.g., physics for non-majors or Math 210: Math appreciation), you can present the course as an overview, with general information, because the students will never have to use the course content in a practical situation.

When you offer a course for teachers, the situation is very different.
1. The value of a course for teachers comes mainly when they can use the knowledge they learn in their classrooms. General ideas are not enough. The knowledge must be very specific.
2. Even if the course you offer is not the only course in your subject area that teachers will take, the course needs to be self-contained. It is not a prerequisite for others, and others are not a prerequisite for it; it is not part of a sequence.

3. You can expect that the students who take the course will have a much larger variety of backgrounds and abilities than students who are majors have.

You don't need to consider the three points above as a handicap; they offer some aspects that are not necessarily possible in other courses:

• In a course for teachers, you have much more individual freedom in choosing the specific topics you want to cover.

• When you have students with a broad spectrum of backgrounds (e.g., you may have graduate students in math together with undergraduate elementary education majors, high school specialists in physics, and elementary teachers all in the same class), you can organize the class into groups such that each group has a mix of different people. Such an organization works well because the roles of the members are well defined. Each group member is judged for his/her contribution using a different criterion.

2. The importance of courses for teachers

Teaching non-majors, especially future teachers, is typically left to instructors who are usually working without any faculty supervision. The quality of textbooks used in these courses is usually dismal, and the books are often full of errors. High-quality courses should be offered by engineering, chemistry, and physics not only for majors, but also for current and future teachers.

My claim.
Teaching content courses for teachers is the most important thing a professor can do. Courses for teachers are the most important courses in an academic department. They have an impact (which can be good or bad) that can last over 25 years. They impact the lives of children (for good or bad) for years to come. So we should prepare courses for teachers thoughtfully and teach them well.

3. A sequence of courses for teachers offered in the Math Department

I teach courses at NMSU that integrate math, technology, and science. The courses are geared toward prospective and practicing elementary and middle school teachers, teaching grades K-8, but they are also open to high school teachers and other university students interested in education.
The demographics of people taking my classes:
The students are mostly women (≥ 90%). Prospective teachers are mostly young undergraduates who have already chosen teaching as their future career. But some students are older people starting a second career. Practicing teachers are usually experienced and in the middle of their careers. They usually have families, and work all day teaching, so it is not easy for them to spend two evenings per week in university classes.
The population of prospective and practicing teachers is diverse. Half are Hispanic; some are Native American. Many are bilingual (English and Spanish), but they have never had any formal education in Spanish. (So math/science terminology in Spanish may be new to them.) (The public school student body in Las Cruces is 65.6% Hispanic, 30.3% Anglo, 2.3% African American, 1% Asian, and 0.8% Native American (about 23,000 students total).)

Responsibility for preparation of teachers.
There are many well-justified complaints in this country that teachers do not know the subjects they teach well enough (e.g., CBMS {1}; Ma {2}). Who is responsible for this? I think that the responsibility lies squarely on the faculty of departments of mathematics and departments of sciences and engineering at universities and colleges. We provide content courses for prospective and practicing teachers. And for the most part we do not do a good job.

There are three aspects of this problem that I will briefly address here:
a. Content of the courses for teachers.
There is a lack of high-level courses in mathematics, sciences, and technology that are appropriate for teachers. At present we offer to prospective teachers low-level refresher courses in school mathematics. Almost no high-level courses deal with material that is related to topics that teachers will actually teach in schools. There are no content courses that prepare teachers to use modern technology.
b. Fragmentation of subject matter:
In its call for change, the “Math Reform Movement” recommends that what is taught in schools should be taught in an interconnected way. Technology should be infused throughout. Mathematics should be integrated with science. Besides, teachers in elementary and middle grades re “generalists” and not “specialists; they teach all or many subjects, and this makes the boundaries between subjects more fluid. Courses at universities are organized differently. Different topics are taught as disjoint subjects. Even related topics, such as calculus and dynamics, are taught as different subjects, often in different departments. Such fragmentation doesn’t prepare teachers to teach in an integrated way. It has just the opposite effect.
c. Format of the courses for teachers
Almost all elementary learning, and most middle school learning, is laboratory learning. Children don’t listen to lectures and take notes. They learn interactively through activities that are carried out in classrooms and organized and directed by teachers.
The pattern of university courses is different. We have lectures, homework, exams. This difference in format makes transfer of material from university classrooms to school classrooms difficult and often impossible. This leads to a strange situation. Schoolteachers in elementary grades often rely more on their own early school experiences (teaching as they were taught) than on the material they learn in college.

So to improve the situation we need to:
(1) provide the right content in the courses; it must not be low level remedial content, and it must cover topics that are connected with actual school mathematics.
(2) integrate the strands of mathematics, science, and technology into a coherent sequence of courses.
(3) use a format that is compatible with the daily routines that teachers use in their classroom work with young pupils.
(4) provide opportunities for present and future teachers to try units studied in the university class with children in classrooms.
At NMSU we are trying to do all four of these things in the Mathematics Department. (We are not doing it alone; we’re collaborating with the NMSU College of Education and the Las Cruces School District (LCPS).) We offer a sequence of five courses (two and a half years).

About the sequence of five courses in the NMSU Department of Mathematical Sciences:
(1) It covers the arithmetic of real numbers and its subsets, rational numbers, integers and whole numbers. It covers three-dimensional metric geometry (based on the concept of a distance and related concepts of measurements (angles, and areas and volumes of elementary figures.) Algebra is not taught as a separate topic, but algebraic notation provides a language that is used in all courses.

(2) All courses are taught as courses in applied mathematics. Applications are the design and construction of physical objects, mensuration, and scientific experiments, with a stress on physics, and statistical investigations. Word problems are rarely used, and hands-on activities take a considerable amount of classroom time at all levels. Use of calculator and computer technology is integrated with all topics. Students learn to use four operation calculators, scientific calculators, and graphing calculators and some computer software.

(3) All courses are taught in a lab format. Most learning takes place in the classroom, where students work in groups or individually on assigned tasks. They are provided with extensive handouts, so a lecture format in which the instructor talks and students listen, is limited to administrative issues. The handouts contain a large amount of classroom-ready materials. (See http://math.nmsu.edu/breakingaway.)

(4) Present and future teachers are in the same university class, receiving graduate and undergraduate credit respectively. Undergraduates visit teachers' classes at least ten times during a semester; they observe, co-teach, and eventually teach alone under supervision, trying units they studied in the university class. Students give "classroom reports" in the university class, and bring in children's work. In this way, we can determine what worked and what didn't, and revise and hopefully improve the lessons. We are trying to prepare teachers to work in a bilingual community; it is our obligation to provide terminology and material in two languages. So the material needs to be appropriate, and the preparation needs to be appropriate.

Each of the five courses focuses on a different aspect of school mathematics. The foci of the five different courses are: arithmetic, geometry, algebra, calculator and computer technology, and science.

4. The course Math 301/501. Math and science with technology

This is our fifth course in the series. The central theme of the course is the development of three main concepts of physics, force, momentum, and energy. The course starts with statics and simple machines. It deals with forces and related concepts, such as moments of forces and the center of mass. It progresses to dynamics, introducing momentum and kinetic energy, and a plethora of related concepts, mass, velocity, acceleration, and so on. It leads also to the concept of potential energy, and this forms a background for future investigations of heat, electricity, and magnetism. Because the approach is experimental, students have to get used to operations on vectors (force, momentum, velocity, acceleration) as well as on scalars (mass, energy).

Measurements of physical quantities are the core of the experimental method, so students have to learn several units of measurements that are used in physics, which are unfamiliar to them, such as newtons and joules. Elements of dimensional analysis are an important part of the theoretical aspect of the course.

Besides the central theme of developing the physical concepts of force, momentum, and energy, several other selected topics are covered, in order to provide variety to the course, and also to provide material that is suitable for the earlier grades. The central theme mainly covers topics that are suitable for middle school, when students start learning algebra.

The role of technology is essential. In the first half of the course students use four-operation and scientific calculators for most computations, and internet resources for additional material. (There is no textbook for the course, only extensive handouts, written primarily by Andrzej Ehrenfeucht; a book of the materials is in progress).
In the second half of the course, students learn some rudiments of computer simulations of some physical processes (e.g. magnetic fields) using programmable graphing calculators (TI-83s).

We do not have a physics lab; we have a "normal" classroom. We put the chairs in groups of four or six, and we beg, borrow, or steal (or sometimes purchase) the equipment and supplies that we need.

General comments.
Many courses in science provide a popular survey that avoids both quantitative and mathematical aspects of the modern sciences. This course takes a different approach. It is
• experimental,

• heavily oriented toward measurements, and
• mathematically oriented.

It doesn't stress the mathematical derivation of formulas, so it doesn't require high algebraic skills. But it does stress interpreting formulas and comparing theoretically expected results with outcomes of actual experiments students perform in class. This approach does not leave time to cover very many topics, but it shows how science can be used in everyday situations, and it provides the intellectual tools for these applications.

5. A list of the experiments and other hands-on activities in the course.

They are put in the order in which they have been introduced. Asterisks indicate additional topics (i.e., those that are not basic physics) (During the talk I will give a brief demonstration of at least one lesson.)

*** Tree rings
*** Volume of an ostrich egg
Archimedes' principle
*** Measuring the height of a tree
Several experiments dealing with the stability of a structure built from wooden blocks.
Experimenting with spring scales.
Finding the center of gravity.
Experiments with pulleys.
Experiments with ramps.
Measuring the coefficient of friction.
Friction revisited.
Rolling and spinning balls.
Colliding balls
Measuring average speed, and computing speed at a given moment
Experiments with swinging weights
*** Spinning maple seeds (real, paper, Origami)
Throwing soft "golf" balls with a sling
Potential energy
Spring-powered cars
Water/air rockets
Magnetism, electricity, magnetic forces
Reading an electric bill
Dimensional analysis
Heat and temperature; calories
Working with mirrors
Hydrostatics and hydrodynamics

6. Final remarks.

I have stressed the importance of high-level, appropriately designed, university content courses for current and future teachers, and discussed one such course. I have talked about matching the presentation of such classes with the needs of the students:

- Less lecture; more hands-on activities
- Integrated content (math and science)
- Visual, verbal, tactile; easy transfer to school classrooms
- Modular; information immediately useful

The courses are not easy to teach. They take more time to prepare, and students' writing assignments (which I have not discussed!) take time to read and critique. But teachers appreciate such courses. Some math majors, and some math graduate students, have taken some of these courses, and have indicated that they wished they had been taught math and science in this integrated format from the beginning. Here is a hypothesis: Could it be that courses such as the ones I have described are appropriate, not just for teachers, but also for other non-majors, and perhaps even for majors?

Bibliography

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