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ABSTRACT

The traditional differences in philosophy and approaches to teaching and learning between colleges of education and sciences have been repeatedly cited as one of the major obstacles in providing appropriate teacher training programs. In an effort to alleviate this problem, Wright State University (Ohio) has fostered a unique environment through a collaboration between the College of Science and Math (COSM) and the College of Education and Human Services (CEHS) by creating dual appointments for faculty within these two colleges. The revitalization of the teacher education programs in science included consideration that prospective science teachers should be involved in investigative activities; have lab courses that focus on topics in biology, chemistry, earth science, and physics; understand the interrelatedness of science disciplines; and have a sound understanding of the nature of learning and how it can be applied to the learning of science. (Author/DDR)

Development of a Comprehensive Undergraduate Science Education Program for Preparation of Elementary and Middle School Teachers

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Introduction

In the November 1996 issue of *NSTA Reports!*, under the headlines *Basic College Science Courses Filter Out Most Students, Says New NSF Report*, the NSTA quotes the recently released NSF report, *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (NSF, 1996; NSTA, 1996). According to the NSTA article, the NSF report's primary recommendation is that "college science and math programs should be refocused in order to better educate the 80 percent of the students who do not major in the science disciplines. 'All students should learn these subjects by direct experience with the method and processes of inquiry'. Furthermore, any sustained national effort to improve science and math teaching eventually must address the quality of teacher education at the undergraduate level. Because few teachers, particularly those at the elementary level, experience any college science teaching that stresses the skills of inquiry and investigation, they simply never learn to use those methods in their teaching". The report goes on to state, that America's science, math, engineering, and technology faculty must actively engage their students preparing to be K-12 teachers (as well as others) by assisting them to "learn not only science facts, but also the methods and processes of research, what scientists and engineers do, how to make informed judgments about technical matters, and how to communicate and work in teams to solve complex problems". The NSF report further charges, that "while some institutions already are making the changes needed to help them meet that goal, most are not." (NSTA Reports, p. 11).

The traditional differences in philosophy and approaches to teaching and learning between colleges of education and sciences has been repeatedly cited as one of the major obstacles in providing appropriate teacher-training programs. In an effort to alleviate this problem, Wright State University has fostered a unique environment through a collaboration between the College of Science and Math (COSM) and the College Education and Human Services (CEHS) by creating dual appointments for faculty within these two colleges. These faculty have the primary responsibility for the design, implementation and evaluation of science teacher education programs. The faculty, through their individual strengths and expertise in science disciplines and teacher education and a shared commitment to and vision of science teacher education, have formed a highly complementary and effective team.

In our planning to revitalize the teacher preparation program in science we had the following guiding principles:

- "Every elementary-middle-secondary science education preservice student should experience the investigative nature of science.". This translates into 1) "direct investigative activities; 2) at least one open-ended investigation carried out over an extended period of time; 3) given opportunities to collaborate with others -- do as scientists do -- and develop team work habits.
- "Every elementary-middle-secondary science education preservice student should have classroom and laboratory experiences that focus on relatively few, but powerful, topics in biology, chemistry, earth/space science, and physics.
- "All elementary-middle-secondary science education preservice students should understand the interrelatedness of science disciplines and the connections between science and other areas of knowledge." Our roles are then to assist students in understanding the connections among areas of science and to recognize that the efforts to learn how natural science, social science, mathematics, philosophy, and literature complement each other.
- "All elementary-middle-secondary science education preservice students should learn scientific content and thinking process in the context of contemporary, relevant, personal and societal issues and problems." This would be accomplished by designing courses that have application to the real world and by integrating scientific-technical and social issues.
- "All elementary-middle-secondary science education preservice students must have a sound understanding of the nature of learning and how it can be applied to the learning of science." Once again, courses and student learning experiences needed to include content and activities that are carefully selected to be appropriate and sequentially ordered to be cumulative and build over time using an exemplary hands-on, minds-on science curriculum.
- "All elementary-middle-secondary science education preservice students should have several intense and extended clinical teaching experiences at a variety of grade levels in diverse socio-economic and cultural settings". These experiences needed to be grounded in theory and pedagogical knowledge, and students must receive regular and systematic feedback from practicing master teachers, professors of science, and science educators. Courses and teaching

must reflect appreciation for different learning styles, and modeling of higher-order questioning, use cooperative learning, and problem solving strategies. And another key element was good communication in that this type of endeavor requires intense and lively cooperation between faculties in education ant the arts and sciences (Glass, Russell, and Anderson, 1993).

The Science Education Program

The science teacher program incorporates the five major key elements of the NRC standards for science education (NRC, 1996), the NSTA standards for science preparation of elementary teachers (NSTA, 1992), and the Ohio Model (Ohio Department of Education, 1994). These are: Processes and Inquiry of Science (historical perspectives, the nature of science); Physical Sciences, Life and Earth Sciences, concepts and applications, articulated with broad themes and ideas, unifying concepts; STS perspectives, all taught within a constructivist learning environment, integrating pedagogy with conceptual understanding and content knowledge (See Figure 1). The program is founded on current content-specific science education research, science curricular guidelines as outlined by the national science standards, published curricular materials, and feedback from master teachers and partnership schools. The courses in the program are taught within a cooperative, constructivist, hands-on and minds-on environment. Furthermore, the courses integrate science content with content-specific pedagogy and employ authentic assessment strategies.

The specific goals of the elementary education science program are:

1) Students acquire an in-depth conceptual understanding of the fundamental science concepts in each content area through the inquiry process. This requires the successful application of these concepts in a wide variety of real-life situations which connect these concepts through unifying, interdisciplinary themes;

2) Students develop science process, problem-solving, and critical analysis skills utilized not only in the scientific process, but also in everyday life and decision-making;

3) Students develop appropriate attitudes toward science and science teaching, including the understanding of science as an ongoing process of questioning, designing experiments, implementing these experiments, and evaluating the results as opposed to a set of facts or procedures to be memorized;

4) Students become effective life-long learners and collaborative workers capable of independent and cooperative problem-solving, as well as, self-directed and motivated analysis, decision-making, and action;

5) Students will be able to effectively implement constructivist teaching methodologies and utilize content-specific pedagogical knowledge to enable their future students to achieve scientific literacy.

All the courses were specifically designed emphasize science concepts and applications, constructivist pedagogy, pedagogical content knowledge, and science as a process. As such, the courses have a concise scope, in keeping with the philosophy of "less is more", are articulated with themes and "big ideas", include STS perspectives, and address student "misconceptions". The courses are subsequently taught in a classroom setting of approximately 25 students who cooperatively work in small groups on hands-on inquiry activities.

The Foundation Course.

As shown in Figure 2, the introductory course is *Foundations for Science Literacy and Problem-Solving* which provides the beginning student with a philosophical and experiential understanding of a constructivist, cooperative classroom environment. This understanding is acquired through introductory hands-on inquiry experiences within the context of fundamental, unifying, interdisciplinary science themes and core concepts such as systems and interactions, change and constancy, properties of matter. These experiences emphasize science as a process, problem-solving and critical analysis skills. Students are required to analyze their class experiences relative to their previous science experiences, the impending science courses of the program, and their future science teaching practices. The goals of the course are to prepare the students for the subsequent science and education courses in the program by:

1) developing skills and thought processes necessary to become a complex thinker;

2) orienting students toward constructivist learning environment;

3) developing understanding of core science concepts such as mass, heat, temperature, etc. through unifying themes of properties and interactions of matter and systems, forms of energy, and change;

4) developing communication skills and the facility to utilize multiple representations;

5) familiarizing students with the national and state science standards;

6) developing appropriate student attitudes toward science and learning in general;
7) developing cooperative skills to become an effective collaborative worker;
8) developing skills and habits of mind that will enable the students to become effective life-long learners capable of independent, self-directed analysis, decision-making, and action.

This course is additionally the writing intensive course (as part of the initiative *Writing Across the Curriculum*) for the science program. This affords the students the opportunity to express their views and attitudes toward science teaching and learning methods, as well as, to develop necessary critical writing skills.

This course affords the science educators the opportunity to begin tracking the students in areas of attitudes toward science process, science learning, science teaching, as well as. their own science literacy. Each of these components is assessed throughout the program, beginning in this course.

Physics and Chemistry

Following the Foundations course, as illustrated in Figure 2, the students next take their physics and chemistry courses. Since these subjects are typically the subjects that students have had the least experience in, developing positive student attitudes is imperative. The integration of mathematics with these courses, although many times a source of trepidation for the students, allows the students to develop a further understanding of applications of mathematical skills within the context of a science investigation. These courses utilize the learning cycle in a constructivist way by providing a concrete science situation illustrating the science concepts first, then analyzing the "how do we know, why do we believe" component of inquiry, and finally investigating an application of the concepts in other situations. The students go through many learning cycles starting with concrete examples before they are expected to manipulate abstract ideas. This method affords opportunities to address student misconceptions and to allow the students to acquire a depth of conceptual understanding in such areas as motion, forces, and energy transfers.

These courses emphasize development of science process skills and problem-solving skills, as well as, conceptual depth. For instance, in the physics course, students utilize multiple representations of physical situations to aid in the abstract analysis of the concepts within these situations, and to aid with applications of the concepts in many different situations. The science, technology and society component of the course is incorporated through the many real-life applications of the science concepts that the students experience.

The students also have course projects in which they design, implement and assess elementary/middle level science activities. In their activity design, they not only emphasize correct science process and conceptual aspects, but also the constructivist and cooperative methods utilized in implementing the activity. The students facilitate their own activities for the class and the class, as a whole, helps in the assessment.

Biology and Geology

As illustrated in Figure 2, following the physical science courses, students enroll in their biology and geology courses. The *Concepts in Biology* course was specifically designed to better prepare teachers to teach life science in today's elementary and middle school environments. Two science educators with backgrounds in biology and biology teaching worked to develop a course which addressed the content needed to teach elementary science as well as middle school life science and to demonstrate appropriate teaching materials and methods.

First, we literally turned the course around from the traditional presentation of material -- chemistry of the cell to the (usually rushed or omitted) ending point of ecology/ environmental science. Discussions with previous students led us to believe that they felt more comfortable and familiar with the concepts presented in the "bigger picture" areas of biology -- ecology and environmental science. This also made intuitive sense in terms of teaching because we would be starting with material that was part of the everyday lives of students, even if they had not fully made the necessary connections. It was our job to help them develop those connections and to understand the underlying concepts in these, and other areas of biology, using an activities-based focus on broad themes (cycles, patterns and change, systems and interactions, etc.) incorporating science process skills. We then proceeded to weave in needed content such as: ecological concepts, diversity of living organisms, genetics, taxonomic classification and the characteristics of plant and animal life, animal body systems, cell biology, and finally coming full circle to study some environmental issues relating in a very interdisciplinary fashion to all of the life sciences. This ending point also provides a logical lead into the final capstone course.

One goal of this course was to foster more positive student attitudes toward life science and to capitalize on both positive and negative experiences in helping students to see how teachers can influence students' interest in science. Initial data was collected using a questionnaire and survey regarding students' attitudes toward science based on positive and negative science experiences. Learning about students' attitudes toward science and prior experiences with science were important starting points in developing positive, "let's find out" approaches to teaching life science. One trend revealed in the data was that several of the students had had some degree of success in the traditional lecture and occasional demonstration format. Throughout the course, these students voiced a degree of discomfort and dissatisfaction with the opened-ended, hands-on format of the course. Students who had less success in traditional courses and initially had less positive attitudes toward science overall expressed near relief that biology could taught in a more interesting fashion. Based on the findings of this study, the biology course herein described continues to evolve and change to better accommodate students' understanding of biological concepts and more effective approaches to teaching science courses.

Concepts in Geology was developed to meet the Ohio Competency-Based Science Model, and the National Research Council's content standards for Earth Science. Course topics begin with minerals, then progress to Igneous, Metamorphic, and Sedimentary rocks. The history of the Earth, geologic time, fossils, the interior of the Earth, and plate tectonics follow. The Interior of the Earth is studied using earthquakes and seismic reflection and refraction principles (introduced first in Physics). The theory of plate tectonics, the Earth-Moon system and Meteorology round out this course offering. This course is content based (the only Earth Science the future teachers will receive in their training) and so the topics may be thought of as traditional. But the treatment of the topics is not. Each broad topic noted above is accompanied by hands-on activities designed to enrich the student's understanding of the topic under consideration. Real-time data available on the Internet/world-wide web is used to bring the nature of scientific inquiry alive for the future teachers.

Students come to geology having heard of the theory of plate tectonics, but are unclear as to the details of the paradigm. Virtually none understand how, for instance, scientists determine the boundaries or the nature of tectonic plates. The following is an example of how this course uses internet/world-wide web technology to bring scientific inquiry to the course in the context of plate tectonics. Students attending the university receive e-mail accounts and through their personal passwords, are able to access the internet/world-wide web. During the first week of the quarter students are given two world wide web site addresses. One is for the National Earthquake

Information Center (http://www.neic.cr.usgs.gov), and the other for Volcano World at (http://volcano.und.nodak.edu). They are also provided with a physiographic chart of the oceans complete with longitude and latitude. They then plot the occurrence of earthquakes and volcanic activity over the course of a ten week quarter, using different symbols to plot deep and shallow quakes. When the topic of plate tectonics is encountered late in the quarter the students have substantially delineated the boundaries of some tectonic plates. They begin to understand the reasoning that scientists use to determine plate boundaries. Since deeper earthquakes are common at converging plate boundaries and shallow earthquakes dominate diverging boundary settings such as the Mid-Ocean Ridge, they internalize the concept of a thinner oceanic crust. The differences between volcanism at converging boundaries and intraplate volcanism (Hawaii) become topics for class discussion rather than professor's lecture. Geography and map skills are also enhanced.

The Capstone Course

Projects in Science, as the capstone course, is being designed to be a culminating experience in which the students apply the science content and processes acquired through the previous classes in the design, implementation, evaluation, and communication of an investigation of their choosing. The projects are interdisciplinary in that the concepts and processes involved cut across discipline lines. For instance, students could choose to investigate the effects of pollution (air, water, or sound), including technological and societal impacts. The students would perform direct experimentation and data collection, utilize library and computer information resources, analyze and present their results. This course permits students to gain natural multidisciplinary, technological, and societal perspectives of how a science investigation is genuinely conducted. The students also are expected to explore the potential applications of how similar science experiences could be used in their future classrooms. The goals of the course are:

1) to further develop student understanding of the scientific process;

2) to develop students abilities to design, implement, evaluate, and communicate scientific investigations;

3) to develop student understanding of the relationships between science, technology, and society;

4) to further develop student understanding of the concepts learned in previous science courses in the program within an interdisciplinary, thematic, investigative environment;

5) to further develop and apply problem-solving, critical analysis, and decision-making skills and abilities within an interdisciplinary, thematic, investigative environment.

Further Science Education Preparation

When students have completed this sequence of specially designed science courses (see Fig. 2), they begin their professional sequence of education courses and experiences. The *Elementary School Science: Methods, Curriculum, and Materials* course is designed to provide the developing elementary teacher with the central concepts, tools of inquiry, and structures of elementary school science enabling them to create learning experiences that make science meaningful for their future students. In this course, the preservice teachers acquire an understanding of how to utilize a variety of instructional strategies to encourage their student's development of conceptual knowledge, critical thinking, problem solving, and performance skills. Moreover, they learn how to plan for instruction based on knowledge of the national and state science standards, the nature of science, the nature of how students learn and develop, and how to accommodate differing approaches to learning such that the developing teacher can create instructional opportunities that are equitable and adaptable to diverse learners. The overarching goal of the course is to provide the prospective elementary teacher with a broad set of viable approaches to effectively teaching science. These approaches are couched within the framework of the nature of science and the nature of the learner. More specifically, this course is designed to actualize the following objectives:

1) the ability to plan and implement a constructivist, inquiry-based science program which challenges student to accept and share responsibility for their own learning;

2) the ability to select developmentally appropriate science content, adapt and design curricular materials that recognize and respond to student diversity and encourages all students to participate in science inquiry and learning;

3) the ability to design, manage, and manipulate the learning environment to create a situation for the student which is supportive of science exploration and inquiry;

4) the ability to understand how to access resources and guide students as they use science equipment and everyday materials, media and technological tools in such a way as they facilitate the acquisition of both declarative and procedural knowledge within the context of a safe and productive classroom environment;

5) the ability to engage and motivate students to pursue science inquiry and to facilitate the development of a community of learners that reflect attitudes and social values that are conducive to science inquiry;

6) the ability to design and implement instructional frameworks that provide opportunities for active explorations into the connections and interactions between science, technology, and other human endeavors such as mathematics, history, the arts, and humanities, and to explore those connections and interactions as they relate to personal and/or global issues.

The teacher preparation program at WSU incorporates a wide variety of field-based experiences prior to student teaching. Another teacher preparation option for individuals with undergraduate degrees who wish to enter the teaching profession is the Professional Educator's Program (PEP) which is part of the Goodlad network. The PEP is designed for individuals possessing an undergraduate degree to enter an intensive year-long program of clinical experiences and closely related course work, and after completion of the program to have teaching certification as well as a master's degree. An interdisciplinary science teaching master's degree is in development to individually tailor the science teaching and content needs of inservice teachers. Another aspect of the program that is in the development stage is to systematically pair preservice with "best practices" inservice K-12 teachers. This pairing aspect of the teacher preparation program will enable us to better sustain teacher professional development on both levels by more fully involving exemplary science teachers in preparing the next wave of classroom teachers.

Concluding Remarks

Being on a 10 week quarter system has serious draw backs particularly when addressing the science content needs of elementary preservice teachers. This aside, the science educators are presently more concerned with and continue to work on the middle level component of the program as that area of certification is designed within the CEHS.

Regardless of the cognitive understanding students have of the science education standards and the need for process skills approach to science teaching to reach all students, departure from the lecture- memorization- regurgitation- teacher-centered- passive student model of science courses were not initially well-received by a number of students who have succeeded in that traditional mode. Recent data indicate that students are now, two years into the new program, more receptive and are actually welcoming the changes in the science courses. Perhaps we are doing a better job of explaining the importance to this type of science teaching, or perhaps the students early field experiences permit them to have a better conceptual understanding of children's' science learning, or it may be a combination of these and other factors. The program as we have described it is, as it should be, an evolving program, dynamic in nature. We are learning along the way and more than willing to revisit original ideas and to change, design and redesign to best serve the preservice teachers and the inservice teachers involved in our program.

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Figure 1

AAAS 2061 CHAPTERS	NRC STANDARDS	OHIO MODEL GOALS	NSTA STANDARDS	AGENDA PRINCIPLES
Nature of Science	Science as Inquiry	Nature of Science	#3	#1
Habits of Mind				
Historical Perspectives	History/Nature of Sci.			
Physical Setting	Physical Science	Physical Setting	#1 & #4	#2
	Earth/Space Science			
Living Environment	Life Science	Living Environment	#1 & #4	#2
Human Organism				
Common Themes	Unifying Concepts & Processes	Thematic Ideas	#1	#3
Human Society,	Personal/Social Perspectives	Societal Perspectives	#2 & #5	#4
Designed World	Science & Technology			
Nature of Technology				
Mathematical World				#6
Nature of Mathematics				

Figure 2

Supervised Student Teaching

- implementing constructivist teaching methodologies
- utilizing science content-specific pedagogical knowledge
- mentor matches congruent with philosophy of program

Elementary Science: Curriculum and Materials

- learning theory based
- implementation and design of constructivist methodologies/activities
- curricular designs congruent with Project 2061, NSES, and Ohio Science Model
- teachers as problem-solvers
- congruent with PRAXIS III performance assessment

Projects in Science

- multidisciplinary perspective
- applications based
- design, implementation, evaluation and communication of investigation
- pedagogical content knowledge
- STS perspectives

Concepts in Geology

- concepts and applications
- constructivist environment
- process and problem-solving oriented
- articulated with themes and "big ideas"
- pedagogical content knowledge
- STS perspectives

Concepts in Biology

- concepts and applications
- constructivist environment
- process and problem-solving oriented
- articulated with themes and "big ideas"
- pedagogical content knowledge
- STS perspectives

Concepts in Physics

- concepts and applications
- constructivist environment
- process and problem-solving oriented
- articulated with themes and "big ideas"
- pedagogical content knowledge
- STS perspectives

Concepts in Chemistry

- concepts and applications
- constructivist environment
- process and problem-solving oriented
- articulated with themes and "big ideas"
- pedagogical content knowledge
- STS perspectives

Foundations for Science Literacy and Problem-Solving

- science process, problem-solving, and critical thinking skills
- unifying science themes and core concepts
- introduction to constructivism
- attitudes towards science
- familiarization with science standards

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