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ABSTRACT

While there is general agreement that student attitudes toward science education are poor, there is little agreement in defining, measuring, or improving attitudes. The nature of how students relate to science rather than what they know about science is becoming an area of increased focus in science education research. This case study specifically addresses attitudes and perceptions within an experiential context. Middle school student perceptions of science education were investigated by looking at attitudes toward instructional variables and perceptions of the nature of science. Experiential education was considered as an approach to enhance attitudes and perceptions while improving students' understanding of science. This study analyzed 20 Upward Bound students' attitudes and perceptions. Core factors from four learning activities (a marine biology lab lesson, an agricultural science lesson, an estuary field trip, and a physics lesson) were identified by collecting multiple sources of student data and observations. Results include a collection of perspectives that distinguish between pre- and post-perceptions and attitudes, three themes of enhanced images of science and scientists, and a proposed model to improve student perceptions of the nature of science. (Contains 53 references.) (PVD)

Student Perceptions of the Nature of Science and Attitudes Towards Science Education in an Experiential Science Program

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by

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ABSTRACT

This case study analyzes 20 Upward Bound students' attitudes toward science education and perceptions of the nature of science; then considers experiential education as an approach to enhance those attitudes and perceptions. Core factors from four learning activities (marine biology lab lesson, agricultural science lesson, estuary field trip, and physics lesson) were identified by collecting multiple sources of student data and observations. Results include: a collection of emic perspectives that distinguish between pre- and post-perceptions and attitudes; three themes of enhanced images of science and scientists, and a proposed model to improve student perceptions of the nature of science.

Introduction

The purpose of this study is to investigate middle school student perceptions of science education by looking at attitudes toward instructional variables and perceptions of the nature of science; then to consider experiential education as an approach to enhance attitudes and perceptions while improving their understanding of science. The literature reveals that a large percentage of middle school students' enthusiasm for science is low; likewise, their awareness of the contributions science makes to society is minimal --- in spite of a plethora of curricular approaches designed to produce the opposite. Why? And what elements of science curricula are effective in meaningfully engaging students?

The element common to most success stories is some form of experience-based activity Experiential learning theory is well-defined in the works of John Dewey and his advocates, yet evidence of the role experience plays, if any, in significantly enhancing attitudes or perceptions of the nature of science seems to be mostly anecdotal and unsubstantiated.

A survey of the literature provides a variety of initial conclusions and hypotheses, most notably:

1. While there is general agreement that student attitudes toward science education are poor, there is little agreement in defining, measuring, or improving attitudes. However, the evidence suggests that most assessments of attitudes have been largely ineffectual (Hofstein, Maoz & Rishpon, 1990b; Koballa, 1988; Munby, 1983). New approaches to investigating attitudes seem necessary.

2. The nature of how students relate to science rather than what they know about science is becoming an area of increased focus in science education research (Lederman, 1992; Meichtry, 1992). Most pedagogical strategies addressing student perceptions of the nature of science have been minimally effective (Bell, 1993; Carver, 1996; Gass, 1992; Meichtry, 1993; Romance & Vitale, 1992; Shamos, 1995)(Bell, 1993; Carver, 1996; Gass, 1992; Meichtry, 1993; Romance & Vitale, 1992; Shamos, 19950. Further research is needed.

3. The theory of experiential learning in science education needs to be more clearly defined, and its role in actual practice and effectiveness studied (Bell, 1993; Carver, 1996; Gass, 1992).

This study specifically address attitudes and perceptions within an experiential context. The study draws upon previous research on attitudes but provides new insights because it has relied almost entirely upon emic perspectives generated from analysis of student voices. Likewise, the study advances the understanding of student perceptions of the nature of science because, unlike prior studies that relied on predetermined variables of investigation, this study derived core issues from repeated analysis of students' perspectives. Finally, this study helps to fill the gap in research of experiential education by, first, analyzing Dewey's contributions in light of more recent findings in teaching and learning theories; and second, by investigating practical applications of the theory specifically in relationship to attitudes and perceptions.

The population under investigation in this study is limited to the 20 Upward Bound students that participated in this program. Therefore, unless otherwise noted, all references to Upward Bound students that are made in this study signify references to the 20 students of this study. There are no generalizations to other populations, yet a central premise of this study is that students with negative attitudes towards science education or whose perceptions reflect naive stereotypes are more likely to remain less scientifically literate compared to students without such attitudes and perceptions (Driver, Leach, Millar & Scott, 1996; Giere, 1991). The ramifications are numerous but based on one obvious argument: science educators stand a far better chance to persuade students to pursue a science-related profession if those students are well-informed about the nature of the scientific enterprise (Hamm & Adams, 1992; Hawkins & Pea, 1987; Shamos, 1995). As science educators continue to provide alternative, more authentic forms of instruction it is critical to conduct research to study such factors as meaning, relevance, motivation, attitudes, and perceptions in the students' experiences.

Theoretical Framework

The theoretical framework for this study is derived from both an analysis of nature of science literature and from experiential learning theory.

Nature of science

This perspective is derived from historians, philosophers, and sociologists of science and education who argue that knowledge about the scientific enterprise is potentially more important than knowledge of science content (Duschl, 1990, pp. 40-43). There is no agreement on definitions of the nature of science, yet at least two distinct bodies of educational writing shape the research: (a) science-technology-society (STS) literature emphasizing interaction between science and society, including students' understandings and perceptions of STS issues; and (b) conceptions about the nature of science, including beliefs and conceptual understandings of scientific content (Cunningham, 1995). A consideration of conceptions about the nature of science reveals why there has been such little agreement in defining the field. The foci of studies have been multifaceted, including what Meichtry (1993) describes as either knowledge studies or scientific enterprise and nature of scientist studies. For example, Duschl (1990) argues that an analysis of the role of theory development in the acquisition of scientific knowledge can guide what is taught in the classroom and, ultimately, what conceptions about the nature of science are transmitted to students. Lederman (1995) also investigates the nature of scientific knowledge, but from the standpoint of its tentativeness and how this is translated into classroom learning. Shamos (1995) likewise addresses science's tentative character and argues that "how much of the ultimate truth we actually know depends upon how well we phrase our questions of nature, that is, how carefully we design our experiments" (p. 51). Another approach to nature of science perspectives is provided by Kelly, Carlsen, and Cunningham (1993) who argue that sociological roles significantly affect what eventually comes down as a scientific decision. According to this view, values, human interests, and political aspects influence interpretations of what counts as science; personal and societal factors, social negotiation, and communications among communities of scientists affect scientific decision-making (Cunningham, 1995; Collins & Pinch, 1993).

It is reasonable to assume that student perceptions of the nature of science will be influenced by which perspective is emphasized in school science. An argument of this study is that scientific enterprise and nature of scientist lessons have received less emphasis than knowledge lessons in typical school science. The result is failure to take into consideration the role of affective factors, and more specifically student attitudes, in the acquisition of an understanding of science. An emphasis of knowledge lessons has generated a set of major obstacles to effective science education, which will be briefly stated below then addressed fully in the paper.

The first major obstacle is the considerable gap between school science instruction and real scientific activity (Brown, Collins & Duguid, 1989; Lemke, 1990). The second obstacle is the idealized and mythic image of the nature of science that prevails in our schools, portrayed as impersonal, sterile, and inflexible (Austin, 1978). The third obstacle is a sense of relevance. The fourth obstacle is lack of instructional time, resulting in a lack of in-depth science instruction including hands-on activities and science processing skills (Mullis & Jenking, 1988; Romance & Vitale, 1992; Schoeneberger & Russel, 1986).

Attitudes and Learning. There is a growing consensus that how students feel towards science makes an impact on how well they do and how likely they are to choose science as a career. Haladyna, Olsen, and Shaughnessy (1982) make a strong argument that student attitudes toward science is correlated to perceptions of self and the ability to learn, yet studies continue to indicate that student attitudes toward science remain low and get lower as they stay in school longer (Hofstein, Maoz & Rishpon, 1990a; Yager & Yager, 1985; Yager & Penick, 1986). Perhaps, as Hofstein (Hofstein, Scherz & Yager, 1986) and a growing constituency argue, measures of success are still too concerned with "mastery of science concepts".

Oliver and Simpson's longitudinal study of 5,000 students concluded that attitude in science education is a significant predictor of achievement and accounts for a large percentage of the variance in achievement (Oliver & Simpson, 1988). Shrigley (1990) also found a positive correlation between attitude and achievement. Schibeci and Riley (1986) found substantial probability that attitude and achievement are highly correlated. Also, their data supported the position that students' perceptions of instruction influence these attitudes. They concluded that such teacher variables as enthusiasm, enjoyment, and motivation can influence student achievement, challenging the findings of Eisenhardt's

1977 study of 70,000 students which found that while achievement creates positive attitudes, positive attitudes probably do not create higher achievement .

Problems with Attitude Research. Some of the major problems in research on attitudes have been weak methodology, poor theoretical analysis, and failure to examine specific issues necessary to gain an understanding of the development of attitudes toward science (Andre, Whigham, Hendrickson & Chambers, 1997).

Attitude research includes research on attitudes toward instructional variables (Allen, Klingsportn & Christensen, 1980; Durkee, 1974; Sparks & McCallon, 1974); in specialized programs (Yager, 1982); influenced by classroom climate (Haukoos & Penick, 1983); and toward science and scientists (Fraser, 1978). These studies and their results produced ambiguous findings, and when those studies involved affective factors in science education serious issues of confidence and validity arose. Munby (1983) examined the use of the Scientific Attitude Inventory (SAI) in thirty studies conducted over a ten year period and concluded " ... not only is the field of measuring attitudes replete with instruments, but that these instruments are used in a rather cavalier fashion, without heed to their reliability and validity" (p. 161). Shibecci's report (Schibeci & Riley, 1986) of over 200 studies between 1976 and 1983 examined affective variables and concluded that concepts in the affective domain remain inconsistently defined in science education literature. He provided five tentative findings: (a) gender is an important variable, (b) there are no consistent results for effects of particular science programs on attitudes, (c) home background and peer group are probably important variables, though their influence is indirect, (d) students attitudes to biological science appear to be more favorable than to physical science, and (e) positive attitudes towards science tend to decline as the number of years in school increase.

Koballa (1988) also pointed out weaknesses in attitude research but concurrently tried to channel it along more productive lines. He proposed three reasons for attitude studies in science education:

1. Attitudes are relatively enduring; that is, people's feelings toward objects and issues are relatively stable over time.... something must happen to cause [a change in attitudes].

2. Attitudes are learned. Our students are not born liking or disliking the study of science in school; they learn to like or dislike it.

3. Attitudes are related to behavior; that is, people's actions reflect their feelings toward relevant objects and issues in a probabilistic way.... With the exception of a few studies, science educators seem to have totally neglected [the] important relationship ... that attitudes are related to behavior.... Is not our ultimate purpose for studying attitudes their relationship to science-related behaviors? (pp. 123-124)

Experiential Learning

This theory possesses a sound pedagogical perspective and provides a lens for viewing and designing science curricula. Most notably, the work of John Dewey receives attention in this study because it helps to ground the theory. Logic, rationality, the scientific method, and discovery of intrinsic meanings signify important elements of Dewey's philosophy (Dewey, 1938). Life, according to Dewey, was a combination of overlapping and interrelated experiences, and his criticism of the traditional educational system was that it inculcated into students ideas and facts of the past, stressing passive sitting and committing ideas to memories. It rewarded obedience and docility while devaluing initiative (Dewey, 1938). According to Dewey the goal of education should be to understand and use experience which is achieved by developing the reflective nature of one's thought processes in order to examine what has been experienced. Knowing, he said, was the consequence of "directed action" by a participator (Dewey, 1960). He did not reject the cognitive nature but argued the reflective quality (the process of how the student learns) was necessary to make education whole (Dewey, 1938). The enemy of experience, he stated, was not the intellect but the extremes of diffusion or rigidity which would divert the process of reflective meaningfulness. Most experiential approaches emphasize the central role of *context*, arguing cognitive skills development and context are closely linked. From this standpoint purposeful activities and the social environment in which the learning takes place are of critical importance (Suchman, 1987; Greeno, 1988). Meaning, including one's cognitive activity, is a function of the contextual situation (Greeno, 1988). As opposed to the view that explicit problem solving steps develop effective practical skills, the experiential learning perspective suggests these skilled activities may proceed as a result of using contextual cues that interface with tacit knowledge (Rogoff, 1984; Shon, 1987).

Dewey's division of the inquiry process helped form the basis for a five stage pedagogical system: (a) the indeterminate situation, (b) identification of the problem, (c) determination of a problem-solution through hypotheses, (d) reasoning, and (e) construction of judgment. (Rich, 1992). Gaining knowledge is the process of making determinate the indeterminate experience.

Dewey's philosophy was revived during the 1960's due, in part, to the influence of Jean Piaget's developmentalist-constructivist model of cognition. Central to Piagetian theory is the principle that intellectual growth results from interactions with experiences in the learner's environment, progressing through three phases: (a) exploration (assimilation and disequilibration); (b) conceptual invention (accommodation); and (c) conceptual expansion (organization) (Piaget, 1973). The results of many of Piaget's education experiments lent significant credence to the theory that concrete experiences with phenomena in their varying contexts should precede categorization, explanations, terminology, and conceptualization (Aldridge, 1992; Piaget, 1963). Piaget's stage theory built upon Dewey's argument that the ability to cognitively manipulate abstract concepts to an effective degree does not occur until the formal operational stage (Sakofs, 1995). Subsequent research has demonstrated that as much as 85% of middle school students and 69% high school students in the United States function within the concrete operational stage (Maynard, 1975), leading to the hypothesis that traditional curriculum methods often require students to conceptualize abstractions before they are developmentally able to do so.

In terms of curriculum development such research suggests the importance to, first, help students undo the linear, answer-oriented training they have been conditioned to do; second, provide experiences which are developmentally suited to their levels; and third, train students how to benefit by the experience of authentic environments. The experiential/constructivist approach emphasizes "...individual development, free activity, learning through experience and the willingness to adapt to a changing world" (Rainer & Guyton, 1994). Students learn to engage themselves physically and mentally, made to "think" at every stage of their educational process, providing them "...with a complete understanding of the subject" (Clough & Clark, 1994). The teacher's job is as a facilitator, structuring meaningful engagements between partners and all learning groups, using cooperative and other such learning strategies which foster constructivist learning. "Learning is not discovering more, but interpreting through a different scheme or structure" (Brooks & Brooks, 1993).

Constructivism has generally been characterized as innovative, experiential, and creative. It is minimally dependent on rules and regulations, and advocates depth over coverage, longer class blocks, team teaching, varieties of grouping strategies, and community nurturing (Brooks & Brooks, 1993; Clough & Clark, 1994; Garmston & Wellman, 1994; Kelly, 1995; Taylor, Dawson & Fraser, 1995). Knowledge is not passively received, but is actively built up by the cognizing subject. Ideas and thoughts cannot be communicated in the sense that meaning is packaged into words and "sent" to another who unpacks the meaning from the sentences.

The majority of studies on experiential/constructivist theory agree on the following 3 points:

1. The importance to create a climate conducive to learning by emphasizing participant-to-participant interactions rather than presenter-to-participant.

2. Structuring meaningful engagements between partners and all learning groups.

3. Using cooperative, collaborative, and related learning strategies.

Experience and Pedagogy. In designing the strategies for this study a number of pedagogical factors were considered, beginning with a quote from Dewey's Human Nature and Conduct (1930) to set the spirit:

> The elaborate systems of science are born not of reason but of impulses at first slight and flickering; impulses to handle, to move about, to hunt, to uncover, to mix things separated and divide things combined, to talk and to listen. Method is their effectual organization into continuous dispositions of inquiry, development, and testing.... Reason, the rational attitude, is the resulting disposition (p. 55).

A pedagogical approach to experiential methodology can first be approached by considering the traditional teaching model of transmission, also called command, expository, or information assimilation model. Here, the learner is a passive recipient of definitions and other second-hand information with the assumption that , by listening to the teacher who is more experienced and knowledgeable, will absorb what is necessary to be learned (Herbert, 1995). Students are expected to absorb verbal or symbolic information, whether it be from lectures, presentations, readings, or some other format void of an experiential framework. The question must be asked, however, if the minds, feelings, and actions of the learners have been engaged, and if not, has any meaning been derived? Students are often conditioned to become intellectually dependent on teachers, remain in lower-level cognitive learning, and confuse principles of accountability for and justification of phenomena (Bloom, 1954; Tuss, 1994).

One effective model for experiential pedagogy is derived from sociologist James Coleman's (1984) model of the information assimilation process in reverse order: as opposed to the process of given information which is transmitted through symbolic media, assimilated by the learner, generalized, and finally applied; Coleman speaks of the experiential learning model proceeding in reverse order -- from activity to comprehending the consequences of the activity to symbolically generalizing the principle to a wide range of conditions. He argues these two learning processes are complementary and, for optimal learning to occur, both should be present. The information assimilation process is a tremendous time saver because it does not rely on a real world context, but the experiential mode generates meaning, motivation, retention, and application in a manner not likely with the assimilation process (Tuss, 1994).

Various experiential models have been designed relying on these principles, including David Kolb's four-stage cycle of concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984); and Laura Joplin's five-stage model of focus, action, support, feedback, and debrief (Crosby, 1981; Joplin, 1981).

In designing the experiential learning program Gass provides a series of elements (Gass, 1985):

1. Design conditions for transfer before the learning activities actually begin.

2. Create elements in the student's learning environment similar to those elements likely to be found in future learning environments.

3. Provide students with the opportunities to practice the transfer of learning while still in the program.

4. Make the consequences of learning natural, not artificial.

5. Provide the means for students to internalize their own learning.

In general, the experiential teacher must be more adept than traditional teachers in managing logistics, guarding the learning environment, serving as nurturer, establishing accessible relationships with students, recognizing differences, and stimulating authentic learning experiences (Warren, 1993).

Experience and Attitudes. To tie experience in with the factor of attitudes, Dewey's discussion of appropriate and "bad" conditions for the exercise of the mind is excerpted below, then interpreted in figures 2 and 3.

> The false sense of abstraction is connected with thinking of mental activity as something that can go on wholly by itself, apart from objects or from the world of persons and things. Real subject-matter being removed, something else has to be supplied in its place for the mind to occupy itself with.... the first-hand subject-matter which gives them meaning has been excluded .... The world of studies then becomes a strange and peculiar world, because a world cut off from -- abstracted from -- the world in which pupils as human beings live and act and suffer. lack of "interest." lack of power to hold attention and stir thought, are a necessary consequence of the unreality attendant upon such a realm for study.... such indifference and aversion are always evidence -- either directly or as a consequence of previous bad conditions -- that the appropriate conditions for the exercise of mind are not there. (Dewey, 1913, pp. 93-94).

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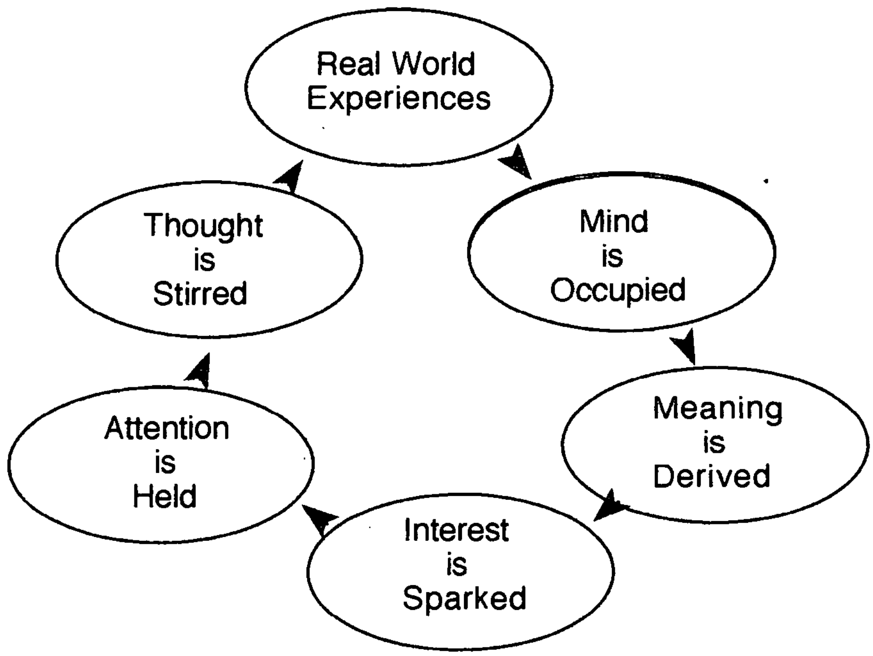

Figure 2. Cycle of Sparked Interest

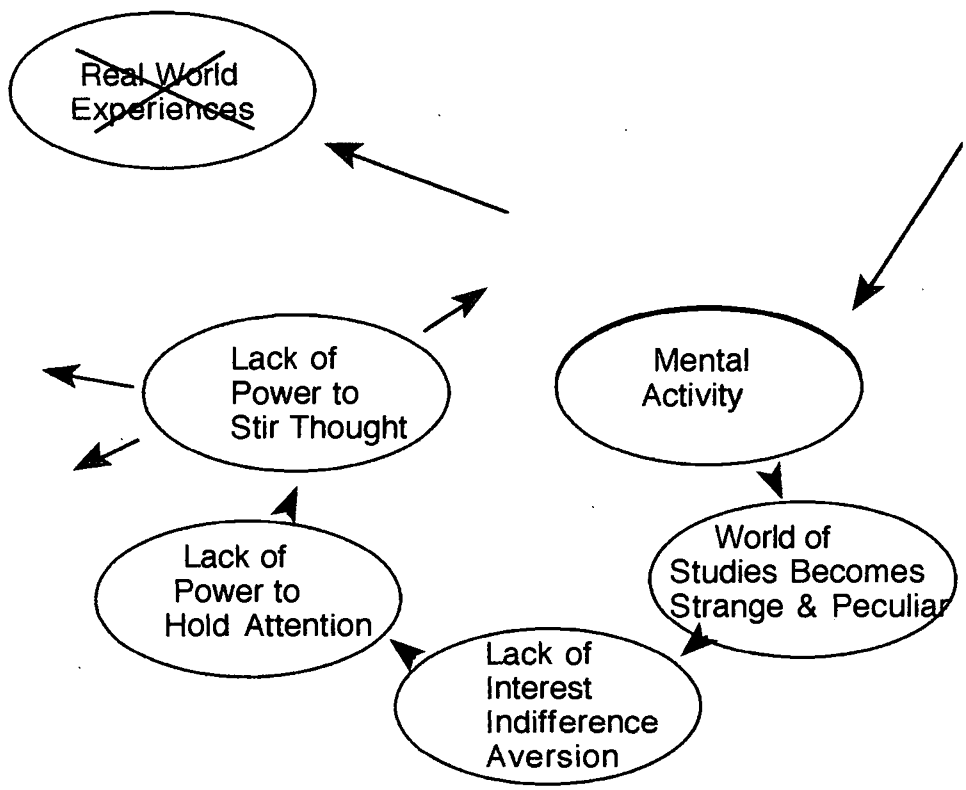

Figure 3. Broken Cycle of Interest

In figure 2 the process begins with the real world of object, people, and experiences. First hand occupation with real subject matter provides meaning which in turn sparks interest. This provides the appropriate conditions to hold attention and stir thought. The cycle of appropriate conditions for exercise of the mind is complete.

Figure 3 depicts the cycle when real world experiences are removed, or when mental activity is viewed as something wholly apart from the real world of objects, people, and things. When this real subject matter is removed something else from someplace (characterized in figure 3 with a "?" mark) has to be supplied in its place for the mind to occupy itself with. With the first hand subject matter excluded the world of studies becomes a "strange and peculiar" place. It is cut off, abstracted from, the real world experiences where human beings live and act. This results in a lack of interest, indifference, or aversion. The power to hold attention is lost and therefore there is a lack of power to stir thought. Thought dissipates. The cycle of appropriate conditions for exercise of the mind is broken and incomplete.

Design and Procedures

This is an explorative case study of 20 high school students participating in an Upward Bound summer science program at the University of California. The study documents pre- and post-views of science instructional processes related to four learning activities, and of perceptions of the nature of science. Serving as an instructor and researcher, I designed a six-week course drawing upon experiential learning theory, then administered various qualitative data collection materials. The case study design was used because it helps to explain causal links and describe the real life context of the program, and it serves as a useful strategy to "explore those situations in which the intervention being evaluated has no clear, single set of outcomes" (Yin, 1984).

Core factors from the following four learning activities were identified by collecting multiple sources of student data and observations:

1. A marine biology lab lesson,
2. An agricultural science lesson,
3. An estuary field trip, and
4. A physics lesson.

Description of Learning Activities

This paper will focus on a comparison of two of the above four learning activities: the marine biology lab lesson and the agricultural science lesson.

Marine Biology Lesson. A marine biologist at the University of California Marine Biology Lab gave the students a tour through the lab and discussed the kinds of research and activities occurring at the center. Upon arriving at the marine biology lab students were instructed to "listen up" as the scientist had some "important" things to tell them about this place. He introduced himself, began talking about the importance of this lab to the world of science, then provided extensive explanations. The first movement occurred one hour later when the students were brought through the lab. They were told they could walk down the hall and look in the doors, but to stay quiet and not enter any of the rooms as scientists were doing their work. They engaged in no hands on activities.

Agricultural Science Lesson. An agricultural scientist gave a tour of a commercial organic farm and students took part in harvesting and farm activities. The scientist presented his viewpoints on chemical fertilization versus organic, discussed concepts of habitat, community, and various agricultural concepts. Students participated in a 45 minute "in-the-round" question-answer format where each student asked a question relative to the tour or observations, followed by responses and group discussions.

Participants

The participants chosen for this study are 20 students attending the Upward Bound program, funded through a grant from the U.S. Department of Education. It is a college preparatory program for students interested in going to college, who have the potential and motivation to succeed, but who may be currently achieving below their academic potential. The goal of Upward Bound is to provide assistance to eligible students to help them finish high school and obtain a college degree. The program includes a variety of elements, including tutoring assistance, college and career planning, educational field trips, and a summer residential program. Upward Bound students spend six weeks at the university and enroll in English, Math, Science, and other enrichment classes for high school credit. Additionally, they participate in various cultural, social, and recreational activities during the summer residential program, allowing students an opportunity to experience different aspects of college life while still in high school. The cohort of 20 students in this study range in age from 12 to 16, the majority are 14 and 15 years old. They came from 9 different schools. All 20 students came from minority backgrounds, including Laotian, Asian, Chicano, and African-American. Attendance of the residential program took place from June 24, 1996 to August 4, 1996.

Research Questions

1. What are the characteristics of the Upward Bound student attitudes towards science education before, during, and after involvement in a curriculum specifically designed to address attitudes towards science instruction and perceptions of the nature of science?

2. What does a case study of an experiential approach to teaching the nature of science tell us about the relationship between student attitudes, perceptions, and curriculum improvement?

    a. What major themes emerge from the data?

    b. What insights has the case study provided into experiential science curriculum design?

    c. What are the indicators of effectiveness in experiential methods?

Data

Primary sources of data were: written responses, observations, interviews & debriefings, and questionnaires. Secondary sources of data were: assignments, curriculum notes, classroom activities notes, and reflections on informal conversations.

The development of the data-collection materials relied on a synthesis of important issues derived from those reviews, including Ryan and Aikenhead's work on high school students' preconceptions about the epistemology of science (Aikenhead & Ryan, 1992; Aikenhead, Ryan & Fleming, 1989; Ryan & Aikenhead, 1992) and on Draw-A-Scientist tests (Chambers, 1983; Mason, Kahle & Gardner, 1991).

Aikenhead and Ryan are responsible for the development of a qualitative research instrument that monitors students' views of science, technology, and society (VOSTS). I did not administer the VOSTS instrument to my sample but I used some of the questions to help shape my own materials. Studies centered around draw-a-scientist tests (DAST) helped me develop the writing activities for pre- and post-instruction views by providing research activities and results which suggest the strong preconceived stereotypes regarding science and scientists held by the majority of students. My purpose was not to replicate the DAST test but to use some of the same methodology as a starting place to help determine what student views coming into the program were and how experiential methodology might help students develop a broader perspective. As can be seen by examining pre- and post- writing activities, students were asked to draw or at least describe what a scientist is, looks like, and does.

The following two tables present the primary and secondary sources of data.

Table 1 Primary Sources of Data

Written Responses	Description
What is a Scientist?	Writing activity used to gain initial student views.
Most/least interesting	Writing activity asking students to rank most and least interesting aspects of science education.
How scientists form theories	Writing activity aimed at gathering data about student views of Nature of Science by writing about scientific process.
Scenarios	Students worked in small groups solving science scenarios, then wrote about their experiences.

(Table 1 continued on next page)

(Table 1 continued)

Written Responses	Description
Textbook project	A multi-faceted project gaining student views and attitudes.
Tour Guide	Last day writing activity similar to the first day activity.
Observations of:	
Field trips	I kept field notes of observations of all student field trips.
Presentations	I also kept notes of observations of student presentations.
Class activities	I kept reflective notes of class activities.
Interactions	I kept field notes of student interactions that might have some bearing on attitudes or perceptions.
11 Debriefing questions	Questionnaire administered in 5th week to assess views regarding curriculum variables.
Classroom debriefings	Daily debriefings were conducted to gather student perceptions and attitudes.
Focus group interviews	I interviewed students in groups of 3 to 4 as a follow-up strategy 3 months after program had ended.
Written Responses	
Questionnaires	
1st Day Questionnaire	Administered on 1st day of program to gain individual and group profiles.
Debriefing questionnaire	Administered at end of program to solicit views regarding curriculum and nature of science variables.

Table 2 Secondary Sources of Data

Category	Description
Blackboard work	I copied all blackboard entries that resulted from class discussions or debriefings.
Journals	Students kept journals of observations, activities, and thoughts.
Artistic work	Artistic work added data regarding views and attitudes.
Reports/essays	Some students expressed views in the context of written reports and essays.
Presentations/ demonstrations	Processes of preparing and making presentations served as useful observational data.
Classroom activities notes	I observed various aspects of classroom processes and recorded data pertinent to perceptions and/or attitudes.

Analysis

Data were analyzed under four separate categories, then each of these categories was subcategorized. The categories and subcategories are:

1. Pre-instruction views of Science.
   a. Perceptions of the nature of science
   b. Attitudes towards science education
      1) Most/least enjoy about science classes
      2) Naive/moderate/advanced views & attitudes
2. During Views of Science.
   a. Perspectives about:
      1) Marine biology lab lesson
      2) Agricultural science lesson
      3) Estuary field trip
      4) Physics lesson
   b. Perceptions of the nature of science derived from:
      1) Marine biology lab lesson
      2) Agricultural science lesson
      3) Estuary field trip
      4) Physics lesson
3. Post-instruction views of Science.
   a. Perceptions of the nature of science
   b. Attitudes towards science education
4. Follow-up Interviews.

Constant comparative analysis (CCA) was used to study the multiple data sources and generate a coding system and categories (Glaser, 1969; Strauss, 1987). CCA uses techniques of theoretical sampling and constant comparison, generating dense conceptual analysis and tightness around the phenomena. It is less concerned with thick description than are detailed case studies. The following points, gleaned from Strauss' rules of thumb for constructing case studies (p 219-220), illustrate how the case study design was used in this study:

1. Data were collected, coded, analyzed, and recoded until significant core categories emerged.

2. I focused on emerging themes rather than developing highly illustrative material.

3. Illustrative data were built up selectively; that is, according to "the usual canons of good science": significance, theory-observations compatibility, generalizability, consistency, reproducibility, precision, and verification.

4. I avoided the tendency to overload the case with too much descriptive material.

The coded categories of data were then used to provide detailed descriptions and analyses of the various processes, themes, activities, interactions, and voices of students participating in the program.

Procedure

My first objective was to assess student views of science at the very beginning of the six-week program--before any discussion about program contents, purpose, or objectives was made. I wanted to know how they viewed the work of science and scientists in society, what they thought and felt about science instruction, and what relevance science had to them personally. A variety of writing activities were administered to address these core issues. Next, once they participated in each of the learning activities, I solicited student views again; this time through class activities , discussions, and observations as well as with additional writing activities. Last, I conducted post- and follow-up assessments with writing activities similar to the pre-instruction views writing activities, and with follow-up interviews conducted four months later.

Limitations

There are limitations to such a study. First, this study does not measure changes in scientific knowledge, processing skills, and other conceptual factors, but rather changes in attitudes and perceptions; it can be argued that this change variable is highly subjective and not necessarily a reasonable indicator of improved student success. Second, due to the qualitative nature of the study the sample size is only 20 students. Third, the researcher was also the instructor.

My Role

Because my role was that of instructor and researcher considerable attention had to be given to the critical nature of conducting reliable research while playing an active part in the process. I employed at least three methodological practices to assure quality of my role in the process: (a) I used the continual process of collection, coding, and refinement so signals of researcher bias would be given numerable opportunities to emerge and be addressed; (b) I provide a detailed picture of my role involvement throughout each day of the program; and (c) I approached the project with a full understanding that an action researcher is not an impartial observer. My role was intended to affect change, so the guiding principle was whether I, as researcher of that change process, could collect, analyze, and report on the process in a reliable fashion. To the students I was a science teacher introducing a different way of going about the study of science. I arranged field trips and facilitated activities and discussions and handed out a variety of writing assignments to solicit their views, opinions, ideas, and reflections. I did not grade the students on what they said or how they participated, and I was careful not to exert any influence to force answers in any particular way. All "right" and "wrong" answer approaches were avoided.

Inwardly I was a researcher. I collected and recorded the student responses by entering them verbatim into a database and analyzing them to determine how to tailor the program to best address the pedagogical issues at hand. I reflected on my daily experiences and observations of the students and kept a journal. Though the students were aware of this work it was underemphasized--that is, they at no time were treated as subjects in a research project being manipulated or analyzed.

The convergence of these two roles occurred after the six week program had ended. I notified the students that I would like to use their written work and other data for my study and that I would like to conduct further interviews with them. Thus I began the official role of researcher after the six-week period had ended.

Findings

Pre and Post Comparisons of Students' Perceptions of the Nature of Science

Students' perceptions of the nature of science fell into three categories that remained useful for purposes of categorization and comparison. They are: (a) naive, simplistic perceptions, with no apparent experience or knowledge of the topic; (b) moderately informed, reflecting some kind of reference to experience or knowledge of the topic, even if inaccurately stated; and (c) advanced, demonstrating some experience and/or knowledge of the topic, with justifications provided for explanations . When these views were analyzed on the Nature of Science matrix it was possible to arrive at composite views for each of the 3 categories of students.

Naive perceptions. These referred to the scientist as somebody who spends most of the time in a lab, often as a "weird mad inventor" experimenting with lots of chemicals. The scientist usually has white hair, wears a white lab coat, goggles, and is male. Scientists get their answers as a result of mixing chemicals together until new discoveries are made. Naive students see three applications of science in society: (a) medicine, (b) developing household formulas, and (c) coming up with new inventions.

Moderate perceptions. These views see scientists as men or women who look like ordinary people. They investigate a variety of phenomena in nature or the laboratory, using instruments like microscopes, Bunsen burners, and beakers of chemicals. They may study plants, animals, or people; and their activities include predicting, experimenting, exploring, and discovering the unknown. Scientists make many contributions to society to make living easier, including numerous technological inventions, medicine, and food production. Several students in this category also noted that scientists make ecological contributions to society.

Advanced perceptions. These views cite a wide variety of scientist types, from researchers to chemists to molecular biologists; and many specific references are made such as the study of fungus, AIDS, molecules, genes, and so forth. Scientists try to answer questions that will advance knowledge and help society. For example, how can tornadoes be predicted, what is the nature of deadly viruses, or what is the result of the interaction of certain chemicals? They explore, discover, and learn through careful observation and study, often using powerful tools to aid in observation and experiments. The scientists do not look any particular way and how they dress is dependent upon the type of work they are doing. They may work in the laboratory, the field, the ocean, or virtually any place in the world or even outer space. Scientists help the world by finding solutions to such conditions as pollution, overpopulation, hunger, and technological needs.

Tables 3 and 4 provide counts of naive, moderate, and advanced statements expressed towards four categories of student perceptions. The total number of student statements for each category was 20. Some students made more than 1 statement per category, but for purposes of this analysis I combined their statements so I could ascribe 1 statement per student.

Table 3. Student Pre-Perceptions of the Nature of Science

Categories of Student Perceptions	Naive	Moderate	Advanced
What is a scientist?	14	3	3
Where do scientists work?	16	4	0
How do scientists get their answers?	15	2	3
Science in society.*	2	3	2

Table 4. Student Post-Perceptions of the Nature of Science

Categories of Student Perceptions	Naive	Moderate	Advanced
What is a scientist?	3	12	5
Where do scientists work?	2	14	4
How do scientists get their answers?	2	9	6
Science in society.	3	6	8

Compared to pre-instruction perceptions naive statements dropped from 14 to 3, moderate statements increased from 3 to 14, and advanced statements gained from 3 to 5. Except for the 3 naive statements, all references to a scientist included some kind of demonstration of learned concepts, qualifying for the moderate category. The 5 advanced statements demonstrated topic knowledge and provided justifications.

Table 5 compares results from matrices measuring pre- and post-perceptions of the nature of science. The number of naive, moderate, and advanced student responses. Since these matrices classify responses to similar writing activities using identical codes and decision rules the results provide a reasonable comparison of pre- and post-instruction views results. As table 5 indicates, there was a preponderance of naive perceptions in the pre-instruction views stage and of advanced perceptions in the post-instruction views stage. The percentage of moderate responses remained about the same.

Table 5 Comparisons of Pre and Post Perceptions

	Percentage of Naive Responses	Percentage of Moderate Responses	Percentage of Advanced Responses	Total Responses
Pre-instruction responses	30%	46%	24%	100%
Post-instruction responses	10%	48%	42%	100%

Pre and Post Comparisons of Students' Attitudes Towards Science Education

A composite picture of student attitudes was gained by considering instructional variables they considered most interesting and least interesting, as presented in tables 6 and 7.

Table 6. Comparison of Pre/Post Most Interesting

Variable	Pre-instruction views	Post-instruction views	% Change
LABS Hands on work; Experiments; Dissect animals' Play with chemicals; Looking at things closer; Using microscopes; Computer labs; Working with dangerous things	44%	28%	- 16%
ASSIGNMENTS Learn how things we use got here; Understand universe a little better; Go out of class to discover/field trips; Nature; Exploring something different; Projects; Little homework/tests	23%	52%	+ 29%
CLASSROOM Studying about plants and animals; Free time; Learning about new stuff; The math; Free time; Videos; Interesting class; Drawing pictures; Playing science games	17%	5%	- 12%
SOCIETY Meeting new people; Group activity	13%	8%	- 5%
TEACHER Not much teacher talk; Helpful/ nice	3%	7%	+ 4%

In analyzing table 6 my first question was why did post-instruction views attitudes towards lab activity drop? One plausible reason is because such a large percentage found the next category, assignments, to be the most interesting, because this category includes field trips which ranked number one among all the students. For example, many references to the assignments category were similar to the following:

I think studying science should be taught in a fun way by not just looking for information in a textbook and working on worksheets all the time. I think it's better to put your hands on the things you're trying to learn. It's not just for the fun of it, it's also because you learn something from going on field trips and experiencing new facts.

Thus, if we take the lab and assignments variables together 80% of the post-instruction views attitudes expressed these as most interesting compared to 67% of the pre-instruction views. The other significant decline is in the class activities variable. The figures suggest that prior to the summer program students were more inclined to cite such activities as free time, videos, guest speakers, and playing games as the most interesting, but subsequent to participation in the summer program activities they chose non-classroom variables more frequently. The social variable dropped also, which surprised me because it had been cited as a major issue during pre-instruction views investigations and continued to be throughout the duration of the program. My interpretation suggests that even though social factors were very important to these students, when judged alongside the other four variables students simply did not rank them as the most interesting. The same is true for teacher related factors, which gained only 4% points over pre-instruction views. Again, lab and assignment variables took such a large percentage of the most interesting ranking that social factors and teacher factors could not.

Table 7. Comparison of Pre/Post Least Interesting

Variable	Pre-instruction views	Post-instruction views	% Change
LABS Getting dirty; Using the same tools; Dissecting; Working alone on labs; Boring experiments/boring science projects; Sit and wait type stuff; Listening to instructions before doing anything; Labs that are on a piece of paper/packets that tell about the stuff; Writing down a conclusion; Weighing things	13%	4%	- 9%
ASSIGNMENTS Reviewing; Learning new subjects; Tests/ writing assignments/ homework; Reading from a book and answering questions; Equations; Teacher's assignments; Boring trips; Extra credit work; Learning parts of a microscope	51%	27%	- 24%
CLASSROOM Doing old stuff; Staying in classroom; Worksheets; Staying in seat; Discussions; Boring science videos; Bingo games	20%	23%	+ 3%
SOCIETY Working by yourself; Mean classmates	3%	2%	- 1%
TEACHER Poor teacher attitudes; Boring teachers; Lot of teacher talk; Teacher experiments but we don't get to	13%	44%	+ 31%

The assignment variable experienced the largest percentage decrease, with post-instruction views rankings of least interesting dropping 24%. There appeared to be two major reasons for this: (a) students' current perceptions of assignments were based on "interesting" experiences and (b) many of the factors listed as least interesting in pre-instruction views data were nonexistent in post-instruction views. In fact, over 60% of the least interesting statements made about assignment variables were based on memories of previous experiences.

Teacher variables experienced the largest percentage increase. A full 44% of the students of post-instruction views statements cited "boring" teachers or teachers that "talk too much" as the least interesting compared to only 13% from pre-instruction views. I propose two major reasons for this: (a) students developed a greater awareness of the strong connection between teacher factors and students attitudes, and (b) so many pre-instruction views statements ranked assignment and classroom variables as least interesting (71%) that the teacher variables by comparison were low.

Overall, the pre/post data comparisons suggest that, from the students' point of view, interest in learning science could be improved by the following:

1. Hands-on engagement and/or active participation in field settings.
2. Avoidance of too much talking or explaining, especially in technical terms.

3. Minimizing reading ,writing , and unnecessary classroom-related activities.

An increasing number of students pointed out that while they wanted learning to be fun and interesting, they also wanted to be challenged. The following statement represents those views:

I think you can have fun with science and learn at the same time. What I mean is that you can make it boring and stay in the class all day and write, or you can make it fun and go on field trips.... When we went to the physics lab I learned a lot of new things. I think that's having fun with science, and while you're having fun with science you also learn about new stuff ...

Themes

Two major themes emerged from student emic perspectives: *Boring Classes and Teachers* and *Relevance.*

Boring Classes and Teachers. Students provided numerous references to "boring" situations but in most cases provided no basis for these judgments. In certain instances justifications for the judgments were provided, allowing me the opportunity to determine factors that may contribute to student disinclinations towards learning science. Those are: (a) lessons that are too technical, (b) too much class or teacher talking, and (c) too much reading or paperwork. Student suggestions for mitigating the boredom factor were: (a) get out of the classroom, (b) relate lessons to student interest, and (c) encourage active participation. The following statements represent student voices on boredom.

The way some teachers approach teaching students and how some teachers teach is pretty boring.

Sometimes they get too boring , too technical and dull.

I got the least out of getting in groups to discuss what observations were made at the beach. It was the least because that was boring and just staying in class talking was boring. I think it's better to do things outside because it's more fun.

Science should be taught not just reading books and staying in the classrooms. Science should be taught outdoors, taking field trips to places, and doing fun experience. I learned a lot in his class because he never made it boring.

I think that science is kinda boring but it depends on what we're learning. If we're learning about oceanography that's fun cause I learn about different kinds of creatures. If we're learning chemistry now that's boring. That's all I have to say.

Science is fun only when you make it fun. If you ask many questions and pay attention to who's talking and what that person says could be very interesting. But if you tell yourself that it's boring then no matter what it will be boring.

The vast majority of students referred to boring teachers as the major reason for a lack of interest in science. When I probed for distinguishing features of a boring teacher the number one characterization was teachers that talk too much. A few representative statements are provided below. Also note that students are quite clear that if teachers expect students to understand more of what they are trying to tell them should replace explanations with more hands-on engagements.

The Physics lab is better than the marine lab because he teaches us in a fun way instead of talking for almost two hours.

I think the activities that our class did was helpful in many ways in the procedure of learning. We learned better because of the experience of being in the scene and graphically not have to picture any science because you're already there to witness the activities of what the professor or the teacher is doing.

I don't like to sit up in a room and just listen to the teacher talk. I think that's boring, but if we had experiments in the class that would be fun. It helps me understand science because I am right there observing it at first hand.

I feel you need to observe .... You know it's true and that it's not make-believe. You get to go out and have fun while learning. Cause when you are in a classroom you are just daydreaming or saying this teacher is so boring, so I think field-trips are better and you learn more.

I think that teachers should make science classes fun, for example do experiments, go outside where you can prove whatever you are looking for, because I think that is something really important that every student should know about, and in order for students to pay good attention it should be fun because then we could be satisfied and knowledgeable.

... the guy was just talking and talking. And I was getting bored. He was a living encyclopedia.

He didn't really show us what he was talking about. But when he showed us the touch tank we didn't have time to touch anything because he talked most of the time.

Relevance. When students recognized connections between science and their personal lives, they were more inclined to display an improved attitude toward learning science. Students tried to make connections between science and its usefulness in society from the earliest phase of pre-instruction views investigations onward, suggesting the following: if students are unable to make or recognize connections they will be turned away from an involvement with science, choosing a field that represents more "real life" connectedness.

Agricultural Lesson and Marine Biology Lesson

Agricultural Lesson. Students ranked this as their favorite and most useful field trip because they said the experience provided opportunities to handle materials and the scientist showed and explained things in comprehensible ways. Group reflective sessions regarding the farm field trip were conducted so students could share what they had gotten out of their experiences. The first characteristic was the ability of many students to enthusiastically share their impressions and interpretations. The second characteristic centered around conceptual learning. Students not only comprehended the concepts of niche, habitat, community, and so forth; they embellished them with descriptive examples from the farm and other experiences. Thus, the emotionally satisfying experience derived from the field trip provided imaginative fuel to comprehend complex concepts in a broader perspective. The students then wrote about their experiences, both in free-flow personal journal-writing fashion and in terms more specific to scientific concepts.

A representative statement regarding experiences with the scientist follows:

He told us a lot of details about fruits, vegetables, and even soil. Soil was the most interesting topic that we discussed,. For example, he took us under an avocado tree and we were sitting on leaves, so he told us to separate the leaves and it was funny cause there was little leaves under them. It seems like if they recycle . We were eating watermelon and he told us to put the peel under the leaves cause it was going to become soil.

Marine Biology Lab. As with the agricultural lesson, follow-up and reflective activities were conducted, leading to a unanimous student concurrence that this was their least favorite field trip. The experience provided little opportunity to do anything but sit as the scientist talked excessively and in incomprehensible terms.

Representative statements of students were:

Some of the things were interesting but he just talked forever about boring things. He was talking so long and it was so boring that I got distracted thinking about other things, and not paying attention. The best part of that trip was when we got to see the sea animals. Otherwise I didn't really get anything out of it.

He expected us to know all those hard scientific terms that he used. I think he expected us to listen to him more than we asking him any questions. I didn't get much out of that field trip because I didn't learn much and I expected him to show us around more instead of just making us sit somewhere and started giving us a very long talk.

He didn't have any physical evidence to show us how the animals look like.

...we didn't get to ask as many questions because he talked for at least half an hour.

A representative statement regarding experiences with the scientist follows:

The Marine lab was the least funnest. It was boring because he kept on talking and we didn't get to look at the stuff that long. But one thing although he talked a lot I kind of learned some stuff but not that much.

Student *interest* in light of these two instructional activities is represented in the statements below.

Agricultural Field Trip

I learned a lot from why soil is so important to this whole world, to why pesticides are so bad to our health and our food.

Probably because we were out there in the farm experiencing what the farmers do everyday. It was fun to learn about the different fruits and vegetables that they grow. The experience was fun, so it was fun to learn what he taught us.

Mike the tour guide had all this information ... like organic and inorganic foods, soil, and of course pesticides. We learned a lot and had fun. I think one of the main things we learned was how Mike planted his crops after another. For example, after planting corn which takes up a lot of nourishment, Mike would plant beans which would put back the nourishment.

Marine Lab

...because all that was going on was talking.

When the person was talking I couldn't understand because he talked too long and in a way that I couldn't understand.

He didn't really show us what he was talking about. But when he showed us the touch tank we didn't have time to touch anything because he talked most of the time.

It was boring because he didn't have us do anything fun.

The man there gave us plenty of good information, but he talked too much and everyone was getting restless. He also didn't say too much about the animals in the touch tank.

He expected us to know all those hard scientific terms that he used. I think he expected us to listen to him more than we asking him any questions. .... I expected him to show us around more instead of just making us sit somewhere and started giving us a very long talk.

The best part of that trip was when we got to see the sea animals. Otherwise I didn't really get anything out of it.

He didn't have any physical evidence to show us how the animals looks like.

Discussion

To address whether perceptions were enhanced this section compares the nature of student justifications for ranking the farm tour and the marine biology lab. When the students arrived on the farm the scientist made personal connections through humor, stories, and questions; then began a physical tour of the farm, which is to say the students engaged in movement and activity early on. The scientist would stop, explain a process, and have different students try their hands at it. If students were distracted he focused in on them--that is, he demanded their attention and participation. For close to an hour this process of movement, explanations, hands-on, and question-answer feedback proceeded, then all the students sat on the ground and asked questions about something they had just seen, done, or heard. In fact, it was required that each student ask at least one question. This transpired for another 45 minutes with very little distraction. By comparison the students arrived at the marine biology lab and were immediately thrust into a "be quite and listen to the expert" situation which consisted of nearly an hour of talking with no interaction. Then, when the student eventually walked through the lab, they were instructed to not to bother the scientists -- creating a distancing effect for the students.

I probed to determine the nature of their conceptual learning. Justifications for the farm tour reflected students' experiences while references to the marine lab reflected prior knowledge of a more abstract nature. For example, relative to the farm some students discussed a better understanding of how to grow fruits and vegetables, about the varied characteristics of crops, of chemical explanations for organic versus inorganic, and of natural processes such as soil aeration by worms. In the case of the marine lab experience, much less discussion of a conceptual nature ensued, but that which did referred generally to cells and genetics, presumably because these subjects had been learned in a prior classroom experience.

In the case of the marine lab experience the students were immediately thrust into a situation of abstraction as the marine biologist provided presumably important information about research in marine biology, cell theory, and so forth. These abstractions made little reference to the real life conditions, or at least to real life in the minds of the students; providing little to relate to. They lost interest, their attention was not held, and their thought was not stirred. The result was that learning was highly unlikely because interest was absent.

While we can not go so far as to say high interest would have resulted in higher learning, it is reasonable to hypothesize that the opportunity for learning could have been enhanced had interest been more adequately addressed. And while it can be argued the agricultural field trip justifications hardly represent enhanced perceptions, the counter argument is that students were at least open to exploring scientific concepts. However, there are clear deficiencies in both the farm tour and marine lab as exemplars of strong enhancement of perceptions of the nature of science. With the agricultural field trip interest is high, students were having "fun", but conceptual learning at a high school science level is dubious. With the marine biology lab interest is low, students were "bored", and conceptual learning was limited to references to abstract principles.

Research suggests high interest added as a "seductive" lure does not facilitate learning and may, in fact, hinder the processing of important information (Garner, Gillingham & White, 1989; Hidi, 1990; Mitchell, 1992; Wade, 1992). Wade (1992) differentiates between high interest/high importance and high interest/low importance and hypothesizes that while both capture the attention of the learner, the former requires a concentrated effort or *will* that activates attentional resources and a conscious awareness to achieve particular learning objectives (p. 271). The latter, while attracting considerable attention, serves as a distraction to important information processing (p. 272). While Wade's research centers on text-based learning, Mitchell's (1992) study of interest in mathematics confirms Wade's conclusions that high interest/high importance factors serve the learning process while high interest/low importance factors hinder it or at least do not support it.

Many of the experiential education techniques implemented in this program served to help generate high interest by providing first hand experiences, connections to real life applications, and activity-driven processes. This addresses the high interest factor but does little for high importance (a factor presumably necessary if perceptions of science as a human activity, driven from human needs, interests, and values, are to be enhanced). One question still to be answered is whether this pilot study provides insight into curriculum improvement that will enhance student perceptions of the nature of science. How can high importance be conveyed and perceptions of the scientific enterprise be enhanced?

Model of Curriculum Design to Enhance Student Perceptions of the Nature of Science

The findings provide a collection of emic perspectives into *interest* and *boredom* , resulting in three proposed tools educators and researchers can use to analyze the effectiveness of science lessons to address high importance and high interest factors. A curriculum model designed to address nature of science perspectives requires a number of criteria.

First, it should include an orientation to the growth of scientific knowledge that incorporates an understanding of the role of theory development (Duschl, 1990), the tentativeness of scientific knowledge (Lederman, 1995; Shamos, 1995), and the problematic nature of experimentation (Collins & Pinch, 1993). Second, it should address the role of sociological factors inherent in scientific decision making; including the influence of values, human interests, and political aspects that influence interpretations (Kelly, Carlsen, & Cunningham, 1993). Third, it should incorporate sociological processes in authentic scientific activities that engage students in roles and decision making representative of practicing scientists; including personal and societal factors, social negotiation, and collaborative decision-making (Cunningham, 1995; Collins & Pinch, 1993; Roth, 1993). Fourth, it should communicate the role of science in society and technology, including the importance of science in democratic decision making (Aikenhead et al., 1989; Hofstein & Yager, 1982).

With the above criteria in mind a number of strategies may be proposed to assist the process of instructional and curriculum design, summarized in the following four-step model.

1. The 4-step Model to Enhance High Importance Perceptions of Science. The 4-steps of this model are: (a) engagement in meaningful, first-hand activities; (b) student accountability for active participation and reflectiveness; (c) identification of factors constituting "high importance" and "high interest"; and (d) in-depth, multiple encounters with the phenomena and processes.

2. The Cyclical Model to assist Sparking High Interest. This model addresses how to "catch" interest by considering first hand occupations with real world objects, people, and experiences. It theorizes that such occupations provide meaning which in turn sparks interest. When the appropriate conditions are present interest is sparked, attention is held, and thought is stirred. If, on the other hand, first hand subject matter is excluded the world of studies becomes a "strange and peculiar" place -- cut off, abstracted from, the real world experiences where human beings live and act. This results in a lack of interest, indifference, or aversion. The power to hold attention is lost and therefore there is a lack of power to stir thought.

3. Change Factors to Hold Interest Long Term. "Holding" interest long term is a major consideration for the learning process, and this tool suggests two key components to increase the likelihood that change factors will "hold" long term: meaningfulness and imagination. The definition of meaningfulness follows along the thinking of Maehr (1984), who found learning experiences are perceived as meaningful only when they are viewed as part of a person's "world"; and Papert (1980), who equated meaningfulness with a cultural "fit". The characterization of imagination is derived from Mitchell's (1992) definition: "An environment which facilitates most students' ability to understand what was previously unknown by using activities to get students emotionally involved with the material" (p. 32).

In Conclusion, this study provided findings that allowed hypotheses about the science attitudes of interest and boredom to be formulated, but its population and scope of study were too limited to generalize beyond the original group of 20. The pilot study provided a variety of situations and activities able to catch student interest and afforded the opportunity to advance tentative instructional strategies, but whether interest was held long term, or whether scientific literacy and/or performance were enhanced, could not be conclusively ascertained. Based on the results of this study it is reasonable to hypothesize that: (a) educators' broadened understanding of student attitudes and perceptions may improve efforts for recruiting students who might otherwise turn away from the pursuit of science, and (b) that various experiential strategies can be successful in catching student interest. While it is beyond the findings whether the effects will hold long term, the implications are that catching and holding interest are central factors to address in the effort to motivate students to learn science and to develop more sophisticated perspectives. The primary implications are to provide a high interest/high importance science curriculum that endeavors to enhance perceptions of the nature of science by incorporating the four steps of high importance, the cyclical model of high interest, and the two change factors of meaningfulness and imagination.

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