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ABSTRACT

Meeting the needs of the nation for science teachers who can prepare future citizens for a technological world requires a new curriculum. Middle school science education spans all of the natural sciences and therefore a college program to prepare teachers for this kind of assignment should include a strong background in interdisciplinary science and professional skills particularly suited to the characteristics of middle school students. With these ideas in mind, two model teacher preparation programs were developed at the State University of New York at Potsdam and Hampton University. This document focuses on the characteristics of the programs at these two institutions. Discussed are the interdisciplinary science major at Potsdam including course outlines for chemistry/physics courses and geology/biology courses, and a description of the middle school teacher preparation program at Hampton University. These two programs are among nine such programs funded by the National Science Foundation in 1986. (CW)

National Science Foundation Model Programs of Preparation of Middle School Science and Mathematics Teachers

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SUNY Potsdam Hampton University

Introduction

Today's crisis of science education is twofold. First, there is the problem of preparing too few students with the competency required to pursue careers in science and technology . Second, there is the problem of the failure to develop positive attitudes towards science and basic scientific literacy in the general public . Both of these problems have critical junctures in the middle school grades; it is there that students formulate lasting attitudes towards science which influence subsequent selection of courses and basic scientific literacy . The middle school is thus the place where the crisis in science education must be addressed.

In light of the importance of middle school teachers, it is unfortunate that few teacher education programs are directed specifically toward preparing middle school teachers. Both teacher education and teacher certification programs typically treat middle school as "upper elementary" and/or "lower secondary" tag-a-longs. Since young adolescents, in the throes of rapid physical, emotional and intellectual changes, are perhaps the most challenging of all students to teach, special courses in science and professional education for middle school teachers should have a high priority, but, in fact such courses are rare.

Meeting the needs of the nation for science teachers who can prepare future citizens for a technological world requires a new curriculum. Middle school science education spans all of the natural sciences. Traditional college science programs either focus on a series of courses in one domain of science, or provide isolated courses in general science which do not provide for continual increase in rigor and depth through a series of related courses. A model college program to prepare teachers of multiple sciences and interdisciplinary science should include a strong background in interdisciplinary science. Furthermore, middle school teachers must be masters of professional skills particularly suited to the characteristics of middle school students. Some of these skills are learned in professional education courses, while others are learned in liberal arts courses which are not part of the professional education program. To some extent teachers emulate the methods of professors by whom they were taught. It is thus important that teacher preparation programs not only include a well designed professional education program, but also liberal arts science courses which model good teaching. With these ideas in mind, two model science teacher preparation programs were developed at SUNY Potsdam and Hampton University.

The goals of the project were:

1) to improve the teaching of science on the middle school level;
2) to incorporate the best understanding and latest beliefs about science education, the experience of practicing teachers and the expertise of scientists; and
3) to prepare teachers who understand importance of the science and technology to society and can use that understanding to make science relevant to all middle school students.

Both programs include new courses in science, new courses in professional education, and partnership with the public schools as integral parts of the programs. Below, attention will be focused on the science portion of the program at Potsdam, and the community emphasis of the program at Hampton.

The Interdisciplinary Science Major at SUNY Potsdam

The interdisciplinary science curriculum (ISC) consists of four sequential interdisciplinary science courses (24 semester credit hours) at the freshman and sophomore levels and a set of science electives (12 semester credit hours) at the junior year level. The senior year of the program is allocated to completion of liberal arts and professional education program requirements. The first two years provide not only a broad background in interdisciplinary science, but also preparation to take upper division courses in any of the four sciences. To bring ISC students to this level, the first two years of the ISC are carefully designed to include the fundamental concepts of biology, chemistry, geology and physics. Students who decide to leave program after two years receive credit for the introductory year in each science area and may then pursue a science major if they so desire.

Intensive laboratory experience through the first and second years illustrate scientific concepts and build mastery of the most basic laboratory activities: measurement, observation, distinguishing observation from inference, use of data, and forming and testing hypotheses. Several features of the laboratories make them particularly appropriate for middle school teachers, for example:

1) The laboratory exercises include simple, direct illustrations of the principles or skills being taught.
2) Students perform such "preparatory" activities as making solutions and assembling (or making) apparatus. The laboratory manuals include preparatory instructions to prepare students not only to perform and explain the laboratory activities, but actually reproduce them.
3) Lab safety, equipment maintenance, and care and use of laboratory organisms are integrated into the laboratory activities so that students learn how to direct, rather than simply work in a laboratory.

The curriculum purposefully does not include a separate course in computer science. Rather, learning and using computer skills is integrated into science course work. In the laboratory, students interface computers with laboratory equipment, use the Appleworks data base for keeping lab records, and use the Appleworks word processing system for writing laboratory reports. Computer simulations supplement laboratory exercises and illustrate lectures. Teachers who have become thoroughly comfortable with computers through extensive use have both the knowledge and the confidence to put them to use in their classrooms.

The breadth of knowledge required for teaching middle school science necessitates background in all areas of science. The model science curriculum does not simply "teach the middle school science syllabus" because: 1) many graduates will teach in states with different syllabi; and 2) the syllabus will change many times during a teacher's career (in fact, it is currently being revised). Rather, by incorporating topics in the syllabus into a strong scientific background, this curriculum, together with a commitment to continuing education, prepares students to teach any syllabus for middle school science.

The interdisciplinary nature of the courses provides a model of teaching interdisciplinary science. The interdisciplinary science courses consist of three one hour lectures and two three hour labs per week. An emphasis on laboratory activity provides a model of "hands on" learning. Microcomputers are frequently used in laboratory activities for recording and writing, and as laboratory instruments. A model of appropriate use of the microcomputer as a tool in the classroom is thus provided. Students have increased responsibility for management and preparation of lab activities, providing a model technique of engaging students in assuming responsibility for learning. The net outcome of including the recommendations of science education research in the design of interdisciplinary science courses is to enhance the quality of the science courses themselves while simultaneously providing models of good teaching. The science courses are enhanced by providing instruction and laboratory activities at a level which is consistent with the ability of college freshmen. The teaching technique of future teachers is enhanced by each of the above.

<u>Science Course Content</u>

Chemistry/Physics 195 was first offered in the Fall of 1987. The course was designed and taught by Professors Nicholas Zevos (Chemistry) and Arthur McRobbie (Physics), Chairs of the Departments of Chemistry and Physics respectively. Six Topical Units (Table 1, Lecture; Table 2, Lab), alternating between physics and chemistry, were sequenced to build upon one another while simultaneously including content found in introductory physics and chemistry courses. Some topics traditionally found in introductory physics and chemistry which could not be included in the introductory interdisciplinary course were allocated to Chemistry/Physics 295 (semester 4 of the program). Combined, these courses include much, but not all, of the content which would be included in introductory courses for chemistry and physics majors.

The integration of topics from chemistry and physics was facilitated in a number of ways. First, both professors participated in each lecture and laboratory. Second, topics from physics and chemistry were selected and arranged so that the basic concepts of unit 1 (physics) were utilized in unit 2 (chemistry), which concepts were then utilized in unit 3 (physics), etc. A unit on "Measurement" in physics was followed by "Bohr's Theory of the Hydrogen Atom" in chemistry which was followed by a unit on "Work and Energy" in physics, each taught with the rigor and depth characteristic of introductory courses for science majors.

The second and third interdisciplinary science courses are Biology /Geology 196 and Biology/Geology 295. The initial offering of Biology/Geology 196 is now in session and Biology/Geology 295 will first be offered in the Fall of 1988. Professors William Kirchgasser (Geology) and Albert Robinson (Biology) have designed these two courses around three general parameters:

1.The courses integrate the principles of biology and geology around the theme: Evolution of the Earth and Life.

2. Biology/Geology 295 will be a continuation of Biology/Geology 196 with more derivative topics covered in 295. Thus the survey of the Earth and Life through time in geology and genetics and ecology in biology will be emphasized in the second (Fall) term.

3. The methods and format of instruction in both lecture and laboratories will attempt to speak to the needs of the future Middle School Science Teacher. Without sacrificing science content we will stress methods of instruction that may be effective on the middle school level: the "discovery" approach (inductive mode: "observe and seek to explain"); little distinction between lecture and laboratory; experiments and demonstration using simple(i.e.inexpensive) materials, with students setting up their own labs. Joint Biology-Geology field trips will provide opportunity for students to experience the interconnectedness of these sciences in the natural environment.

Topics covered in these two courses are given in Table 3 (topical units covered in the interdisciplinary science course) and Table 4 (Indexes of Biology and Geology concepts included in the interdisciplinary science topics).

Table 1

Chemistry/Physics 195

Nicholas Zevos (Chemistry) and Arthur McRobbie (Physics)

Unit One: Units and Measurements

A. Measurement (Estimates, Significant Figures).

B. Units (Dimensional Analysis, Standard Notation, S.I. Units).

C. Vector Mathematics (Vector & Non vector calculations).

Unit Two - Atoms and the Periodic Table.

A. Atoms Subatomic Particles (Electron, Proton, Isotopes, etc.).

B. Bohr's Theory of the Hydrogen Atom.

C. Quantum Numbers; Atomic Orbitals (type, energy, rules, etc.).

D. Periodic Classification of the Elements.

- Representing free elements in chemical equations.

E. Periodic Variation on Physical Properties.

- Atomic Radius, Variation of physical properties across a period; Predicting physical properties.

F. Ionization Energy, Electron affinity.

G. Variations in Chemical Properties, General trends.

Unit Three - Work and Energy.

A. Definition of Work and Energy, Power.

B. Energy Interrelationships.

- Kinetic Energy, Potential, Internal Energy.

C. Heat.

- Specific Heat; constant volume; constant pressure.

D. Ideal Gas Laws, States of Matter.

E. State - variables and equations of state.

Table 1 (continued)

F. Density, Pressure, Archimedes Principle, Bernoulli's Equation.

Unit Four - Chemical Reactions and Calculations.

A. Chemical Formulas (Molecular Formula, Empirical Formula).

B. Atomic Masses, Avogadro's Number, Molecular Mass.

C. Ions and Ionic Compounds.

D. Naming Inorganic Compounds.

E. Chemical Equations; Properties of Aqueous Solutions.

F. Combination Reactions; Decomposition Reactions, Displacement Reactions.

G. Metatheses Reactions; Neutralization Reactions.

H. Amounts of Reactants and Products; Limiting Reagents.

I. Yields: Theoretical, Actual,and Percent.

J. Concentration of Solutions; Gravimetric Analysis; Acid/Bases.

Unit Five - Newton's Laws and Motion.

A. Velocity and Speed; Acceleration.

B. Newton's Laws; Free Fall, Mass and Weight.

C. Linear Momentum as a Vector; Rotational Motion.

D. Equilibrium of a Point; Rotational Equilibrium and Torque.

E. Angular Momentum and Rotational Energy; Centripetal Force.

F. Orbital Motion, Vibratory Motion, Wave Motion, Sound.

Unit Six - Chemical Bonding.

A. Ionic Compounds; Covalent Compounds.

B. The Geometry of Molecules.

C. Molecular Orbitals.

Table 2 Chemistry/Physics 195 Labs.

Date	Topic	Professor
8/28/87	Force Table, Vectors.	McRobbie
8/31/87	Weighing.	Zevos
9/4/87	Statistics - Popcorn.	Zevos
9/11/87	Spectra, Grating Experiment.	McRobbie
9/14/87	Spectra, Emission and Absorption.	Zevos
9/18/87	Absorption Spectra, Beer Lambert Law	Zevos
9/21&25/87	Unit Lab Exam & Volume and Graphing Lab	McRobbie
9/28/87	Mechanical Equivalent of Heat	McRobbie
10/2/87	Specific Heat	McRobbie
10/5/87	Unit Lab Exam & Calorimetry Experiment	Zevos
10/9/87	Density	McRobbie
10/16/87	Acids and Bases (Titration)	Zevos
10/19/87	Reaction of Metals	Zevos
10/23/87	Preparation of K(3) Fe [C(2) O(4)]3	Zevos
10/26/87	Preparation of K(3) Fe [C(2) O(4)]3	Zevos
11/2/87	Free Fall	McRobbie
11/6/87	Attwood	McRobbie
11/9/87	Linear Momentum	McRobbie
11/13/87	Unit Lab Exam & Wave Motion Lab	McRobbie
11/16/87	Torque	McRobbie
11/20/87	Lewis Structures Models	Zevos
11/30/87	Molecular Models	Zevos
12/4&7/87	Practical Chemistry	Zevos
12/11/87	Comprehensive Semester Lab Exam	McRobbie and Zevos

Table 3

Biology/Geology 196 and Biology/Geology 295

Designed by

William Kirchgasser (Geology) and Albert Robinson (Biology)

I. Science in the 18th and 19th centuries and the emergence of biology and geology; scientific method; paradigms in science; scientific revolutions in biology and geology.

II. Biochemistry and geochemistry of Life : the carbon, carbon dioxide and oxygen cycles, the water cycle, the oceans.

III. The Origin of Life (the cell; Precambrian Life).

IV. Theory of Evolution (genetics/theory of evolution/fossil record).

V. Evolution of Life: morphology/physiology of extant and fossil plants, invertebrates and vertebrates; biogeography and paleobiography.

VI. Oceanic and terrestrial environments and ecosystems: modern and fossil ecology and paleoecology

Table 4

Biology and Geology Concepts Contained in

Biology/Geology 196 and Biology Geology 295

Biology

I. The cell - structure and function;
energy: fermentation,respiration; photosynthesis

II. Bacteria - fungi, viruses

III. Plants - Structure, development, reproduction, major plant taxa

IV. Animals - structure, major taxa, basic systems, development, reproduction

V. Theory of Evolution

VI. Genetics

VII. Ecology (including soils)

Geology

I. The Earth and the Solar System

a. Geologic time - radiometric and biostratigraphic dating

b. Earths interior - heat; earthquakes; volcanism

c. Physical & biological oceanography - the atmosphere

II. Global Plate Tectonics

III. Surface process & environmental weathering, soils, erosion, sedimentation, tectonics, the water cycle, landscape, rivers, deserts, glaciers.

IV. Earth and Life through Time. Rock record and fossil record of plants and animals.

The Model Program at Hampton University

During the first year of this project a select group of science professors working with educators has participated in a series of workshops, conferences, and seminars focusing on the relationship between science, technology, and society. As a result of this interdisciplinary faculty effort, a core of science courses designed to enhance the education of middle school science teachers is being developed. The first two of these science courses, biology and physical science, were completed and piloted in the Fall of 1987. A physics course is now being piloted (Spring 1988).

The biology class contained both science majors and science education majors. Similar sections of biology with the same content objectives ran concurrently with the experimental course. Physical science contained science education majors as well as students from other disciplines who took it as a required course.

In addition to the normal course content, the new courses were designed to provide appropriate teaching models. Attention was given to teaching these courses in a manner that would have direct application to the middle school classroom. Professors of science recognized that pre-service teachers are inclined to emulate the science teaching techniques they experience at the college level when they teach at lower levels.

The experimental courses differed from traditional courses in that science concepts were developed around societal relevant issues. Classes were student centered and activity oriented without the traditional separation of lecture and lab. Course settings were in rooms with tables and chairs where both experimentation and dialogue could easily occur between students and with the professor.

Laboratory work typically involves the use of chemicals and apparatus foreign to students. Consequently it is difficult for them to extrapolate results that are relevant to their daily experiences with science and technology. The experimental courses used familiar materials wherever possible. For example, a bicycle was used in a number of ways to demonstrate various principles of physics, and photography provided content for teaching principles of chemistry. Societal issues such as in vitro fertilization, the question of parenthood, China's stand on zero population growth, genetic engineering, and the sociological implications of AIDS were posed in biology.

Hampton University Program

The model middle school teacher preparation program at Hampton consists of a liberal arts science major and a professional education program specifically designed for the middle school. The science program consists of 36 semester credit hours including Biology 103 (referred to above), Physical Science 104 (referred to above), Chemistry, Physics, Earth Science, Environmental Science, Zoology or Botany, Advanced Zoology or Advanced Plant Biology), a second semester of Chemistry or Physics, and an elective from Geology or Marine Science. Six semester credit hours of mathematics and general education requirements of the college of liberal arts complete the liberal arts component of the program.

The professional education program is structured to develop professional competency in concert with concurrent development in the liberal arts, and in concert with the development of professional relationships with master middle school teachers over the course of several years. In the sophomore year, an STS Seminar taught by science faculty, and developed with the assistance of master middle school teachers, familiarizes students with applied science and its implications for teachers. During this year students also spend 2. clock hours during one semester observing model middle school science teachers, thereby developing a consciousness of middle school science teaching concurrent with their growing understanding of science. In the junior year, student observe model middle school science teaching for 50 hours each semester, and become familiar with some of the responsibilities of teaching. In conjunction with observations in the field, students take professional education course work in Instructional Methods, Curriculum Design, and Evaluation and Measurement, specifically tailored to meet the needs of middle school education. The professional education program also includes course work in developmental and educational psychology, reading, and philosophy and management directed towards the middle school grades. In the senior year, a one semester student internship and a seminar in education provide opportunity for students to synthesize their skills and knowledge.

The development process of Hampton University Model Program has included local and state education community input at each stage. This process has resulted in close cooperation between local teachers, school administrators, the State Education Department, and Hampton University faculty and administration. A network of local master middle school teachers now have an intrinsic interest in the implementation and conduct of the model program in which they had a significant developmental role. University liberal arts faculty have an ongoing investment in working with local teachers in facilitating the implementation and conduct of the professional education component of the model program. The State Education Department has endorsed this innovative program and is reviewing the effectiveness of new courses and new partnerships with the public school teachers and administrators as policy is formulated on future directions to be taken to enhance the preparation of middle school science and mathematics teachers.

Conclusion

The National Science Foundation has provided significant impetus to the enhancement of the quality of middle school science and/or mathematics education through the funding of model undergraduate teacher preparation programs. Above we briefly described portions of two of the nine model middle school programs first funded by N.S.F. in 1986. Several characteristics are common to the two programs. Each program is developing professional education and\or liberal arts courses which are designed to provide knowledge, skills, and understandings which are prerequisite for excellence in teaching at the middle school level. Each program has an emphasis on a rounded liberal arts education as well as an enhanced professional education program. Each program provides models of teaching in the sciences at college level which may be emulated with success by middle school teachers. Each program has enhanced communication between liberal arts faculty, education faculty, and public school teachers in a common quest for the enhancement of undergraduate programs for the preparation of teachers. Each program includes laboratory activities which emphasize applied "hands on" science, some activities focus on issues which are of concern and relevancy to students, and some activities permit students to assume new levels of responsibility in the management and conduct of the science laboratory. These common characteristics are shared by several of the nine NSF Model Programs, each of which has unique characteristics of excellence as well. To obtain additional information about these programs, contact the Project Directors on the attached list.