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Abstract: Recently, Southeast Missouri State University redesigned its program for elementary education majors. Physical Science: A Process Approach is the name given to the physical science component of a unique sequence of four courses. The course employs the process approach and develops the course material in chemistry and physics with particular attention to those areas of content taught in the Core Competencies and Key Skills, state objectives for Missouri public schools. The learning cycle is used as a model to help students formulate ideas through hands-on classroom activities. The development of the course, its subject matter, teaching strategies, and student evaluations are discussed.

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A PROCESS APPROACH IN A COLLEGE LEVEL PHYSICAL SCIENCE COURSE

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INTRODUCTION

Science education teaching methods in the United States have changed dramatically over the past century. Nature and object teaching dominated in the late 1800's, replaced in the 1900's with the descriptive, deductive approach. After October 4, 1957, and the brilliant launching of Sputnik, America responded by self-questioning, doubt, and then action to upgrade the teaching and learning of science. Premier programs such as Chemical Bond Approach, CBA (1959); Chemical Education Materials Study, CHEM Study (1960); Biological Sciences Curriculum Study, BSCS (1959); Science: A Process Approach, SAPA (1963); Science Curriculum Improvement Study, SCIS (1962) and Physical Science Study Committee, PSSC (1965) were developed with NSF aid and support.

Most of these programs had in common 1) no textbooks, 2) hands-on inductive activities, and 3) the development of scientific thinking skills. Students were to model the behavior of scientists and hopefully become critical thinkers and problem-solvers. Unfortunately, these classic programs have not been widely incorporated into the classroom with much success. A possible cause is that although the social expectations of schooling and science have changed in the last thirty years, most teachers are still teaching pre-Sputnik style. Several studies in the 1980's (Yager, 1987) indicate that teachers still teach to and test solely for acquisition of information; 90% of test items written by teachers test content in the form of recall.

Other research indicates that the teacher's behavior directly affects the cognitive processes that students use. These studies (Vannan, 1971; Westerback, 1982; Washton, 1971) conclude that a teacher's attitude may be the most single influence affecting student attitudes towards science. Student perceptions of teacher methods and instruction influence student achievement in the sciences. Schibeci and Riley (1986) statistically tested a model predicting a chain relationship connecting perception of science instruction to student attitudes to student achievement. Their findings indicated "evidence of a substantial causal link from attitude toward achievement." It would therefore be important to prepare teachers who are philosophically dedicated to developing positive student attitudes in the classroom.

Pedagogy that employs process/inquiry modes has positive impacts on student attitudes. Students in inquiry-oriented science courses clearly improve their attitude towards science and scientists when compared to students in traditionally-taught courses (Kyle et al., 1986). Because "hands-on" activities incorporate specific, concrete examples, inductive reasoning is developed to allow the student to proceed from the specific to the general. Bruner believes that such methods allow students to develop their own patterns for problem solving, (Bruner, 1979). It is these methods that allow for successful transfer of learning to other situations; meaningful learning should subsequently occur and memorization of facts should decrease.

Lastly, there is a need for communication between teachers, present and future, and science educators. A needs assessment of Missouri elementary teachers in 1982 and a survey of secondary science teachers in 1988 (Coleman, 1990) indicated that many teachers are not aware of changes occurring in the field of science education. For instance, only 6 % of 198 Missouri teachers in 1988 indicated they were familiar with Project Synthesis, a research study conducted by Dr. Norris Harms and a team of 23 science educators. Four goal clusters, representing major goals for science education in the United States, were formulated as a result of synthesizing research and literature data; this document was published by the National Science Teachers Association in 1981. That teachers were not aware of (nor had even heard of) Project Synthesis at that time was most discouraging. To respond to this information lag and to better prepare future teachers for the challenge of assimilating new techniques into their science lessons, Southeast Missouri State University recently redesigned its elementary education program. A coordinated effort between the College of Education and the College of

Science and Technology has produced a program which has been cited as exemplary by state and national agencies.

In the past, science has not been a favorite subject for elementary education majors at Southeast Missouri State University, and they often treated science as an obstacle to be avoided as much as possible. Originally, these students could move through their program without receiving a balanced background in the sciences. Most students typically chose a 5-hr course in biology, a 3-hr earth science or geography course, and a 2-hr nature study course. Physical science was often non-existent in their program.

The new program is a unique ten-hour science package built specifically to introduce and employ the processes of science. There is a three 3-hr course in each of the three key areas of science: biological science, earth science, and physical science. A 1-hr course that introduces and develops the science processes is a prerequisite for the three content courses; it is a laboratory-centered course which focuses on activities that teach and illustrate process skills to help students feel more comfortable with hands-on science. The premise is that "all experiments work correctly" and different data represents different experiments. This encourages students to look at alternative explanations while examining their own actions. The three content courses serve as general education courses (called University Studies) that emphasize understanding through critical thinking and analysis procedures.

The following sequence was developed, based upon the process approach, utilizing content closely related to the <u>Missouri Key Skills and Core Competencies</u> (state goals and objectives). Each course is a prerequisite for the following one, culminating with the earth science interdisciplinary course which incorporates knowledge and concepts from the previous three.

BS118 Introduction to Process Science for the Elementary Teacher (1 semester hour)

PH218 Physical Science: A Process Approach (3 semester hours)

BS218 Biological Science: A Process Approach (3 semester hours)

UI318 Earth Science: A Process Approach (3 semester hours)

COURSE DESCRIPTION

The physical science course meets three times a week, twice for a one-hour "lecture" and once for a two-hour laboratory. Class size is limited to 24 students so that hands-on classroom activities may be employed during the traditional "lecture" time. During the semester, students spend eight weeks studying chemistry topics with a chemistry professor and eights weeks with a physics professor. The two-hour laboratory employs mainly formal laboratory exercises using standard laboratory equipment and involving collection and manipulation of data to reinforce science skills and concepts. The classroom activities reflect various teaching techniques such as the learning cycle, inquiry, and concept attainment and are exercises designed to be used later by the students when they subsequently teach the concept in their own classroom. Many are lessons modified from an activity book generated from the KSAM project (**K**indergarten-six **S**cience **A**nd **M**ath) which provides inservice training for teachers via short courses through Southeast Missouri State University. At present, one physical science book, one chemistry book and one physics book serve as texts. Students ideally should take this course in their sophomore year.

Because this is a University Studies course, several major objectives were considered in designing the strategies and content. It was decided initially to establish a course outline that: 1) addresses content needed by the future teacher to teach the Missouri Key Skills and Core Competencies, 2) includes current pedagogies applicable to science activities that would be helpful to the future teacher, 3) satisfies several major University Studies objectives, and 4) provides a nurturing atmosphere to change attitudes of students who have avoided science in the past. A complete syllabus and course description is included in this paper.

TEACHING STRATEGIES AND ASSIGNMENTS

The processs skills which were introduced in the BS118 course are elaborated and applied to various physical science topics in both the classroom setting and the chemistry laboratory. It is hoped that the emphasis of concrete examples and hands-on experiences will make the student comfortable and allow for inductive development of concepts. Several illustrations of teaching strategies and/or assignments for the PH218 course will be presented. Students encounter scientific information in various forms, and they must organize and convert that information to clarify patterns or principles.

The first in-class activity emphasizes observation and inference with everyday household materials, utilizing the Learning Cycle strategy. The activity, called "Silly Spaghetti" is a modification of the dancing raisin or mothball demonstration. Students work in groups and are told that their group becomes the "scientific community." Vinegar, baking soda and small spaghetti pieces are added to a clear glass; students make predictions (or guesses) then observe. They are asked to confer and provide 2 facts, a law, and a theory based on their observations. After a time, the instructor initiates a discussion of the terms, provides definitions and then allows each group to complete the activity. Further discussion centers on density, "apparent" density (volume of displaced water as it is changed by formation of bubbles on the spaghetti), and the concept of floating related to floatation devices and life jackets.

A follow-up activity (the application phase) consists of a discrepant event presented in the inquiry training mode of Richard Suchman (Suchman, 1962). Two glasses are half-filled with clear, colorless liquids; students make observations as the instructor adds what appears to be crushed ice to each. The added material floats in one and sinks in the other, then students must conduct verbal investigations by asking the teacher yes/no questions to explain the phenomena.

The use of classification systems to aid the scientific community in understanding an overabundance of information is emphasized in an in-class activity called "The Color Connection." Here students invent their own categories to form concepts of the historical definition of acid, base and neutral using the common traits they find after examining seven nameless liquids using both physical and chemical tests. The data, including extraneous information, are organized into a grid on the board, and students are asked to distinguish features and list attributes of "yes" and "no" examples which might be matched to a concept. This emphasis on the categorization of information is based on Bruner's concept attainment model where the concept already exists and students try to discover it (Bruner et al., 1977).

It should be stressed that the various teaching techniques are always modeled in the classroom before the strategy is discussed. Often the teaching scheme is implemented over a period of weeks in activities dealing with several content areas before reference is made, and a name given. Thus the introduction of various pedagogies is itself an example of the learning cycle.

COURSE EVALUATION

Since Spring, 1990, an evaluation has been given at the end of the course where students may express themselves using a scale of 1(agree) to 5(disagree) regarding three questions:

1. I now have the background to teach physical science to elementary pupils.
2. My attitude towards science has improved since taking this course.
3. I believe hands-on activities can be used to teach science in elementary grades.

Mean values for each question are listed in the following table.

QUESTION	n	MEAN
1. Background	183	2.23
2. Attitude	183	2.02
3. Hands-on	183	1.21

In addition, students were asked to comment and/or describe one or more things about the course that they would recommend continuing. Student reaction was very favorable regarding the teaching techniques and strategies used in the course. Some representative exerpts follow:

I liked the hands-on learning during classroom lectures. It makes you understand concepts better. I'm going to miss this class! It was fun and interesting, even though it was hard.

This is the first time I ever had fun and enjoyed a science class. The labs and class activities were very helpful.

I enjoyed working in small groups and the hands-on experience. I learned a lot more this way.

The labs help me to apply some of the concepts to concrete observations. They gave me new understanding about science.

Experimentation is an excellent learning tool. We were able to see how concepts were developed rather than just reading about it in a text.

If you get to work in the actual process [when] learning how and why, you feel more comfortable about the subject.

I could see what [the instructor] tried to get across...actually happening.

COURSE SYLLABUS AND OUTLINE

1. INVESTIGATIVE ISSUES IN SCIENCE
   Variables associated with issues..........1 lecture
      Identifying value positions and players in a science-related social issue; facts, laws
      and theories
2. MATHEMATICAL FOUNDATIONS
   Significant figures, measurements,
   dimensional analysis................1 lecture, 1 lab
3. MATTER: ITS CHARACTERIZATION AND PROPERTIES
   Density, specific heat............2 lectures, 1 lab
      uniqueness of water in our world,
      heat transfer, calorimetry
   Physical and chemical changes......1 lecture, 1 lab
      changes of state, indicators of chemical
      reactions
   Elements, compounds and mixtures...1 lecture, 1 lab
      conservation of mass, constant composition,

solutions
Atomic structure and models.......2 lectures, 1 lab
isotopes, atomic weight, electronic
configuration, valence, periodic properties

4. MATTER: ITS INTERACTIONS AND IMPACT ON SOCIETY
Reactions and equations...........2 lectures, 1 lab
periodic properties,chemical formulas,
oxidation and reduction
Acids and bases.................. 2 lectures, 1 lab
Arrhenius theory, pH, everyday acids and
bases, acid rain; cultural cause and
responsibility

5. MAJOR CONCEPTS OF PHYSICS AND THEIR CULTURAL IMPACT
Mechanics........................4 lectures, 2 labs
motion, Newton's Laws, energy
simple machines, pendulum
Heat.............................2 lectures, 1 lab
temperature, expansion, thermodynamics:
first and second law, a world view of
entropy
Sound............................3 lectures, 1 lab
vibrations and waves, sound energy
and noise pollution
Electricity and magnetism........4 lectures, 2 labs
electrostatics and electromagnets,
current, electrical production
Light...........................3 lectures, 2 labs
geometric optics, optical devices;
mirrors and lenses

II. EVALUATION OF STUDENTS

3 exams plus final exam.....................50%
Lab reports................................20%
Investigative Issue Project.................10%
Homework...................................20%

III. JUSTIFICATION FOR INCLUSION IN UNIVERSITY STUDIES

Objective 1: Demonstrate the Ability to Locate and Gather Information

Emphasis: Significant

Content: This objective will be addressed by several modes. First, the gathering of data will be of utmost importance in the laboratory experiments performed by the students each week. The process of observation and measurement will be stressed to assure that the students understand both the precision and limitations of scientific data collection. For instance, in the experiment, "Investigations of Density," students will collect data to determine the volume of an object in two ways, then trace the impact of the two methods on the final result. Second, students will be introduced to standard resource books in the physical sciences such as the CRC Handbook of Chemistry and Physics, as well as others in the broader field of education. Students will also find opportunity to search the more popular literature with regards to their investigative paper. Finding, organizing and graphing data will be an important aspect of several laboratory exercises. Lastly, the Periodic Table will be used in several ways as a source of information.

Teaching Strategies: The primary strategy for involving students in finding and gathering information will be in the "hands-on" activities and laboratory exercises, many of which will be presented in the inquiry/discovery mode. This technique provides enough latitude and freedom to allow the student to observe and gather information which they believe is pertinent to the investigation. In the activity entitled "Batteries and Bulbs," the students use personal observations to obtain information and collect data which must then be organized in a meaningful way.

Student Assignments: The use of various journals, books and scientific catalogues will be incorporated in the formulation of the investigative issue project. In addition, students will be asked to use library resources and search for articles in such journals as Science Scope, Science and Children, The Science Teacher, and the Journal of Chemical Education for activities which illustrate specific processes or content areas.
In addition, the CRC Handbook and the Merck Index will be used to gather specific information about chemical substances.

Evaluation of Students: A portion of the grade for the laboratory assignments will focus on data collection and the measurements associated with scientific investigations. Students will be required to turn in for a grade, a collection of activities they have located in various journals and books.

Objective 2: Demonstrate Capabilities for Critical Thinking, Reasoning and Analyzing.

Emphasis: Significant

Content: The process skills which were introduced in the BS 118 course will be elaborated and applied to various physical science topics. Thus, the higher order thinking processes will be developed in a practical manner. Students will be asked to analyze written materials such as journal articles, laboratory activities and data tables. Organization and classification of information will be stressed in several laboratory experiments. In addition, students will use their reasoning abilities to draw conclusions from observations, inferences and collected data. The classification and evaluation of science activities with regard to science content and process is an imperative part of this course to educate knowledgeable teachers.

Teaching Strategies: The processes will be reviewed by in-class discussions and activities. To learn a process, an individual needs to be shown <u>what</u> the <u>skill</u> is, <u>how</u> to do it, and be provided <u>opportunities</u> to practice it. This course will give students numerous and varied ways to practice the strategy previously introduced in BS 118. In addition, students will be taught using some of the same methods by which they might teach their students. For instance, in the laboratory "Acids and Bases" students will be taught using the technique known as "concept attainment." Here data and extraneous information are organized into a grid, and students are asked to find patterns in the information which satisfy the attributes of a particular concept known only to the teacher, in this case, the concept of an acid. This strategy involves and emphasizes reasoning abilities, encouraging the students into abstract ideas and concepts. The inquiry/discovery mode of many of the follow-up activities also fosters formal thought processes. Students are asked to draw conclusions and propose solutions; some of these activities are, "Investigation of Four Liquids", "Scientific Models", and "Twelve Liquids."

Student Assignments: The use of science teaching resources will be emphasized in collecting activities which illustrate certain science concepts. The classification and evaluation of the activity is the important factor. Students will be given guidelines to aid them in their evaluation of classroom materials. These criteria include 1) appropriateness of the activity to teach the objective, 2) difficulty level, 3) reasonable time required and materials needed, 4) use of inquiry/discovery mode (does the activity actually employ this method, or only appear to do so?). Also, various assignments will require the student to reason out an open-ended situation. The worksheet entitled "Twelve Liquids" incorporates several properties of liquids as the data base. The objective is the formulation of several viable hypotheses consistent with the data. Afterwards, additional data is added to the data base. Students must state how the data affects their hypotheses and revise them if necessary. Finally, many of the laboratory experiments require conclusions based on analyzing the collected data.

Evaluation of Students: Analytical abilities are required to complete several assignments, and the conclusions reached by the students on these assignments will constitute a portion of the grade. The major grade for the activity project will depend on the choice and sequence of activities included. The consistency of the plan and the students' understanding of the development of the concept will be considered.

Objective 3: Demonstrate effective communication skills.

Emphasis: Considerable

Content: The communication of scientific information to others is part of the nature of science itself; science is public and open to scrutiny by all. Scientists communicate with each other via certain accepted measurement systems and terms. The ability to state and present knowledge, data, and suppositions clearly and precisely is a fundamental tool essential for all educated persons. Not only should a study of science incorporate the symbols, systems and terms of a particular discipline, but it should provide examples of accepted formats for organizing information so that others might easily comprehend. Thus, students will learn to use chemical and mathematical equations, etc., (graphing and tabulating data, and writing hypotheses and conclusions). Accurate descriptions of observations and procedures will be stressed in both the written and verbal mode.
Also, there will be opportunities for students to express their own opinions and perceptions when analyzing and investigating issues.

Teaching

Strategy: Students will encounter scientific information of various forms in laboratory exercises and classroom activities. Organization and conversion of that information into tables and/or graphs will aid students in the clarification of patterns and principles. Basic rules for graphing will be discussed in lecture and students will be given opportunities to incorporate these into their work. Utilization of the metric system in measuring and calculations will give the student practice in reporting numerical values in the correct dimensions. In addition, several written assignments will require expression of logic in developing a sequential plan for the teaching of a chosen scientific concept. Verbal communication employing scientific terms will be used in the classroom, as groups will report findings of their in-class activities and/or laboratory exercises. Extensive use of tables and grids on the blackboard will provide the framework for group reporting and sharing of data.

Student Assignments: Many of the laboratory assignments involve the measurement and calculation of quantities which are traditionally expressed in the metric system. Calculation of density units in g/mL, recording temperatures in degrees celsius, and expressing acidity in pH units are a few of the methods with which students will become familiar. Summarization of data is stressed in some assignments. For instance, in the activity entitled "Twelve Liquids," participants are asked to choose the most appropriate way to communicate patterns found in a table of data. Three graphing techniques are suggested (pie graph, bar graph, and line graph). Students must decide which method best fits the particular data they choose, and they must state the reason for their choice.

Evaluation of Students: A portion of the grade for the laboratory exercises will be assigned for reporting data with regards to proper dimensions in the metric system. Methods of graphing and representing data will be the major focus of several assignments. Proper use of grammar, as well as the sequential logic of the written work will constitute a basis for scoring the investigative issue project and the activity assignment.

Objective 4: Demonstrate an ability to integrate the breadth and diversity of knowledge and experience

Emphasis: Considerable

Course Content: We belong to many worlds: a political world, a human social world as well as a physical universe. In the physical sciences of Physics, Chemistry, Geology, and Astronomy we ask the students to assimilate everything from atoms and molecules to the planets and stars and everything in between. No single volume could cover everything significant in these fields.

What we are interested in is not only knowing basic ideas of each discipline but being able to formulate questions and reasonable responses to those questions that help us understand the physical world around us. To paraphrase James Thurber, it is better to question intelligently than to know all the answers.

This is especially worthwhile when it is impossible to know all the answers. Therefore, to demonstrate an ability to question intelligently as well as be able to express oneself in scientific terms would be the main objective. A second objective would be to understand the technological progress as related to the Physical Sciences, since modern technology depends heavily on physics and chemistry. Such advances as the laser, superconductors, and new energy sources are only a small part of science, which impacts our everyday life.

Teaching Strategies: While applications of the Physical Sciences to other disciplines, to technology and to our everyday life will be discussed throughout the course, we start with basic observations and experiences that will allow students to make their own inferences. From these inferences they should develop questions such as, "Is there an underlying simplicity and order to the observed behavior?" From the quantitative observations as well as the historical perspective, students will develop a method of investigation into most Physical Systems.

Student Assignments: The students will personally interact with physical phenomena in laboratory, attend lectures that elucidate the physical principles through examples and demonstrations and develop their approach to questioning. They will be aided by questioning techniques and examples in the classroom.

Evaluation: The totality of the laboratory experience reflects this objective and will appear in the laboratory evaluation. The instructor will ask questions throughout lecture and demonstrations, to aid students in integrating specific facts into a broader context.

Examination questions will reflect the ability of students to question and develop that talent into practical application.

Objective 5: Demonstrate the ability to make informed, intelligent value decisions.

Emphasis: Considerable

Content: The nature of science embraces a built-in value system which is used by scientists to interpret the world around them. Each discipline provides a frame of reference for dealing with one's environment. The historian and the artist have their "way of knowing." Due to the impact of science and technology on society, it is important that students understand the way of science. This course will provide students the opportunity to experience some of the methods and assumptions, the nature of proof and the limitations of science. The development of the atomic theory is an excellent example of the tentativeness of science in aligning facts and theories. The discussion of safety procedures in the classroom should establish a perspective regarding their own ability to weigh the learning experience of an activity against its safe execution.

In addition, a unit of investigative issues in science focuses on identifying value positions (for oneself as well as others) and using the scientist's method of investigation to assess alternative solutions to problems confronting our society today. Most important, students will discover that one "right" answer does not exist for such issues. Such dilemmas are commonplace, and in reality are the basis for many science-related social issues prevalent today.

Teaching Strategies: The collection and analysis of data with the subsequent establishment of cause-effect factors will allow students to operate within the value system of science. In-class analysis of a video tape will force students to find different viewpoints and realize the covert value systems which dictate the particular stance individuals or groups bring to an issue. Students will be asked to express their own opinions, and find the underlying value system from which it comes. They will be required to investigate an issue using a series of steps which will be presented to them.

Student

Assignments: Laboratory assignments will reinforce the methodology of science, and aid students in establishing a system to make decisions regarding the accumulation of data and the subsequent drawing of a conclusion. Several case studies will provide the basis for an investigative paper in which the students must (1) present the problem, including documented factual evidence, (2) provide alternative viewpoints for remediation of the problem, (3) suggest any negative ramifications for both viewpoints, (4) make a decision with regards to their choice of the best solution, and in the process, identify their own value position.

Evaluation of Students: The investigative issue project will be 10% of the course grade. The student's ability to assess information, identify positions and come to a conclusions will be considered when assigning a grade.

Objective 6: Demonstrate the ability to function reponsibly in ones natural, social and political environment

Emphasis: Some

Course Content: The students' ability to function in one's natural environment will have the most emphasis. It is expected that functioning responsibly in ones natural environment will necessitate the development of skills both socially and politically that are needed to accomplish this task.

The Physical Sciences are concerned with the basic laws of nature and thus provide the means of understanding the natural environment. As the students learn the fundamental laws and principles as well as their application to everyday life, an appreciation and understanding of their natural environment is developed.

Examples include understanding the chemistry of food ingested, mechanics of vehicular motion, and electromagnetic conduction properties. Such studies should make students aware of the danger of ignorance when dealing in a world that could be hazardous to one's health. Consumerism in their environment will be discussed from the view point of quality of purchases. The necessity of purchase from a scientific viewpoint of certain products will be helpful to improve the effectiveness of a student's reaction to their own environment. An example could be an unnecessary purchase of Hi-Fi speakers with ranges above 22 Khz, or optical devices such as over-priced and under-engineered binoculars, cameras and telescopes.

Teaching
Strategies: During the course, the instructor will emphasize examples of how energy problems can be resolved; what common everyday materials are made of and how they affect our environment; what the physical aspects of materials are and how to interact safely with them. The introductory lecture will incorporate aspects of teaching physical science in a responsible way. A respect for chemicals, electricity and safety methods will be included in pre-laboratory discussions each week.

Student
Assignment: The acid rain module provides the student with the opportunity to assimilate information and theorize possible solutions while considering personal, political and environmental effects.

Evaluation: Some examination questions may address this objective.

CONCLUSION

It is the belief of this author that teachers will teach in the way that they are taught, and that they can have fun while they are learning both content and process. Concurrently, it will be these positive experiences in the sciences that will influence the next generation, freed from covert opinions, to immerse themselves in the sciences, enjoying their natural curiosity and enthusiasm that make science the intellectual venture it should be.

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