FIRST STEPS TOWARD CHANGE IN TEACHER PREPARATION FOR ELEMENTARY SCIENCE

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Abstract

Unless introductory undergraduate science classes for prospective elementary teachers actively incorporate the philosophy of inquiry-based learning called for in K-12 science education reform, little will change in elementary science education. Thus, at James Madison University, we have developed a new integrated science core curriculum called *Understanding our World* [1]. This course sequence was not only designed to fulfill general education science requirements, but also to focus on content areas our students will need to know as teachers. The objectives of these courses are based on the *National Science Education Standards* and Virginia's *Science Standards of Learning*, including earth and space science, chemistry, physics, life sciences, and environmental science [2,3]. As an integrated package, this course sequence addresses basic science content, calculation skills, the philosophy and history of science, the process of how science is done, the role of science in society, and applications of computers and technology in science. Keeping in mind that students tend to teach in the same way they were taught, *Understanding our World* core classes embrace the concepts associated with reform in elementary math and science.

Project Summary

The *National Science Education Standards* call for prospective teachers to learn science in the way they are going to teach it: as inquiry and for full

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> understanding. They are to learn to teach science in the places where science teaching happens. They are to be members of lifelong communities of learners, and they are to experience coherent and integrated professional development programs. The challenge is to move from national standards that represent a vision to state programs at our colleges and universities in order to work together for the future of education [3].

At James Madison University (JMU), students in pre-professional programs in Early/Elementary Education, Middle Education, and Special Education major in Interdisciplinary Liberal Studies (IDLS). These IDLS majors choose a concentration in either mathematics and science or humanities and social sciences. The split between these concentration choices is about 25% mathematics and science, and 75% Humanities and Social Sciences. For those with a concentration in Humanities and Social Sciences, the only natural science requirements are the introductory science classes for general education. Yet, upon graduation, almost all IDLS majors will teach science to some extent. We developed the *Understanding Our World* science core curriculum to ensure that the introductory science classes these students take will meet their needs as future K-8 teachers. In this paper, we document our first steps toward that goal. Mastery of science content by all students is the principle mission of this project. At the same time, we endeavor to reinforce positive attitudes toward science for all IDLS majors and we hope to increase the number of students who choose to be certified in math and science.

Our goals are to:

- provide science content to learners who do not traditionally do well in standard science courses;
- stress the importance of science for early and middle school educators;
- develop an interest and an increased enthusiasm in science;
- model teaching methods; and,
- send the message that science empowers.

Understanding our World is a three-semester course sequence [1]. The objectives of these courses are based on the *National Science Education Standards* and Virginia's *Science Standards of Learning* [2,3]. Beyond content, these courses emphasize inquiry-based learning, student-centered classrooms, group learning, creating contexts for learning, treating students with respect, facilitating learning with multiple learning modalities, stimulating interest in science among minorities and women, and alternative methods of assessment. Our goal in creating this new course sequence has been to integrate science content with active learning strategies and models of effective science teaching.

There are six, eight-week block courses that span the freshman year and the first semester of the sophomore year:

GSCI 161 - Science Processes

GSCI 162 - The Science of the Planets

GSCI 163 - The Matter of Matter

GSCI 164 - Physical Science: Learning Through Teaching

GSCI 165 - The Way Life Works

GSCI 166 - The Environment in Context

The courses are integrated in both content and learning style to help students connect ideas and build interdisciplinary models to form a basis of understanding. Understanding is not merely the memorization of science facts and formulas, but a process whereby facts and ideas are related through models and hands-on experience. Math and technology applications are embedded in all of the courses in this sequence. Many of the students have deep-seated math and computer phobias. Many have never sent attachments by e-mail. Most have never developed a web page. Most own graphing calculators, but don't know how to use some of the graphing and statistics functions. These courses provide many opportunities for students to master these math and technology skills.

Cooperation between science and education faculty was an essential component and one of our major strengths in planning and implementing this project. However, one of the biggest challenges in bringing this project to fruition was coordination between faculty and administrators in a number of different departments from four colleges. The core group behind this project included teaching faculty and administrative support from the College of Science and Mathematics, the College of Integrated Science and Technology, and the College of Education. The College of General Education also provided financial and administrative support.

Content and Learning Environments

> Elementary school children learn science best when they are involved in first-hand exploration and investigation and inquiry/process skills are nurtured, instruction builds directly on the child's conceptual framework, content is organized on the basis of broad conceptual themes common to all science disciplines and mathematics, and communication skills are an integral part of science instruction [4].

Just as elementary school children learn science best when they are involved in first-hand investigation, this course sequence reflects our philosophy that college students learn best that way, too. Classes are taught in studio classroom environments in which students sit and work in small groups. Each class also has access to laboratory and computer facilities.

The content of these courses follows the eight categories of the National Science Content Standards as summarized in Table 1.

Table 1
Congruence of the IDLS Science Core Sequence with the Eight Categories of National Science Content Standards

1) Unifying concepts and processes in science (*GSCI 161 – Science Processes*)
2) Science as inquiry (all six classes, especially GSCI 161 – Science Processes)
3) Physical science (*GSCI 163 – The Matter of Matter* and *GSCI 164 – Physical Science: Learning through Teaching*)
4) Life science (*GSCI 165 – The Way Life Works* and *GSCI 166 – Environment in Context*)
5) Earth and space science (*GSCI 162 – The Science of the Planets*)
6) Science and technology (all six classes)
7) Science in personal and social perspectives (all six classes)
8) History and nature of science (all six classes, especially *GSCI 161 – Science Processes)*

For curriculum materials, we have made use of excellent existing resources, such as videos and print materials from the Annenberg/CPB Private Universe Project in Science [5].

However, most of the curriculum materials were developed specifically for these courses and are linked on-line either through links from individual course pages or links from the *Understanding Our World* website [1].

Curriculum materials were developed to:

- foster students' understanding of key science concepts;
- encourage problem solving and critical thinking;
- promote the development of positive attitudes about science;
- highlight links between science concepts and social, political, and ethical issues; and,
- present science content in a way that models effective teaching.

These classes are briefly described below along with a few examples of specific course projects and activities.

<u>*GSCI 161 - Science Processes*</u> — As the introductory class in the *Understanding Our World* sequence, *Science Processes* takes a general approach to the role of science processes in all science disciplines. For the first eight weeks of their freshman year, students focus on asking questions, observing, classifying, communicating, measuring, predicting, inferring, experimenting, modeling, interpreting, analyzing, and evaluating data. For example, for one of the activities, students estimate the total number of trees in the JMU arboretum. This project requires on-site data collection in the arboretum, library and on-line research, image analysis of satellite data, statistical modeling, knowledge of unit conversions, and many other science process skills. Through projects such as this, we want students to gain an understanding of how we know what we know, and what evidence supports what we know.

As the final project for this class, students develop lesson plans and collect low cost materials for a specific activity that links a particular science process to a K-8 classroom. Students prepare teaching materials, hands-on supplies and equipment, and assessment activities and tie their lessons to Virginia Science SOL requirements for their target grade level. Activities, background materials, and lesson plans for the *Science Processes* class are available to download in *Microsoft Word* format from the course website [6].

GSCI 162 - Science of the Planets — In the second course in the sequence, we build on the basic science skills developed in the *Science Processes* course and apply them to the specific content area of planetary and earth science. We explore the structure and evolution of our solar system, along with specific processes that shape and change the Earth. We also explore the origin of life, a topic that forces students to take a close look at their own beliefs as they explore the current theories in this area.

The final project in this course is a synthetic one. Students are asked to serve as an advisory board to NASA and help determine which future planetary missions to fund or cut. They also have to develop educational outreach plans for the missions that will fly. In working on the project, they explore the relationship of science and society, and develop an understanding of some of the non-technical factors that go into technical decisions.

GSCI - 163 The Matter of Matter — This course focuses on chemistry. The content of different sections of this class varies depending on the home department of the instructor. However, all sections cover the basics of atomic structure, chemical bonds, the language of chemistry, chemical reactions, simple organic molecules, polymers, acids, bases, salts, and pH. In this class, students design, improve, and perform their own experiments. Since the experiments are not presented in the typical cookbook fashion so often used in introductory courses, it is hoped that the students at least get a feeling for doing what a scientific exploration involves.

GSCI 164 - Physical Science: Learning Through Teaching — At the beginning of this class, students form working groups to pick a topic on which they will become "experts." The term "experts" is based on the discussion of learning presented in *How People Learn* [7]. Each group develops a hands-on activity that explores the science of their area. Examples of class topics include motion, simple machines, sound, the ray model of light, the Doppler Effect, electricity, solutions, electrolytes, acids, bases, and indicators. It doesn't need to be comprehensive. The students design an activity, then prepare material for distribution to the entire class (summaries and procedures). They develop a quiz with at least one question that probes the ability to bring concepts together to solve a new problem. Each group has an entire two-hour class period to teach the science behind their topic. The students administer and grade the activity quiz and any other required material. Classmates complete an evaluation. Activities are usually developed through discussion with the instructor. The department has an excellent collection of materials that can be used to explore science. The students can pick from this equipment or suggest alternatives. The goal is not to require the students to develop the activities, but to learn the material and teach using an activity. Students decide the mix of lecture, experimentation, and discussion. Usually, the session is divided into sections with each student leading a section and with the rest of the team supporting it. A list of the activities for Fall 2002 can be accessed at the course development website [8].

GSCI 165 - How Life Works — From isolation of DNA to understanding the cell biology of cancer, students explore how life works on many levels (molecules, cells, organs, organisms, and populations.) Students isolate DNA from bananas, develop dramatic vignettes to illustrate human pedigrees, build computer models of biological molecules, collect, stain and identify bacteria, investigate the genetics and cell biology of cancer, and develop recipes for meals that contain "cancer healthy foods." (For this last project, groups bring samples for the rest of the class to enjoy.)

For one of the activities in this class, student groups create their own interactive illustrations of the step-by-step processes involved in hearing, vision, balance, inflammation, muscle contraction, and cell division. An interactive activity for nerve transmission, "Encounter at a Neuromuscular Junction," serves as a model for the student projects. How does a nerve impulse travel from the central nervous system to a muscle cell? The entire class acts out this process. Each student has a specific role. Some students are sodium pumps. Others play the role of sodium, potassium or calcium channels, membrane vesicles, and enzymes that destroy excess neurotransmitter molecules. With each student playing their role, the nerve impulse travels like a "wave" from the central nervous system to the muscle cell. For more details, this and other activities are posted on the class website [9].

GSCI 166 - The Environment in Context — This course builds from the content of all of the preceding courses. Students explore environmental issues, such as global warming, air and water quality, habitat destruction, alternative energy, the environmental impact of genetically modified foods, and waste disposal. An example project from this class is a group project in which students investigated alternative energy options. One group videotaped a test drive of a hybrid vehicle, and used the video to promote a class discussion of the advantages and possible drawbacks of buying a hybrid car.

Assessment

In K-12 schools, assessment means teachers listening to and observing students to ensure that each understands the material in their own way. It means teachers talking with other teachers about students' work and about their own classes. It also means students thinking about their own work and attitudes through journals, group work, and projects. We have tried to reflect this view in our own assessment of this course sequence.

The first class of twenty-three started in Fall 2001, with *GSCI 161* and *162.* This first cohort has just finished the entire course sequence. Thus, so far we only have limited data about how well the course sequence is meeting our goals. Our criteria for program success will be assessments of attitudes, knowledge, and skills. We will be looking for an increase in freshmen choosing to seek math and science endorsements during their teacher preparation program, and an increase in each individual student's commitment to community involvement compared to students taking the standard curriculum. As part of this project, we need to assess student learning in the science content areas, to assess our achievement in fostering positive attitudes toward science and science teaching, and to assess the influence of the learning environment and interactive learning methods on student learning and attitudes. Yet, in the same way that we expect students to learn from the classroom environment and teaching methods used in these classes, students will learn from the assessment methods we use for this course sequence. Thus, we have tried to make sure that assessment in these classes is coordinated, multifaceted, unobtrusive, and enhances learning.

Over the first three years of this project, we have collected pre- and post- surveys on student content knowledge, student attitudes toward science and science teaching, and student course evaluations. For course evaluations, we have used the Student Assessment of Learning Gains (SALG) survey from the University of Wisconsin [10]. This assessment instrument focuses on learning gains instead of teaching evaluation. The survey can be customized to fit individual courses and include student attitudes toward science, as well as student assessments of their own learning of science content.

Both students and faculty have taken the Middle School Science Praxis II. We found that the content of our courses is a good fit for the range of subjects covered on this test. So far, we have data for only a few students. Eventually, we plan to compare the performance of our students on the Middle School Praxis II to students who have completed the traditional general science curriculum. Over the long term, we plan to track student teachers as they enter the teaching profession, and collect data on their teaching methods, how their students perform on state standardized tests, and how they assess their students. We started this program with only a single section of each course and gradually built it to include additional sections each year. Thus, we have a built-in control group of students who took traditional general science instead of this curriculum.

Lessons Learned

> Learning experiences for prospective and practicing teachers must include inquiries into the questions and difficulties teachers have. Assessment is an example. Teachers must have opportunities to observe practitioners of good classroom assessment and to review critically assessment instruments and their use. They need to have structured opportunities in aligning curriculum and assessment, in selecting and developing appropriate assessment tasks, and in analyzing and interpreting the gathered information. Teachers also need to have opportunities to collaborate with other teachers to evaluate student work—developing, refining, and applying criteria for evaluation. Practicing teachers will benefit from opportunities to participate in organized sessions for scoring open-ended assessments [2].

Because of the nature of these classes, students have had the opportunity to interact with each of the professors on a much more personal level than in traditional large lecture classes. Even though these were general education science classes and the instructors were science faculty, from the perspective of some of the students, these were their first "education classes." Consequently, their expectations for these classes were different from the expectations they might have had for traditional science classes. In this light, there were wide variations in students' perceptions of instructors and teaching styles.

Overall, students have found the courses to be a better match to their interests than other science courses and more engaging than they expected. Based on student interviews, we conclude that the students have found the courses deliver a better perspective on the importance of science, a keener relationship between science content and elementary school instruction, and an awareness of how science skills can empower teachers. In response to the *GSCI 161* student essay question, "Five years from now, what will you remember from this class?" some students had the following comments:

- "Of all the science classes I have ever taken, this taught me the most. Not only did I learn new things about science; I learned new things about myself as a person, and myself as a teacher. I know that I need to have patience from working with group projects….and I know that if I do not try to solve the problem by myself, then I will never fully understand the solution."

- "After six weeks, we began to understand what a teacher is and what they do. They do not just give you the answers; they help you find them out for yourself."

- "I hope to be so enthusiastic about each topic I teach that my students cannot help but get excited… I wish to know my subjects inside and out so that I can explain anything in many different ways so that the one child, who does not understand can know exactly what is going on."

- "This was by far the most interesting science course I have ever taken. It took a fun approach to science, which is something that as a teacher I will have to continue in my classroom. Science and learning are supposed to be fun and this class allowed me to see a balance between work and play. This class also allowed me to be a teacher instead of just seeing what a teacher should do."

- "The various activities and approaches to this class made the material so interesting that I found myself wanting to pay attention and focus at the work at hand."

- "Science is a field of never-ending questions. As soon as one question is answered, more are uncovered. It is the teacher's job to help her students understand and develop a love for science, not to have all the answers."

- "The hands-on experiments that we performed showed us examples how to apply and teach the "inquiries" that we learned. The class also prepared me for the years ahead in the way that I realized how excited I am to teach and can't wait to start!"

- "The things I will remember from this class are far too many to describe or even list in one page. Most definitely interactive classroom experimentation, communication and asking and answering questions will be at the top of the list. This class has taught me…that it is okay and very often necessary to ask questions in order to develop a good understanding of the topic at hand, and it will be important to me as a future educator to apply this to my own classroom situations."

Teaching Standard "C" from the *National Science Education Standards* requires teachers to "use student data, observations of teaching, and interactions with colleagues to reflect on and improve teaching practice," and "use student data, observations of teaching, and interactions with colleagues to report student achievement and opportunities to learn to students, teachers, parents, policymakers, and the general public." [2] The instructors involved in this course sequence meet regularly to discuss these classes and to look at student learning. The success of this course sequence will depend on such reflections.

Where Are We Going from Here?

These courses are labor intensive both for the students and for faculty. Smaller classes and the emphasis on hands-on activities make this more expensive than traditional undergraduate introductory science classes. Is this worth the extra cost and effort? Ultimately, if we have succeeded in meeting our goals, these courses will make a difference in the way our students teach in their own classes. This will, in turn, affect the preparation of their students who will in time become our students, potentially improving the overall science literacy of entering college classes. For the future, we would like to work on integration between these classes and the upper-level science methods, and teaching practicum classes for IDLS students. We would like to follow students as they complete their student teaching and their first years as classroom teachers. We also hope to increase science faculty involvement so that students are exposed to a diverse group of people who do science.

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