Instructional Strategies to Improve Women's Attitudes toward Science

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(ABSTRACT)

Although negative attitudes toward science are common among women and men in undergraduate introductory science classes, women's attitudes toward science tend to be more negative than men's. The reasons for women's negative attitudes toward science include lack of self-confidence, fear of association with social outcasts, lack of women role models in science, and the fundamental differences between traditional scientific and feminist values. Attitudes are psychological constructs theorized to be composed of emotional, cognitive, and behavioral components. Attitudes serve functions, including social expressive, value expressive, utilitarian, and defensive functions, for the people who hold them. To change attitudes, the new attitudes must serve the same function as the old one, and all three components must be treated. Instructional designers can create instructional environments to effect attitude change. In designing instruction to improve women's attitudes toward science, instructional designers should (a) address the emotions that are associated with existing attitudes, (b) involve credible, attractive women role models, and (c) address the functions of the existing attitudes.

Two experimental instructional modules were developed based on these recommendations, and two control modules were developed that were not based on these recommendations. The asynchronous, web-based modules were administered to 281 undergraduate geology and chemistry students at two universities. Attitude assessment revealed that attitudes toward scientists improved significantly more in the experimental group, although there was no significant difference in overall attitudes toward science. Women's attitudes improved significantly more than men's in both the experimental and control groups. Students whose attitudes changed wrote significantly more in journaling activities associated with the modules. Qualitative analysis of journals revealed that the guidelines worked exactly as predicted for some students.

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Introduction and Needs Assessment

The purpose of this document is to describe a research project designed to identify and test instructional techniques for improving women's attitudes toward science. Many universities require students to take one or more introductory science classes regardless of their majors. Teachers of these classes will attest to the prevalence of negative attitudes toward science in many students for whom the class is a general education requirement. Those same teachers will also likely agree that women in introductory science classes suffer especially from negative attitudes toward science.

This document examines the literature related to the state of women in science and their attitudes toward science. Additionally, the history of attitude and attitude change research is reviewed with special emphasis on attitude change and instruction for women. Previous instructional attempts to change attitudes toward science are reviewed. Finally, a synthesis is presented that defines instructional design guidelines for improving women's attitudes toward science.

Following identification of the instructional strategies, a scientific study was conducted to test the effects of their implementation on college students enrolled in introductory science classes. The study and its results are described and analyzed in this document.

Feminism and Science

Science majors and careers are historically male-dominated. Although major advances in diversity have occurred in the past century, women still tend not to choose these fields. The National Science Foundation has determined that the problem is significant enough to fund projects that seek solutions. According to the National Science Foundation, "relatively fewer girls enter undergraduate studies in [science, technology, engineering, and math] disciplines, particularly in physical sciences, computer sciences, and engineering" (2002, p. 5).

Other researchers have pointed out fundamental contradictions in scientific and feminist communities that impede members of either group from gaining or desiring membership in the other (e.g., Damarin, 1991; Koertge, 1998; Pattatucci, 1998; Riley, 1998; Schiebinger, 1999). It is beyond the scope of this document to explore the entire body of research on science and feminism; a short summary of arguments is presented here.

Women and Science

Feminist thought maintains that the scientific method is a masculine way of developing new knowledge because part of its purpose is to remove emotion from the process. A woman who participated in qualitative research on the nature of knowledge said, “What’s missing in science is a whole sort of human element. It doesn’t seem to be infused with any morality. It doesn’t even seem to be a world about people anymore” (Belenky, Clinchy, Goldberger, & Tarule, 1986, p. 71).

Feminist researchers also criticize traditional science for generally assuming that gender is not a variable of consequence, for destroying natural objects to understand them, and for developing technological applications “without regard to destructive consequences” (Damarin, 1991, p. 110). On why men get interested early in the tinkering aspects of computer science, one researcher wrote, “They are fascinated with anything that moves, especially if it has wheels or wings, and, crucially, is not alive” (De Palma, 2001, p. 27). Science has historically been characterized as “rational, untouched by emotion, analytical, and objective” (Weinreich-Haste, 1986, p. 117). People who value emotions and subjectivity (i.e. feminists) do not fit well in the science community. (See the discussion of attitude research for an example of a realm of social science that largely ignores gender differences.)

There also exist contradictions in the concepts of what is feminine and what is scientific, described by Schiebinger (1999). Femininity includes such qualities as nurturing, subjective, private, passive, religious, and loving. Science, on the other hand, is objective, public, aggressive, rational, and cold. It is interesting to note that the modern concept of science and the modern concept of femininity developed at the same time and place (Enlightenment, middle class Europe), suggesting that the oppositeness of the two concepts is not a coincidence. “In defining why women could not do science, complementarians were not defining women so much as what was unscientific" (Schiebinger, 1999, p. 71). (Complementarians were people who saw men and women as complementary, but with completely and inherently different skills, values, and purposes.) "Ideals of masculinity, femininity, and science developed historically, informed by and responding to the economic need to have women serve as household managers and men work outside the home" (Schiebinger, 1999, p. 72).

Attempts have been made to bring feminism and science closer together. Feminists have proposed changes to traditional science that address their criticisms of science. Damarin's (1991) table comparing the values of traditional science with the values of feminist science is reproduced here (Figure 1).

Values inherent in patriarchal science and technology	**Values present in feminist reconstruction of science and technology**
1. A search for a particular understanding of reality above all else, along with a deadening of empathy.	1. A search for and understanding of “reality,” done with compassion and empathy.
2. Scientist outside the domain of study.	2. Scientist in the same critical plane as the object of study.
3. A mastery over nature and a need to exploit it.	3. Harmony with “nature” and a sense of reverence for life.
4. A way of knowing that is rational and objective, with emotion separated from logical thought.	4. A way of knowing that is rational as well as intuitive.
5. A model of reality that is mechanistic, composed on many non-connected elements.	5. A model of “reality” which is holistic and composed of many interconnected elements.
6. Male and female incorporated in “Man.”	6. Gender considered as a variable of consequence.
7. Scientific knowledge in the hands of an elite group, with a great distance between the scientist, the holder of the special knowledge, and society, the consumer of it.	7. Scientific knowledge in the hands of the public.
8. Sense of personal responsibility or concern for the consequences of action set aside while conducting research.	8. Sense of personal responsibility and concern for the consequences of actions determines the parameters and limits of research.

Figure 1. Damarin's (1991) comparison of traditional science and feminist science.

Women in Science

If fields were equally attractive to both men and women, about 50% of degrees awarded in the field would be awarded to women. In 1996, women received 27.5% of the computer science bachelor's degrees, 16% of the engineering bachelor's degrees, 45.7% of the math bachelor's degrees, and 36% of the physical science and science technology bachelor's degrees (National Center for Education Studies, 2000). Of the sciences, only in biology, health professions, psychology, and social science did the percentage of degrees awarded to women approach or exceed 50% (National Center for Education Studies, 2000).

The percentage of bachelor's degrees in computer science awarded to women declined from a high of about 37% in 1985 to about 27% in 1993 (Morell, 1996a). These data are especially disturbing because, unlike other sciences, computer science does not have a centuries-old patriarchal structure. In fact, the field is just over 50 years old, and some of its first professionals were women (Morell, 1996b). During World War II, women computed ballistic trajectories by hand, and were actually called *computers.* These same women were later employed to program and run the first large, general-purpose electronic computer (Morell, 1996b).

Data presented in the journal *Science* show the slow rise in the number of women per year receiving Ph.D.s in engineering and physical science from the late 1950s to the mid 1990s ("Recent data on women and minorities," 1996). In the same period, the number of men earning Ph.D.s in these fields also grew, and at a faster overall rate. The gender gap in Ph.D. recipients in engineering and physical science is not shrinking. In the life sciences, the gap has begun to close, with men earning about 4500 Ph.D.s to women's about 3250 in 1994. In social sciences as a whole (including the still male-dominated fields of economics and geography), women and men earned about the same number of Ph.D.s in 1994.

Although larger numbers of women than men enroll in 4-year institutions, only 19% of the undergraduates enrolled in engineering programs were women (National

Science Foundation, 2000). Data from engineering programs are used as indicators because these programs typically require students to declare majors in their first year.

Social sciences, especially psychology, anthropology, and sociology, have little trouble attracting women. In 1994, more than half of the Ph.D.s awarded in these subjects were awarded to women, and about 65% of the clinical and counseling psychology Ph.D.s went to women (Holden, 1996). In fact, the high numbers of women in psychology has corresponded with a decline in prestige for the field (Holden, 1996).

Sax (1994) conducted a massive factor analysis to identify correlations between various factors and persistence of undergraduates toward science careers. She separated factors into three groups. Input variables are factors the students possess when they get to college. Environmental variables are factors related to their home and work environment during college. The third group, involvement variables, is most interesting to instructional designers because these variables pertain to the instructional environment the students encounter during college. Of all the involvement variables identified, women's persistence toward science careers correlated positively with only three: the number of science courses taken, the number of math/numerical courses taken, and whether they worked on a professor's research. The first two factors are likely artifacts of the study; naturally, people who were still pursuing a science degree would have taken more science and math courses. The third, however, suggests the importance of mentoring relationships. "Given the male-dominated and often impersonal nature of science fields, getting hands-on research experience, as well as guidance from a professor, may be invaluable in retaining women within science" (Sax, 1994).

Hill, Pettus, and Hedin (1990) identified and tested factors that might predict students' pursuit of science and science-related careers. The factors included interest, enrollment in science courses, achievement, anxiety, personality factors, the image of science, social barriers, role models, teacher encouragement, early career aspirations, and biological factors. They found that girls lacked interest in science, and hypothesized that science's masculine image as well as sex stereotyping and social pressures caused the lack of interest. They also found that "personal acquaintance with a scientist is the major contributing factor to pursuing a career in science" (Hill et al., 1990, p. 302).

In conclusion, science and science-related majors and fields, in general, attract many more men than women. Although there are many interconnected and complicated reasons for this state of affairs, one component is assumed to be women's attitudes toward science.

Attitudes toward Science

Previous quantitative and qualitative research has focused on students' attitudes toward science and related subjects at all levels. As the research cited next demonstrates, girls and young women tend to have negative attitudes toward science fields and careers.

Many research studies have found that as children get older, their attitudes toward science and math grow less positive (Chouinard, Vezeau, Bouffard, & Jenkins, 1999; Kaiser-Messmer, 1993; National Center for Education Studies, 2000; Terwilliger & Titus, 1995). Although attitudes decline for both boys and girls, most research has found that the decline is more pronounced in girls than in boys (National Center for Education Studies, 2000). The trend is the same for mathematically talented children (Terwilliger & Titus, 1995).

By twelfth grade, a marked difference between girls' and boys' attitudes toward science and math occurs. In a national study, the percentage of fourth-grade girls who agreed that they "liked math" and "liked science" was within 2% of the percentage of boys who also agreed with the statements. The difference between twelfth grade boys' and girls' responses to the same survey was 8% (National Center for Education Studies, 2000). The trend continued as students became young men and women choosing college majors and careers. As the gender gap in attitudes grew, so did the gap in achievement (National Center for Education Studies, 2000). A 1993 study (Kaiser-Messmer) found high school age girls were less likely than boys to (a) be interested in math, (b) think it important to achieve in math, and (c) consider a math career.

Sexton (1991) studied the factors that predicted a positive attitude toward science in high school juniors. She found that girls with a high grade point average, an internal locus of control, and androgynous characteristics (as measured by the Bem Sex-Role Inventory) were more likely to exhibit a positive attitude toward science. She also found that girls with positive attitudes toward science came from schools that nurture these traits (Sexton, 1991).

A descriptive study compared the attitudes toward science, as measured by the Test of Science Related Attitudes (TOSRA), of gifted boys and girls in high schools across the United States (Smist, Archambault, & Owen, 1994). The researchers found that boys had more positive attitudes than girls on subscales related to science careers, leisure interest, and science classes. Girls had more positive attitudes than boys on scales related to the normality of scientists and being open to new ideas. There was no significant difference between girls and boys in subscales related to preference for doing experiments and the social value of science.

Attitudes toward science are similar to attitudes toward computer science. Girls in a focus group study were aware of the differences between their own and boys' interactions with computers (AAUW Educational Foundation, 2000). The girls were quick to point out that they were just as able to work with computers as boys were; however, they were still not interested in computer careers. Researchers called it the "'we can, but I don't want to' philosophy" (p. 7). Girls in the study tended to see computers as tools to use to attain goals, rather than as intrinsically motivating. They stereotyped "computer people" as male and anti-social. The researchers pointed to the masculine worldview of computers that made women feel that they "need to choose between the cultural associations of 'femininity' and those of 'computers.'"

Belenky, Clinchy, Goldberger, and Tarule (1986) conducted a famous qualitative research study titled *Women's Ways of Knowing*. Women they interviewed offered their comments on science and scientific research that represent some of women's problems with science as a way of knowing.

> I'm having a hard time with the premise that truth is scientific knowledge, because for me it isn't that at all. For me, truth is internal knowledge. I don't think we need scientific methods to ascertain what's right at all. I

think we need internal exploration and knowledge of self to know what's right and what is true. (Belenky et al., 1986, p. 71-72)

I think women have been cowed by science. We've been told, 'That's unlogical, that's unscientific. Anything you can't prove is not worth talking about.' They're saying if you can't prove your sensations, you don't got 'em. Our society is trying to suppress the senses in favor of what goes on from the eyes up. That's so destructive. (Belenky et al., 1986, p. 72)

In a different approach to determining students' attitudes toward science and scientists, researchers ask students to draw scientists. Their drawings can be analyzed to determine the qualities students equate with scientists and science and to identify positive and negative stereotypes of scientists. Matthews (1996) asked 110 British secondary school students to draw two scientists. Of the drawings where sex was identifiable, 44% were of two males, 44% were of one male and one female, and 13% were of two females. More boys than girls drew two-male pictures. More girls than boys drew male-female and two-female pictures. Scientists were represented doing a variety of laboratory activities. None were drawn outside. Several were drawn as mad scientists, and many were drawn with lab coats and glasses or goggles. One scientist was making a bomb; another was about to inject a sad-looking rabbit. Some were portrayed as teachers. This research points to ongoing negative stereotypes about science and scientists.

Reasons for Women's Attitudes toward Science

Research and theory have suggested a number of reasons why women hold negative attitudes toward science, including its masculine image, stereotypes of anti-social behavior, women's lack of self-confidence, and the perception of irrelevance of science to women.

Science fields have a masculine image, which is exacerbated by the lack of women role models as professors. This perceived masculinity of science disciplines forces women to feel that they must choose between the fields and femininity (AAUW

Educational Foundation, 2000; Adhikari, Givant, & Nolan, 1997; Belenky et al., 1986; Meyer & Koehler, 1990). In computer science, many young men become interested in the field through computer games, and critics complain that many computer games are so violent and misogynistic that girls do not want to play them (e.g., Morell, 1996a).

Science community members are stereotyped as "nerds" or lacking social skills (AAUW Educational Foundation, 2000; Matthews, 1996). Women tend to value personal relationships and nurturing activities (Holden, 1996). Many science careers actually involve extensive collaborative work. However, long-standing stereotypes of solitary scientists have not yet been replaced by generalizations of scientists working cooperatively and collaboratively.

Women lack self-confidence in science fields. A number of research studies have pointed to girls and women's lack of self confidence in science and related fields, especially math (Adhikari et al., 1997; Adhikari & Nolan, 1997; Libarkin & Kurdziel, 2003; Meyer & Koehler, 1990). A math student in a qualitative study talked about the different ways a male and female classmate of hers reacted to their work (Adhikari & Nolan, 1997).

> Both of them were good, but their attitudes toward their work … [were] very different. When responding to questions, the man was quick to answer and confident of his response, right or wrong. The woman, a year his senior in schooling, was less confident in her abilities. Her responses were phrased more like questions than answers, and she worried that, despite her work, our professor was disappointed in her performance. Their relative levels of self-confidence had an insidious effect on me. While I believed that all three of us were competent, when asked who understood the most math and was making the most progress, I was convinced that it was the male student. (p. 22)

Science and related fields are perceived as not relevant or useful to women. Middle school girls were interviewed about their reasons for declining interest in math (Brush, 1985). They found advanced math irrelevant to their future lives. The girls talked of using math for budgets, balancing checkbooks, shopping, and income taxes; they did not talk of using math in a career. Kaiser-Messmer found similar results in her 1993 study. Only those fields in social science that are distinctly people-oriented have no trouble attracting women, because, as Catherine Didion of the Association for Women in Science put it, “We still very much see ourselves as ‘nurturers’” (quoted in Holden, 1996, p. 1919).

The research cited above demonstrates the prevalence of negative attitudes toward science, and outlines some of the issues facing teachers who hope to improve women’s attitudes toward science. The next section will clarify terminology for the purposes of the present research. That section is followed by a discussion of the theoretical underpinnings of attitude and attitudes in instructional design.

Definitions

The following terms are defined below for the purposes of this research: *attitudes*, *science*, *attitude toward science*, *instructional design*, *persuasion*, and *the affective domain*.

Attitudes

The definition of attitude depends on the purpose of the definition. Most attitude researchers include the concept of evaluation as the basis for the definition (e.g., Bohner & Wanke, 2002; Eagly & Chaiken, 1993). For example, attitudes are “general evaluations people hold in regard for themselves, other people, objects, and issues” (Petty & Cacioppo, 1986, p. 127). Instructional designers tend to add to this basic definition references to the emotional, cognitive, and psychomotor components of attitudes (e.g., Bednar & Levie, 1993; Dick, Carey, & Carey, 2001; Driscoll, 2000; Kamradt & Kamradt, 1999). This addition helps attitude instruction fit in the paradigm of instructional design.

For the purposes of the present research, the instructional design definition is used. *Attitude* is defined as a psychological tendency to evaluate an entity, and which is composed of emotional, cognitive, and behavioral (or psychomotor) components.

The emotional component of attitudes relates to the basic feelings and emotions associated with the attitude object, including those such as sadness, frustration, happiness, and anger. The cognitive component of attitudes relates to beliefs associated with the attitude object. The behavioral component relates to behaviors associated with the attitude object.

The attitude object can be an object, a person, an idea, another attitude, or anything else a noun describes. The terms *target*, *object*, and *attitude object* are used interchangeably in this research.

Science

Science can be defined as a way of thinking or a body of knowledge. For the purposes of this research, the word *science* is principally concerned with the fields of earth and life sciences, such as biology, chemistry, geology, and physics, because these are the subjects typically required by colleges to satisfy “science” general education requirements. In this study, social sciences, such as psychology, geography, and economics, are not included in the definition.

Attitude toward Science

The definition of *attitude toward science* depends inherently on the method for measuring it. For this research, the Fraser’s (1981) Test of Science-Related Attitudes (TOSRA) will be used for measuring attitudes; therefore, the definition is based on the rationale for the test. Attitude toward science is based on seven components: the normality of scientists, social implications of science, attitude toward inquiry, scientific attitudes, enjoyment of science classes, leisure interest in science, and career interest in science.

Instructional Design

Instructional design is the process of assessing instructional needs, and then designing, developing, implementing, and evaluating the instruction (Gustafson &

Branch, 2002). Specific instructional design problems may be approached in slightly different ways, depending on the constraints of the problem.

Persuasion

Persuasion is an attitude change technique that is based solely on the presentation of facts and not on the emotional and psychomotor components of attitudes. It is commonly used in marketing and political campaigns (Petty & Cacioppo, 1986).

Affective Domain

The affective domain is one of three domains commonly delineated in instructional design research (e.g., Dick et al., 2001; Gagne, 1985). The other two are the cognitive and psychomotor domains. The cognitive domain includes knowledge and cognitive strategies. For example, the knowledge of theorems and techniques for solving mathematical problems are part of the cognitive domain. The psychomotor (or behavioral) domain includes physical skills. For example, dancing, running, titrating, and using a wrench would be considered part of the psychomotor domain.

The affective domain includes “attitudes, values, ethics, morals, and the self-esteem of learners” (Martin & Briggs, 1986, p. x). Some researchers also include motivation in the affective domain (Krathwohl, Bloom, & Masia, 1964). Recent research has pointed to the importance of affective education in developing good citizens and productive adults (Martin & Reigeluth, 1999).

Some researchers use the words *emotional* and *affective* interchangeably when they refer to the emotional component of attitude. Given the broader definition of the affective domain described above, this author finds the two uses of the word *affective* confusing. For the purpose of this research, the third component of attitude will be called the *emotional* component to differentiate between the two meanings.

Attitudes

In the greater realm of social psychology, attitudes are typically classified with the affective domain, and are part of the larger concept of motivation (Greenwald, 1989d). Attitudes are connected to Bandura's (1977) social cognitive learning theory as one of the personal factors that affect learning.

Attitudes have been a favorite topic for social psychology work since the beginning of the twentieth century. Their importance was summarized by comments made by Anthony Greenwald (1989b), who stated that attitudes are pervasive, they predict behavior, they are a force in perception and memory, and they serve various psychological functions.

There is ongoing debate about the structure of attitudes. Attitudes have long been assumed by instructional designers to be made up of three components: a cognitive component, an emotional component, and a behavioral component (e.g., Bednar & Levie, 1993; Fishbein & Ajzen, 1975; Kamradt & Kamradt, 1999). While not all attitude theorists agree that every attitude has all three components, researchers do generally agree that attitudes can be expressed by cognitive, emotional, and/or behavioral responses (Bohner & Wanke, 2002; Eagly & Chaiken, 1993; Greenwald, 1989a, 1989c). Some argue that attitudes are "based on behavioral, [emotional], and cognitive experiences *and* are capable of influencing or guiding behavioral, [emotional], and cognitive processes" (Petty & Cacioppo, 1986, p. 127, italics added). (In the quotation above, the word *emotional* was substituted for the word *affective*. See the discussion on the difference between these words under the Definitions heading.)

The debate on the existence of the three-component structure of attitude may never be completely resolved because attitudes are constructs, and are therefore not directly observable. Instead, they are typically measured with some combination of cognitive, affective, and behavioral responses.

Most often, participants in attitude research studies are asked to respond to Likert-type or semantic differential questionnaires that require people to process information (cognitive) about their thoughts (cognitive), feelings (emotional), and actions (behavioral), and make a selection (a behavior) based on that information. In an interesting attempt to prevent confounding measurements of attitude, some researchers have attempted to isolate emotional responses with complex physiological monitoring devices to measure facial muscle movements (Cacioppo, Petty, & Geen, 1989). Regardless of their "actual" structure, attitudes are measured by behaviors that typically are based on cognitive or emotional foundations.

Attitude-Behavior Connection

The measurement of attitudes is inextricably tangled with theoretical debate on the nature of attitudes. The very concept of attitude is a construct, so conceived to help social psychologists make sense of their world. Social psychologists noticed that people respond to objects (or ideas) with different degrees of positive to negative evaluations. Responses could be affective (e.g., smiling), cognitive (e.g., stating rational thoughts), or behavioral (e.g., running away). Social psychologists conceived of a driving force behind these responses, and named it "attitude." They proceeded to measure attitude by measuring what they conceived to be the effects of it. It is important to note that all responses are, technically, behaviors (Ajzen, 1989).

As Ostrom (1989) pointed out, there are inherent differences between measured attitudes and the naturally expressed attitudes that are actually important to the attitude researcher. In attitude measurement, people are usually asked to indicate or state their attitudes. In natural settings, attitudes are aroused spontaneously. Most attitude measures focus solely on the degree to which the attitude is positive or negative. Natural attitudes can be neutral, and also vary in intensity, salience, complexity, flexibility, and consciousness.

The difference between measured and naturally expressed attitudes brings up an important assumption in attitude and attitude change research. If a measured attitude is changed, will behavior related to the attitude also necessarily change? More specifically, if women's attitudes toward science improve, will the women's behaviors in the science classroom also change? Will they choose science careers?

The earliest attitude research at the beginning of the twentieth century was based on the explicit assumption that attitudes were predictors of behaviors. Then LaPiere's 1934 study of hotel and restaurant owners' willingness to serve Asian guests called the assumption into question. LaPiere traveled the country with a Chinese couple. Of the 251 restaurants and hotels at which they stopped, only one refused service to the Chinese couple. Later, LaPiere sent an attitude survey to the same business owners. A surprising 92% of the survey respondents indicated that they would *not* serve Asian customers. LaPiere concluded that attitudes did not predict behaviors, and the debate began.

Over the next few decades a number of studies found inconclusive relationships between attitude and behavior, adding to criticism of the assumption that attitudes predict behaviors (Eagly & Chaiken, 1993). An extensive literature review in 1969 (Wicker) presented the strongest evidence against the assumption that attitudes predict behaviors.

Wicker reviewed, directly or indirectly, 46 empirical studies of the relationship between attitude and behavior. A three-page table in his report summarizes the studies and lists the relationship strengths found in each study. Correlations between attitude and behavior range from -.21 to .68, with many between zero and .50. Wicker's conclusions were particularly damning to the attitude-behavior relationship assumption. "Taken as a whole, these studies suggest that it is considerably more likely that attitudes will be unrelated or only slightly related to overt behaviors than that attitudes will be closely related to action" (Wicker, 1969, p. 65). "The assumption that feelings are directly translated into actions has not been demonstrated" (Wicker, 1969, p. 75).

Wicker suggested that the attitude-behavior relationship was not direct, but was instead mediated by personal and situational factors. He called for more research into theoretical constructs that could explain the discrepancy. He mentioned the work of Martin Fishbein, who was in the early stages of developing just such a theoretical construct.

Although several previous studies had questioned the attitude-behavior relationship, Wicker's 1969 article attracted much attention in the social psychology world because it covered so many empirical studies that found weak attitude-behavior connections (Eagly & Chaiken, 1993) and issued such scathing criticism of those studies.

Immediately following Wicker's article, criticisms of his research were published, along with new studies of the attitude-behavior connection. Scholars criticized Wicker's work because it focused only on studies conducted in controlled laboratory settings. Also, later research found that the "magnitude of these correlations [between attitude and behavior] varies systematically with the characteristics of the measuring instruments" (Eagly & Chaiken, 1993, p. 158). Attempts were made to develop a theoretical structure that would explain the variation in findings related to the attitude-behavior connection.

Notably, the young researcher whose work Wicker had praised came to the forefront of the debate, and remained there for at least the next three decades. Martin Fishbein and his colleague Icek Ajzen (1972; 1974; 1975) quickly found that although attitudes may not predict specific behaviors, they were, in fact, very good predictors of ranges of behaviors related to the attitude object. "Although a person's attitude toward an object should be related to the totality of his [or her] behaviors with respect to the object, it is not necessarily related to any given behavior" (Fishbein & Ajzen, 1975, p. 335).

Fishbein and Ajzen (1972; 1974; 1975) made important distinctions between attitudes, beliefs, and behavioral intentions. Attitudes relate to the favorability or unfavorability of the object. Beliefs are cognitions that offer support for attitudes. Behavioral intentions are "the subject's indication of his [or her] willingness to engage in various behaviors" (Fishbein & Ajzen, 1972, p. 495). Behaviors are actual measurable actions.

Fishbein and Ajzen (1975) argued that behaviors are not directly determined by attitudes, as was previously assumed, but by behavioral intentions. The links among attitudes, beliefs, behavioral intentions, and behaviors were complex and affected by other factors such as what others think about behaviors, the magnitude of influence of social pressures, and numerous external factors such as age, sex, religion, education, and personality traits. Fishbein and Ajzen's theory came to be called the theory of reasoned action.

Essentially, beliefs form the foundation of the attitude toward a specific behavior. These beliefs may be evaluative in nature and may include attitudes toward larger entities related to the behavior or attitudes toward outcomes of the behavior. A second set of beliefs corresponds to how others perceive the behavior, and the motivation one feels to comply with those others. These combine to form what Fishbein and Ajzen called the subjective norm, and could be explained as social pressures. The subjective norm and the attitude toward the behavior work together (with different relative importance) to determine one's intention to perform the behavior. This intention predicts the behavior. A concept map of the model is shown in Figure 2.

To illustrate, a woman's attitude toward the behavior of taking a science class is probably mediated by her belief that science is inherently a good thing. She may also believe that outcomes of taking a science class will include a lot of homework (bad outcome), a lot of difficult math (bad outcome), feelings of not being able to do math (bad outcome), and helping her finish her college degree (good outcome). These beliefs combine to form her attitude towards the behavior. She may perceive that her parents would approve, her grandparents and one significant friend would not approve, her mentor would strongly approve, and her boyfriend would be indifferent to her taking the class. She would weigh these opinions according to how much they mattered to her to create the subjective norm. She would then combine her attitude toward taking the class with her subjective norm to determine whether she intends to take the science class.

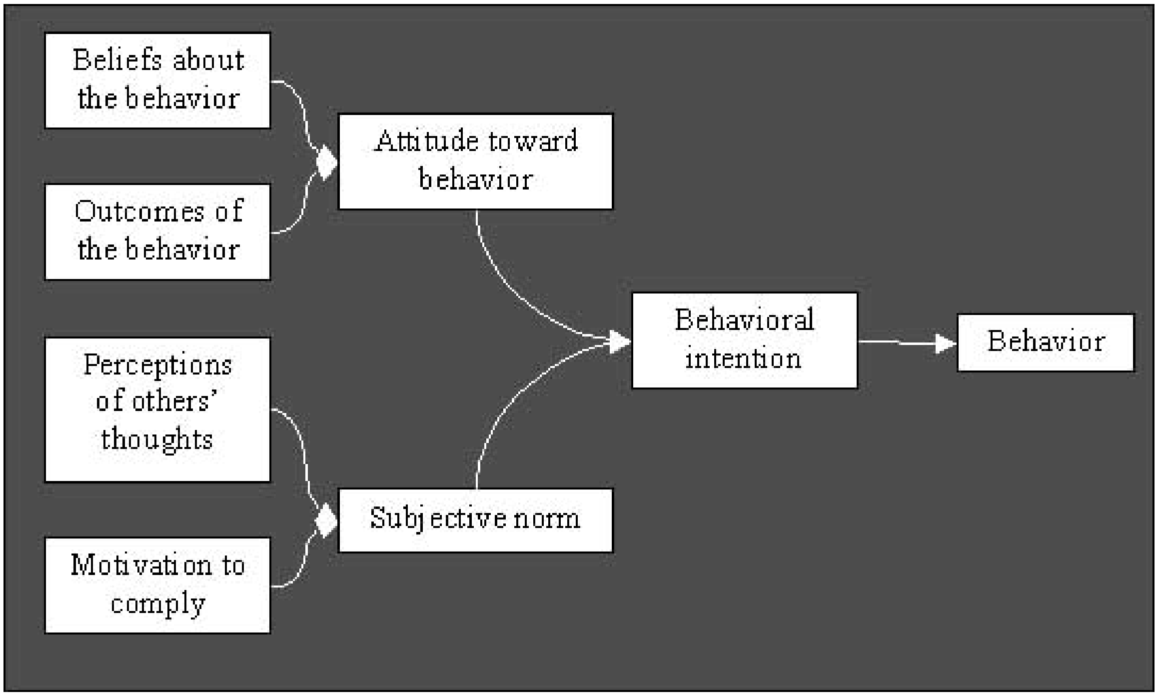

Figure 2. Concept map of the theory of reasoned action (after Fishbein & Ajzen, 1975).

The evolution of the definition of *attitude* played an important role in the attitude-behavior connection debate. Wicker's conclusion that "The assumption that *feelings* are directly translated into action has not been demonstrated" (1969, p. 75, italics added) reveals that his definition of attitude is primarily concerned with the emotional component. Although Fishbein and Ajzen's later work still equated attitudes with emotions, their work on the relationship between emotions, cognitions, and behaviors eventually led to the development of the current definition of attitudes that includes all three components.

Functional Attitude Theories

Early in the development of attitude theories, the concept of attitude function was introduced. The basic assumption of these theories is that people hold attitudes to fill certain psychological needs. Early researchers such as Katz (1960), Smith, Bruner, and White (1956), and Kelman (1958) developed attitude theories that described the various functions of attitudes. These theoretical approaches were criticized because of the difficulty of empirically testing them (e.g., Herek, 1986), and fell out of favor until the mid-1980s. A later generation of researchers (Herek, 1986; Shavitt, 1989, 1990) refined and combined the theories, developed methods for testing them empirically, and determined their relationships to other realms of social psychology research. The research contributions of Katz, Smith et al., Kelman, Herek, and Shavitt are described next.

Daniel Katz. Katz's paper on the functional approach to attitude change (1960) is one of the foundations for functional attitude theory. According to the theory, attitudes are formed and changed to serve four major psychological functions: utilitarian, ego-defensive, value-expressive, and knowledge. The first class, called adjustment or utilitarian function, refers to the need to receive rewards and to avoid punishments. Attitudes are formed and modified to elicit maximum benefit.

The second function Katz described is the ego-defensive function. This reason for forming and modifying attitudes helps people to "live with themselves" (Katz, 1960, p. 172). Ego-defensive functions allow people to defend their self-images through processes of denial, avoidance, rationalization, projection, and displacement of their dissatisfaction. Katz and his colleagues conducted several experiments on ego-defensive functions of attitudes (e.g., Katz, McClintock, & Sarnoff, 1957; Katz, Sarnoff, & McClintock, 1956)

The third function is the value-expressive function. These attitudes are expressed to exhibit one's values or self-concept. People derive satisfaction with expressing attitudes that are compatible with their value system.

The fourth function Katz described is the knowledge function. People have a need to bring order to the chaos of their environment, and knowledge fills that need. Attitudes based on the knowledge function require information about the attitude object. Later research suggested that the knowledge function underlies all attitudes (Shavitt, 1990).

Brewster Smith, Jerome Bruner, and Robert White. After a lengthy qualitative study of ten men's attitudes toward Russia, Smith, Bruner, and White (1956) delineated three attitude functions strongly influenced by Freudian psychology: object appraisal, social adjustment, and externalization. Object appraisal, which correlates generally to

Katz's (1960) utilitarian function, was described as "the process of testing reality in order to access its relevance to one's ongoing enterprises" (p. 261). Social adjustment attitudes "play a part in maintaining relationships with other people" (p. 266). Externalization is the process whereby "a person has responded to an external event in a way that is colored by unresolved inner problems" (p. 271). This function correlates with Katz's (1960) ego-defensive function.

Herbert Kelman. Kelman (1958) identified three functions that he called "processes of influence" (p. 53): compliance, identification, and internalization. He described the functions as being at different levels, and communicated that ideal attitude change occurs at the internalization level. At the compliance level, attitude change occurs as a result of rewards or punishments associated with behaviors related to the attitude. This level is analogous to utilitarian and object appraisal functions described by other theorists (Katz, 1960; M. B. Smith et al., 1956). Attitude changes of this type remain only as long as the rewards or punishments stay the same. At the identification level, attitude change occurs as a result of an individual's desire to identify with another person or social group. The social adjustment function outlined by Smith et al. in 1956 corresponds to the identification level. At the internalization level, attitude change occurs because the new attitude better matches the individual's internal value system. Internalization is parallel to the value-expressive function described earlier (M. B. Smith et al., 1956). This is the most desired class of attitude change because it is assumed to be the most lasting.

Gregory Herek. The second generation of functional attitude research began in the mid 1980s with Herek's "neofunctional" attitude theory (1986). Herek proposed that attitudes are divided into two basic categories: evaluative and expressive. The groups are differentiated by the source of pleasure, reward, or benefit for holding the attitude. Benefits of evaluative (or instrumental) attitudes are derived directly from the attitude object. Benefits of expressive (or symbolic) attitudes are derived from the expression of the attitude.

Herek (1986) defined three groups of evaluative attitudes. The first group, "experiential and specific" (p. 105), includes those attitudes formed toward an attitude object from direct experience with that object. The second group, “experiential and schematic” (p. 105), includes those attitudes formed toward a group from generalized experience with an object that is perceived to be a member of the group. The third group of evaluative attitude is not based on direct experience, but on “expected future utility” (p. 105).

Herek (1986) also defined three types of expressive attitudes. Social-expressive attitudes are “based on needs to be accepted by others in one’s own immediate social environment” (p. 106). Value-expressive attitudes are “based on needs to define oneself by expressing important values and aligning oneself with important reference groups” (p. 106). Defensive attitudes are “based on needs to reduce anxiety caused by intrapsychic conflicts, usually unconscious” (p. 106).

Herek (1986) maintained that a single attitude can have both evaluative and expressive functions to different degrees. If a large benefit comes directly from the object and a small benefit comes from the expression of the attitude, the attitude is primarily evaluative. If a small benefit comes from the object and a large benefit comes from the expression of the attitude, the attitude is primarily expressive. If large benefits come from both sources, the attitude has a complex function. If small benefits come from both sources, the attitude is “nonfunctional” (p. 106).

Sharon Shavitt. Sharon Shavitt (1990) proposed a slightly different organizational scheme for attitude functions that incorporates most previous delineations. She grouped attitude functions into the three categories of utilitarian, social identity, and self-esteem maintenance. She also suggested that all attitudes fit Daniel Katz’s knowledge function category, because all attitudes help people understand the world around them. Other researchers have grouped knowledge function attitudes with utilitarian functions (Eagly & Chaiken, 1993). When attitudes had been clarified in this way, new research focused on how attitudes change. That research is summarized next.

A comparison chart of the different attitude function theories showing roughly equivalent terminology is presented in Figure 3. Herek’s designations will be used for the present research.

<table>
<tr><th>Smith et al.</th><th>Kelman</th><th>Katz</th><th>Herek</th><th colspan="2">Shavitt</th></tr>
<tr><td>Object appraisal</td><td>Compliance</td><td>Utilitarian</td><td>Evaluative</td><td>Utilitarian</td><td rowspan="4">Knowledge</td></tr>
<tr><td>Social adjustment</td><td>Identification</td><td></td><td>Social expressive</td><td>Social identity</td></tr>
<tr><td></td><td rowspan="2">Internalization</td><td>Value expressive</td><td>Value expressive</td><td rowspan="2">Self-esteem maintenance</td></tr>
<tr><td>Externalization</td><td>Ego defensive</td><td>Defensive</td></tr>
<tr><td></td><td></td><td>Knowledge</td><td></td><td colspan="2"></td></tr>
</table>

Figure 3. Comparison of attitude function terminology.

Attitude Change

Theory

With the renewal of attitude research in the 1980s came a new theory (Petty & Cacioppo, 1986) that sought to explain many of the contradictions in the field to that point. In 1986, there was not universal agreement on the roles that functions and other variables play. Also, “nearly every independent variable studied increased persuasion in some situations, had no effect in others, and decreased persuasion in still other contexts” (Petty & Cacioppo, 1986, p. 125).

The Elaboration Likelihood Model (ELM) was a major theoretical step in persuasion research. Petty and Cacioppo’s (1986) theory integrated many aspects of attitude research, including the attitude-behavior connection and functional attitude theory. Their seven postulates served as the foundation for a spate of attitude change and persuasion research in the late 1980s and 1990s. The theory is still important in current research.

Petty and Cacioppo (1986) noticed that changed attitudes seemed to stay changed better if people thought about their reason for attitude change rather than basing their new opinions on less important factors such as their mood when the persuasion occurred or the attractiveness of the source of the counter-attitudinal message. They separated attitude change factors into central process factors (rational thought) and peripheral factors (mood, source, etc.). Attitude change that occurred through the central route was assumed superior to attitude change that occurred through peripheral routes. A schematic diagram of the Elaboration Likelihood Model is presented in Figure 4.

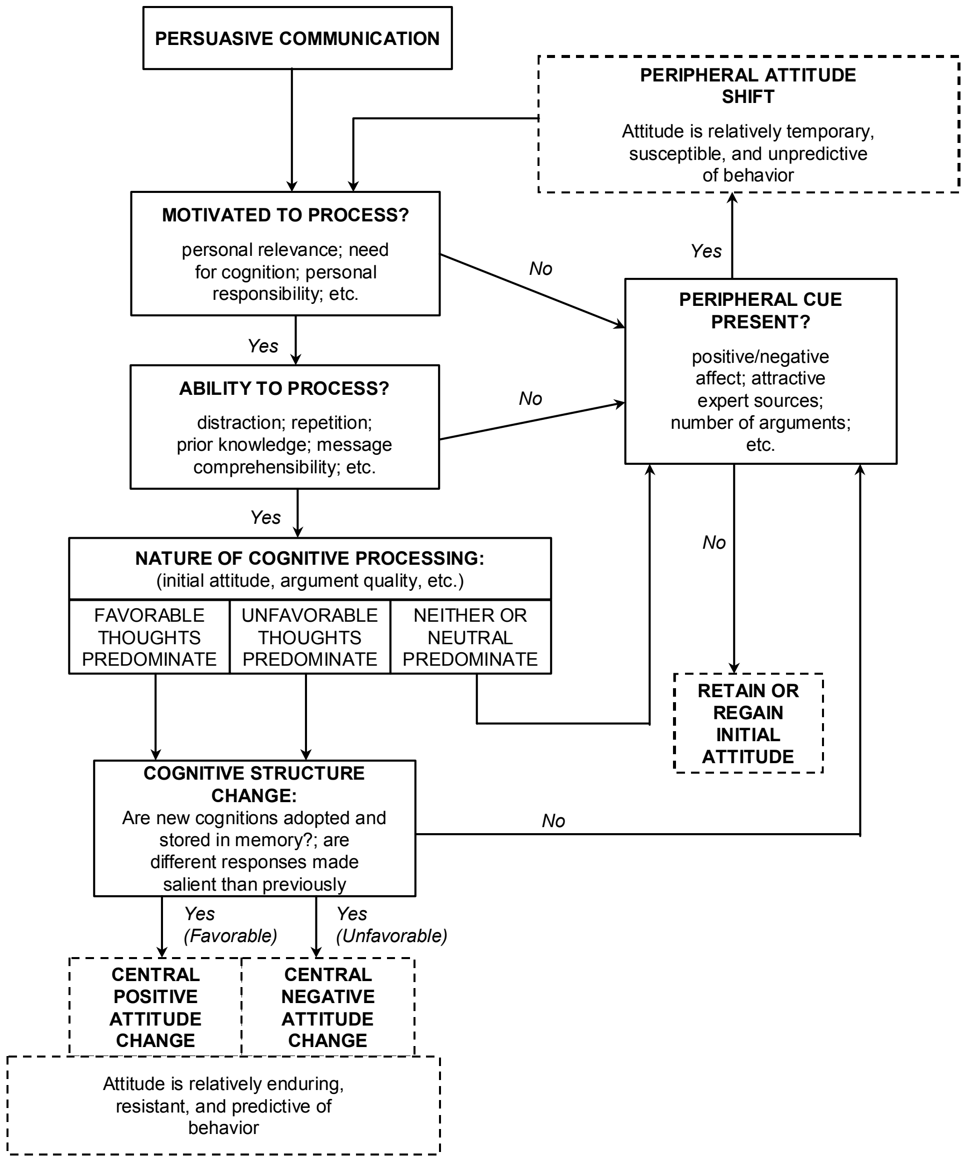

Figure 4. The Elaboration Likelihood Model. Reprinted from Advances in Experimental Social Psychology, Vol 19, Richard E. Petty & John T. Cacioppo, The Elaboration Likelihood Model of Persuasion, pages 123-205, Copyright (1986), with permission from Elsevier.

Their model suggested that attitude change is controlled by the likelihood of the target audience to elaborate on (or think about) the new attitude. Their model is based on seven postulates.

1. People are motivated to hold correct attitudes.
2. Although people want to hold correct attitudes, the amount and nature of issue-relevant elaboration in which people are willing or able to engage to evaluate a message vary with individual and situational factors.
3. Variables can affect the amount and direction of attitude change by (a) serving as persuasive arguments, (b) serving as peripheral cues, and/or (c) affecting the extent or direction of issue and argument elaboration.
4. Variables affecting motivation and/or ability to process a message in a relatively objective manner can do so by either enhancing or reducing argument scrutiny.
5. As motivation and/or ability to process arguments is decreased, peripheral cues become relatively more important determinants of persuasion. Conversely, as argument scrutiny is increased, peripheral cues become relatively less important determinants of persuasion.
6. Variables affecting message processing in a relatively biased manner can produce either a positive (favorable) or negative (unfavorable) motivational and/or ability bias to the issue-relevant thoughts attempted.
7. Attitude changes that result mostly from processing issue-relevant arguments (central route) will show greater temporal persistence, greater prediction of behavior, and greater resistance to counterpersuasion than attitude changes that result mostly from peripheral cues.

Attitude Change Research

The model's focus on variables suggested that attitude change could be controlled by controlling some of the variables. The Elaboration Likelihood Model attracted attention from attitude function researchers because it mentioned the variables that affect attitude change. Five classes of variables can be identified that interact to cause attitude change. These are characteristics of:

1. the learner (need for cognition, need for social acceptance, need for self-acceptance).
2. the existing attitude (function, intensity, domain),
3. the source (familiarity, likeability, attractiveness) of the new attitude,
4. the message (strength), and
5. the attitude object (likely value).

The following paragraphs describe the studies of a number of researchers who have investigated these variables and the interactions among them to determine how they relate to attitude change.

Learner characteristics. A number of persuasion researchers have identified and tested a quality known as self-monitoring. Researchers noticed that some people's attitudes were primarily driven by their need for social acceptance (high self-monitors), while others' seemed to be driven by their personal values (low self-monitors). Research has shown that the degree of self-monitoring is a factor in attitude change (DeBono & Rubin, 1995). DeBono and Rubin (1995) asked participants in a study to evaluate cheese. The researchers led participants to believe that the cheese was from either Kansas or France, and also varied the taste of the cheese (pleasant or not). Before conducting the research, they determined whether each subject was a high or low self-monitor. High self-monitors tended to rate higher the cheese they believed was from France. Low self-monitors tended to rate higher the cheese that tasted good. DeBono and Rubin found that the person characteristic of self-monitoring affects the attitude function.

Maio and Olson (2000) tested the relationship between participants' attitude toward a (fictitious) dance to raise money for the construction of an enclosed smoking lounge on campus and the willingness to write an essay based on the attitude. The researchers found an interaction between behavioral intention and self-monitoring. In the study, low self-monitors (high value-expressive people) were significantly more likely to agree to write an essay in agreement with their attitude about the dance and its purpose. This research lends a new facet to the attitude-behavior connection. Only some of the people with positive or negative attitudes about the dance were willing to write essays (behavior). However, the behavior is easily construed as value-expressive because it asks participants, essentially, to state their values. The conclusion can be made that behaviors that correspond to the attitude function are more likely to correspond to the nature of the attitude.

A number of other studies, described in more detail below, included self-monitoring as a factor (DeBono, 1987; DeBono & Rubin, 1995; Lavine & Snyder, 1996; Petty & Wegener, 1998). The concept of self-monitoring is especially important for the purposes of the present research because it allows the researcher to know whether a person's attitudes are more likely to serve social identity functions (high self-monitors) or value expressive functions (low self-monitors) without specifically activating the attitude to be changed. The basic concept of functional attitude change is that in order to change someone's attitude toward an object, one must match persuasive efforts to the function the existing attitude serves. A test of self-monitoring allows for a more efficient method for making educated guesses at attitude functions.

Research has shown that matching attitude change techniques to attitude function in the target audience has an effect on the acceptance of the message (e.g., Clary, Snyder, Ridge, Miene, & Haugen, 1994; DeBono, 1987; DeBono & Harnish, 1988; DeBono & Telesca, 1990; Lavine & Snyder, 1996). Most of these studies found that matching techniques to attitude function causes greater acceptance of the message; however, several studies found interactions between function matching and other variables (DeBono, 1987; DeBono & Harnish, 1988; Lavine & Snyder, 1996; Petty & Wegener, 1998).

Existing attitude variables. Existing attitudes vary in their function, intensity, and domain. An attitude, as described previously, can serve social expressive, defensive, value-expressive, or evaluative functions, or some combination of these. Attitudes also vary in intensity; an attitude can fall anywhere on the evaluative continuum between strongly positive and strongly negative. Finally, as described in the introduction to this section, attitudes are made up of cognitive, behavioral, and emotional components.

Researchers have studied all of these factors, and their interactions, as they relate to attitude change.

Millar and Tesser (1986) tested how emotional and cognitive evaluative thoughts about attitude objects (puzzles) affected behaviors. Participants were given puzzles and asked to write what they thought (cognitive) *or* how they felt (emotional) about the puzzles. Later the participants answered Likert scales related to both the likeability of the puzzles and the utility of the puzzles in improving analytical ability. They found that participants who had thought about how they *felt* about the puzzles rated the puzzle likeability higher. Conversely, participants who had been encouraged to think *cognitively* about the puzzles rated them higher in utility for improvement of analytical ability. In this study, functions of attitudes toward new objects were successfully manipulated.

Millar and Millar (1990) examined the relationship between attitude type (cognitive vs. emotional) and message type (cognitive vs. emotional). They found that people were more likely to be persuaded by counter-attitudinal messages that *were not* the same type as the existing attitude. For example, participants who held attitudes that were cognitively based responded better to emotional counter-attitudinal arguments. Conversely, participants who held emotionally based attitudes were more persuaded by cognitive counter-attitudinal arguments. Millar and Millar hypothesized that by not threatening the participant's self esteem by presenting arguments that directly countered his or her existing attitude, they would better be able to change the attitude through the opposite channel. Kamradt and Kamradt's (1999) instructional approach to attitude change (described in *Instructional strategies for attitude change*, below) runs exactly counter to the conclusions from Millar and Millar's (1990) study. The present study will address this contradiction.

Source credibility, likeability, and attractiveness. A number of studies have compared the effectiveness of attitude change techniques when counter-attitudinal messages come from sources with different characteristics.

DeBono and Harnish (1988) investigated the interactions between learner characteristics, message strength, and attractive or expert sources. They first divided the sample into groups of high self-monitors (highly motivated by social perception) and low self-monitors (not highly motivated by social perception). Then students were exposed to either an attractive or an expert source who presented either a strong or a weak message. Following the presentation, the students' attitudes toward the target were measured. DeBono and Harnish found a significant interaction among all three factors. When the argument was strong, high self-monitors were more responsive to the expert source, and low self-monitors were more responsive to the attractive source. When the argument was weak, high self-monitors were more responsive to the attractive source, and the low self-monitors were more responsive to the expert source.

In another study, DeBono and Telesca (1990) studied the differences in attitude change between a strong and weak message and delivered by an attractive or unattractive woman. They found that subjects were highly persuaded by strong arguments from an attractive woman, but not persuaded by the weak arguments from the same woman. They were not persuaded by strong or weak arguments from the unattractive woman. On a test of cognitive recall of the premises in the message, the scores of high self-monitors who heard from the attractive source were significantly higher than those of high self-monitors who heard from the unattractive source. There was no significant difference related to source attractiveness between recall scores of low self-monitors.

Chaiken and Maheswaran (1994) studied interactions among source credibility, message strength, and attitude importance. They manipulated all three factors, and found that participants were most likely to have positive attitudes toward a fictional "new" answering machine when they heard unambiguously strong arguments from high-credibility sources. A three way significant interaction was found among the three factors. Participants who thought their opinions did not matter much were not persuaded by low-credibility sources, but were by high-credibility, regardless of the argument strength. Participants who thought their opinions did matter were convinced by strong arguments and not convinced by weak arguments, irrespective of the source credibility. When arguments were ambiguous, these same participants were convinced by the high-credibility source, but not by the low-credibility source.

Message strength. Messages can contain strong or weak arguments. Strong arguments are more likely to persuade than weak arguments. However, argument strength has been shown to interact with functional matching of the counter-attitudinal argument (Lavine & Snyder, 1996; Petty & Wegener, 1998). Lavine and Snyder (1996) found that people's perceptions of message strength were as important as functional matching. For example, a person with a value-expressive attitude was more likely to change that attitude when presented with a value-driven message. However, the benefits of functional matching could be canceled out if the message was weak. They also found that messages were rated as stronger when they were matched with the attitude function of the rater. Petty and Wegener (1998) found that argument strength was more important as a factor in attitude change when the argument functionally matched the attitude of the receiver. As described in the section above, argument strength also interacts with source credibility and perceived importance of task (Chaiken & Maheswaran, 1994). In summary, source credibility and functional matching are not enough to change attitudes; message strength also matters.

Attitude object characteristics. Shavitt (1990) hypothesized that attitudes toward some targets can serve the same function regardless of person and situation variables. For example, attitudes toward air conditioners nearly always serve a utilitarian function, whereas attitudes toward wedding rings nearly always serve a social-identity function. Shavitt found support for her hypothesis, but admitted that many attitudes are complex and serve different functions for different people or even multiple functions for the same person.

In a test of both the attitude-behavior connection and the functions of attitudes, Maio and Olson (1995) made salient either utilitarian or value-expressive functions of attitudes toward donating money to cancer research, and then asked participants to indicate their behavioral intentions (i.e., whether they intended to donate money to cancer research). People exposed to value-expressive arguments indicated a higher likelihood of donating money than those exposed to utilitarian arguments. The researchers noted that usual attitudes toward donating money to cancer research are value-expressive rather than utilitarian. This finding supported Shavitt's (1990) assertion that attitudes toward certain objects are more likely to hold one function over another.

The next section focuses on how these variables can be manipulated in instructional environments to effect attitude change.

Attitude Change and Instruction

A separate body of research has focused on attitudes in educational or instructional environments. That research is discussed in the paragraphs that follow.

Affective Instructional Objectives

After instructional objectives became an important part of instructional design in the 1960s, researchers began to develop taxonomies of instructional objectives. Instructional designers typically divide instructional objectives into the general categories of cognitive, psychomotor, and affective (Dick & Carey, 1996; Gagne, Briggs, & Wager, 1988; Krathwohl et al., 1964; Ormerod, 1983). Affective objectives are the ones of concern here.

Affective objectives have been organized into several hierarchies, the most cited of which is Krathwohl, Bloom, and Masia's 1964 *Taxonomy of Educational Objectives, Handbook II: Affective Domain.* The authors explained five levels of affective objectives: receiving, responding, valuing, organization, and characterization.

The lowest level of affective objectives is *receiving* (Krathwohl et al., 1964). This level contains three sub-levels: awareness, willingness to receive, and controlled or selected attention. As the titles suggest, objectives at this level are that learners be aware of the attitude object, be willing to receive more information about the object, and/or choose to focus attention on the object.

The second level of affective objectives is *responding* (Krathwohl et al., 1964). At this level, learners will respond if they have to, respond willingly, and/or express satisfaction in responding to the attitude object.

At the third level, learners are expected to value the object (Krathwohl et al., 1964). Three sublevels at the *valuing* level are (a) acceptance of the value, where the learner accepts a value presented, (b) preference for a value, where the learner chooses the value over something else, and (c) commitment to the value, where the learner commits to the value even outside the learning environment.

In the last two levels of Krathwohl and others' (1964) hierarchy, organization and characterization, learners begin to conceive of and organize their own sets of values. At the highest level, the learner's entire world is characterized by the object. The authors of the hierarchy allow that affective objectives at these levels are seldom implemented in the classroom. They are considered outside the scope of the present research.

Affective objectives related to attitudes toward science are presented below. These objectives represent the four lowest levels of the hierarchy.

Receiving

1. I listen when a friend talks about a scientific topic.
2. I listen when someone I just met talks about a scientific topic.
3. I attend class lectures in science classes.

Responding

1. I read science-related materials when they are part of a class assignment.
2. I read science-related materials when they are readily available.
3. I read science-related materials when a friend recommends them.
4. I seek out science-related materials to read.
5. I enjoy reading science-related materials
6. I watch science-related television when it is part of a class assignment.

Valuing

1. Science is a good thing to study.
2. Science is good for people and the planet.
3. Science is a better thing to study than most other subjects.
4. All other things being equal, I would rather take a science class than a class in another subject.
5. I want to major in a science field.
6. I want to be a scientist.
7. I would encourage my child to pursue a science career.

Organization

1. I enjoy thinking like a scientist.

2. My friends know I think scientifically.
3. I am a scientist.

An alternate hierarchy that was not so well defined was presented by Ormerod (1983). This hierarchy included both negative and positive components. On the positive side of the axis, Ormerod included the levels of awareness, interest, enthusiasm, and inspiration to study further. On the negative side are the levels unawareness, inattention, apathy, hostility, refusal, and destruction. An inherent problem with this model is that "moves" in a positive direction do not always make sense. For example, a learner could not realistically move from hostility to a subject to unawareness.

Since the development of the hierarchies described above, the definition of the *affective domain* for instruction has expanded to include other topics, such as motivation, morals, self esteem, and ethics (Martin & Briggs, 1986). These topics are not of principal concern to the current research.

Instructional Strategies for Attitude Change: Theories

Instructional designers have long included attitudes as one of the types of knowledge that instruction can teach. Guidelines for instructional designers who want to teach attitudes have been published by Simonson (1983), Gagne et al. (1988), Bednar and Levie (1993), and Kamradt and Kamradt (1999). Simonson's research focused on using instructional technology (mediated instruction) in attitude change instruction. Bednar and Levie published attitude change guidelines based on a number of popular educational psychology theories. Kamradt and Kamradt published specific guidelines for attitude change guidelines based on the affective, behavioral, and cognitive components of attitudes. A summary of the literature on instructional design for attitude change is presented next.

Simonson. Michael Simonson led the research on relationships between instructional technology and instructional attitude change. In the late 1970s and early 1980s, he developed theory-based guidelines for designing instructional materials to change attitudes (Simonson, 1979, 1983, 1984; Simonson & Maushak, 1996). In the late 1980s, he and his colleagues conducted a number of studies (Dimond & Simonson, 1988;

Simonson, 1985; Simonson, Aegerter, Berry, Kloock, & Stone, 1987; Treimer & Simonson, 1988) to test those guidelines, and to determine the effects of different instructional technologies on instruction aimed at attitude change.

Simonson's guidelines relate attitude-changing instruction to instructional design and instructional technology (mediated instruction). He developed six postulates:

1. Learners react favorably to mediated instruction that is realistic, relevant to them, and technically stimulating.
2. Learners are persuaded, and react favorably, when mediated instruction includes the presentation of new information about the topic.
3. Learners are positively affected when persuasive messages are presented in as credible a manner as possible.
4. Learners who are involved in the planning, production, or delivery of mediated instruction are likely to react favorably to the instructional activity and to the message delivered.
5. Learners who participate in post-instructional discussions and critiques are likely to develop favorable attitudes toward the delivery method and content.
6. Learners who experience a purposeful emotional involvement or arousal during instruction are likely to change their attitudes in the direction advocated in a mediated message. (Simonson & Maushak, 1996, p. 1001)

After twenty years of research in instructional technology, Simonson and his colleague Nancy Maushak came to the same conclusion many other media comparison researchers made: "Media, at best, play a minor role in persuasion when compared to the message delivered by the medium or the methodology of instruction" (Simonson & Maushak, 1996, p. 1009).

Gagne, Briggs, and Wager. Gagne and his colleagues included a short section on attitude learning in *Principles of Instructional Design* (1988). The researchers suggested both direct and indirect methods for changing attitudes. The direct method is essentially classical conditioning. By pairing the attitude object with some desired outcome, the learner will come to have a more positive attitude toward the attitude object.

The researchers also outlined an indirect method for changing attitudes, based on Bandura's (1977) social learning theory. Human models, real or fictitious, demonstrate the desired behavior. As long as the learners respect the model, identify with the model, and feel that the model is credible and powerful, they will try to be like the model, and therefore hold the same attitude. The researchers gave four steps for modeling for attitude change (Gagne et al., 1988, p. 89):

1. Presentation of the model and establishment of the model's appeal and credibility.
2. Recall by the learner of knowledge of the situations to which the attitude applies.
3. Communication or demonstration by the model of the desired choices of personal action.
4. Communication or demonstration that the model obtains pleasure or satisfaction with the outcome of the behavior. This step is expected to lead to vicarious reinforcement on the part of the learner.

Bednar and Levie. Five years later, instructional design theorists Anne Bednar and Howard Levie developed twenty-two research-based guidelines for instruction to change attitudes (1993). Their work is strongly influenced by three theories: (a) communication theory (source, message, channel, and receiver), (b) modeling (from Bandura, 1977), and (c) cognitive dissonance theory (from Festinger, 1957). The first eleven guidelines are based in communication theory. The next five are based on modeling behaviors. The final six are based in cognitive dissonance theory. All twenty-two guidelines are presented below.

1. High credibility sources exert more persuasive influence than low-credibility sources.
2. Sources perceived by the receiver as attractive are more influential.
3. The quality and structure of the arguments in a persuasive message are more critical for credible sources than for attractive sources.
4. Be sure the receiver is informed of the expertise of a high-credibility communicator.

5. To enhance communicator attractiveness, establish belief congruence with the receiver by arguing in favor of positions the receiver is known to hold.
6. Arguments are more effective if they are relevant to the receiver's needs.
7. Generally, two-sided arguments are slightly more effective than one-sided messages. (This guideline is qualified by the statement that receivers should be familiar with the issue, disagree with the desired attitude, and be intelligent and inquisitive. If receivers already hold the desired attitude, presenting weak arguments against the undesired attitude may make desired attitudes stronger.)
8. It is almost always advisable to state the conclusion explicitly rather than to allow receivers to draw their own conclusions.
9. Repetition helps, but only one or two repetitions are likely to have any additional effect.
10. No one media type has been explicitly shown to have greater persuasive effectiveness than any other media type. Face-to-face communication, however, is more effective in promoting acceptance than mediated communication, particularly in difficult cases.
11. It is very difficult to change the attitudes of receivers who are highly committed to their position on an issue.
12. High-credibility models exert more persuasive influence than low-credibility models.
13. In order for modeling to be effective, the learners must comprehend the presentation as a demonstration of specific behaviors.
14. In addition to observing the model demonstrating the behavior, learners should observe the model being reinforced for that behavior.
15. Role-playing can have powerful persuasive impact.
16. Active participation produces more attitude change than passive reception of information.
17. If a person can be induced to perform an important act that is counter to the person's own private attitude, attitude change may result.

18. When a person is induced to perform an attitudinally-discrepant act because of promise of reward or punishment, attitude change will occur only to the extent that the person feels the magnitude of the reward or punishment was insufficient to justify the attitudinally-discrepant behavior.
19. Demonstrate the social acceptability of the desired attitude and the reward available socially for behavior consistent with the attitude.
20. Alternate between presenting information discrepant with existing beliefs and inducing behaviors discrepant with existing attitudes to maximize dissonance.
21. Structure attitude-change lessons so that attention is paid to the cognitive (information), affective (feeling), and behavioral (acting) elements of the attitude.
22. Use successive approximations to move attitudes gradually between a current status and a desired state.

Well known instructional designers, including Walter Dick and Lou Carey (1996) and Marcy Driscoll (2000), follow Bednar and Levie's (1993) general approach. The Dick and Carey approach also includes other elements of instructional design such as practice and feedback, vicarious practice, and review and transfer (1996). Driscoll also incorporates behaviorist theory by stressing the importance of consistent reinforcement for appropriate attitudes (2000).

Structured design. University of Illinois faculty members Thomas Kamradt and Elizabeth Kamradt (1999) developed an instructional technique designed especially for changing attitudes. Although their work was published six years later than Bednar and Levie's, Bednar and Levie cited Kamradt and Kamradt's work while it was still under development. Kamradt and Kamradt assumed that attitudes are made up of three interconnected and inseparable components, an affective component, a cognitive component, and a psychomotor component.

Kamradt and Kamradt allowed that attitudes toward many targets have stronger components in one or another of the three. For example, attitudes toward changing a tire are primarily psychomotor, with smaller cognitive and affective components. Attitudes toward writing a song would have stronger affective components.

Kamradt and Kamradt proposed that in stable attitudes, all three components are consistent. That is, they lie at the same location on the attitude continuum between the most positive and the most negative. People change their attitudes when one of the three components is not coordinated with the others. For example, if a person's actions (psychomotor) do not match her beliefs (cognitive), she is likely to alter either her actions or her beliefs to make them consistent. When functions do not correlate, the person is said to be in a state of dissonance.

The process of attitude activation, according to Kamradt and Kamradt (1999), begins with a need that triggers negative emotions. These negative feelings trigger cognitions about ways to meet the need. A decision process occurs, and a psychomotor response is activated, based on the cognitions, to fill the need. If the response fills the need, the attitude is deemed acceptable and does not change. If the response fails to fill the need, the attitude is judged unacceptable and can then be changed. This conceptualization is likely to have been inspired by Festinger's (1957) cognitive dissonance theory, which has been used in other attitude change research (e.g., Misiti & Shrigley, 1994).

In order to teach attitude change, Kamradt and Kamradt (1999) outlined a specific process. First, the instructor should activate the attitude by presenting a problem situation that calls for an attitude slightly different from the existing attitude of the target audience. The participants "solve" the problem. Then, the instructor asks three questions:

1. How did the situation make you feel?
2. What were you thinking?
3. Why did you do what you did?

These questions attend to the affective, cognitive, and psychomotor components of the attitude. After determining which of the components is the most dissonant (the farthest from the ideal attitude), the instructor begins instruction that corresponds to the dissonant component. If the dissonant component is affective, the instructor should use operant conditioning techniques. If the dissonant component is cognitive, the instructor should use persuasion. If the dissonant component is psychomotor, the instructor should use demonstrations and practice. Finally, the instructor should use a review and transfer technique to consolidate the attitude.

As non-examples, Kamradt and Kamradt describe three techniques for attitude change that do not work. The "revival preacher" approach focuses only on the affective component of the attitude. The leader offers inspirational thoughts, encourages tears and hugs, and sends everyone home feeling good. However, the effect is temporary, because the realities of the situation that gave everyone bad attitudes in the first place have not changed. The second non-example is the "debate champion" approach. In an attempt to persuade the audience, the leader offers many logical reasons for the desired attitude. According to Kamradt and Kamradt, this method is also ineffective because it does not address what "feels right" (p. 579). The final non-example is the dictator. In this case, the leader, who has some power over the audience, requires that people exhibit behaviors consistent with the desired attitude. Again, without cognitive or affective reinforcement, the attitude is not internalized, and therefore reverts to its original position as soon as the dictator leaves the room.

Structured design is a new technique, and has not been tested extensively, except as claimed by the authors in the original publication. There exist a number of theoretical differences between the technique and other attitude theories. Kamradt and Kamradt's use of the term *attitude* is different from the use by attitude theorists. In structured design, *attitudes* appear to encompass all aspects of knowledge, including non-evaluative cognitive information and psychomotor skills.

Structured design and feminist theory. An important strength of structured design for the purposes of this study is its focus on the emotional component of attitudes. As described previously, the importance of feelings and emotion are basic themes of feminist thought (Belenky et al., 1986; Boler, 1999; Damarin, 1991). Unlike other authors in instructional design, Kamradt and Kamradt (1999) do not ignore the emotional parts of attitudes that may be especially important to women. The researchers make the following claim, which corresponds neatly with this element of feminism: "Contemporary, domain-focused instructional techniques do well at integrating cognitive and psychomotor components, but they consistently fail to properly integrate the [emotional] component. In other words, they don't teach complete attitudes" (p. 574).

Instructional Attitude Change in Science and Related Fields: Research

A number of researchers (described in the following discussion) in instructional environments have investigated the effects of various factors on attitudes toward science and related fields with hopes of improving those attitudes. Most of these studies involved indirect approaches. For example, instruction was not specifically designed to improve attitudes toward science and related fields; rather, it was designed to accomplish other goals (e.g., incorporate research-based instruction, improve self-confidence), and attitude improvement was assumed to be an effect. Measurement of attitudes seemed to be an afterthought. The studies were not based on attitude theory or on instructional theories for attitude change. None of the studies described below cited even basic attitude research. This disconnect between attitude theory and attitudes toward science is documented (e.g., Koballa, 1988; Schibeci, 1984), and presents additional justification of the present study.

Researchers at the University of North Carolina at Charlotte surveyed all of their math students in all levels of classes at the beginning and end of a semester (Royster, Harris, & Schoeps, 1999). Their study found the most significant positive attitude changes toward math in women and in students in math classes for elementary teachers (many of whom were women). No attempt was made in the article to explain the cause of attitude change, other than exposure to a semester-long math class. However, the researchers do point out that it is encouraging to know that women's and pre-service teachers' attitudes toward math can be improved by instruction (Royster et al., 1999).

A 1994 study examined the effect of research-based science instruction on attitudes toward science, scientists, and careers in science (Lockwood, 1994). One high school class learned science using an "authentic learning, problem-solving, cooperative learning, hands-on, and inquiry-discovery approach" (p. 14). Another high school class learned science using a traditional lecture approach. Lockwood found no significant difference in attitudes toward science or science careers after the instruction. He also found no significant difference between boys and girls' attitudes before or after the treatment. Although difficult to quantify, Lockwood's qualitative data from journals kept by the students during the class showed many differences between the girls' and boys' ways of looking at science. For example, girls in the treatment class wrote about the emotion, excitement, and adventure of science. Girls also reacted very positively to field trips to see scientists at work. Several wrote in their journals about contemplating careers in science following field trips. One girl wrote, "You showed me that science was more than just something I was good at … it is something I can do a good job at, maybe for the rest of my life" (p. 221).

Noting the lack of confidence in new women computer science majors, a researcher at The Richard Stockton College of New Jersey designed and developed an intervention course to improve women's self-confidence (Mathis, 2002). Mathis used many instructional techniques identified as woman-friendly, including cooperative learning and real world problem solving. She also invited professional women to speak on their careers, providing important experiences with potential role models. As the instructor, she hoped to become a mentor to the women in her class. At the end of the semester, the women's confidence in their ability to succeed in computer science did not improve. However, their perceptions of their computer skills related to spreadsheets, graphics, presentations, web page authoring, and computer conferencing increased significantly.

Heller and Zeigler (1996) tested the effects of attributional retraining on college and high school students with promising results. They taught the students to attribute their math successes to their talent and their math failures to a lack of effort. When students attributed their failures to changeable, internal causes, they became empowered to make changes. For example, if the student attributed her failure to a stable internal factor, such as a lack of talent (I am just no good at math), she would have no power to change her study methods for a future test. However, if she attributed her failure to a changeable internal factor, such as lack of effort (I did not study enough for this test), she could study harder for future tests. The method was successful for changing students' attributions. Although attitude was not measured per se in this study, related constructs, such as students' confidence in their ability to do math, were measured with promising results.

Another study attempted to change adolescents' attitudes toward women in nontraditional careers with instruction on sex-role stereotyping, specific careers, and issues in dual-career families (Johnson, 1991). Although the effect did not last, girls who received the instruction had significantly *less* favorable attitudes toward the careers presented than all students in the control group did. Presenting more information about specific science careers and issues related to them is not a promising instructional method (Johnson, 1991).

Pesthy (1989) offered a mathematically non-threatening science class to determine its effects on attitudes, career choice, and the decision to take more science courses. Although attitudes toward science became significantly more favorable, students were less likely to choose science careers or indicate interest in more science classes.

Smith and Erb (1986) studied the effects of exposure to women science career role models on fifth, sixth, seventh, and eighth grade students. Students in the experimental group were exposed to women guest speakers, stories of women who have made important scientific contributions, and stories of young women who used science in their work. Students in the experimental group received additional instruction related to the current class topic. The attitudes of both boys and girls toward women in science and toward scientists in general became significantly more positive. Girls in both groups had significantly more positive attitudes toward women in science than boys.

These studies clearly illustrate the disconnect between attitude theory and attitude instruction. Researchers used a variety of techniques theoretically unrelated to attitude change and, not surprisingly, obtained mixed results in effecting attitude change. These findings support the need for theory-driven attitude instruction. The next section examines how theory has been applied to attempts to change women's attitudes.

Attitudes and Instruction for Women

Women and Attitude Change

Feminist thought criticizes science in general for the omission of studies of gender differences (e.g., Damarin, 1991). Like much of scientific research, very little theoretical research has focused on differences in attitude change by gender.

A small body of research in the 1960s and 1970s examined the relationship between persuasibility and gender. Early research was based on the assumption that women would be more likely to change their attitudes as a result of some intervention than men (Cronkhite, 1969). Later conflicting results made the assumption invalid. For example, Steinbacher and Gilroy (1976) studied small groups to determine how gender relates to persuasiveness and persuasibility. They found no significant difference in the persuasibility of women, but they did find a significant difference between the persuasiveness of women. That is, individual women had more success changing the attitudes of a small group of men than individual men had at changing a small group of women. Plax and Rosenfeld (1977) also found no significant difference in the persuasibility of women and men. On the other hand, Jenks (1978) found that women were more persuasible than men. He presented sociology students with persuasive messages on hot topics such as religion, the right to die, health care, busing, and the business of sports. He measured their attitudes toward the issues before and after the message. Jenks found no interaction between the issue studied and gender.

For the purposes of the present study, the issue of whether women are more persuasible than men is a moot point. If it is indeed easier to persuade women to change their attitudes than men, the goal of the instructional designer to change women's attitudes simply becomes easier to achieve. There seems to be no debate as to whether men are easier to persuade than women.

Women and Learning

Instructional design is about teaching (or changing) intellectual skills, psychomotor skills, and *attitudes* (Dick & Carey, 1996). It follows that research into instruction for women is relevant to determining how changing women's attitudes might be different from changing men's attitudes. A large body of research on how women learn and instructional guidelines for women has been published.

Feminist researchers maintain that education (and most other establishments) has been, consciously or sub-consciously, controlled and directed by men for men (Knupfer, 1997; Knupfer & Rust, 1997). Although women may now participate in any subject, including science, technology, engineering, and math, remnants of the male-designed educational system are still evident in gender biased imagery and language of educational materials (Couch, 1995). Knupfer (1997) maintained that "the first step is to educate instructional designers to attend to the needs of a pluralistic society" (p. 122).

Belenky, Clinchy, Goldberger, and Tarule (1986) published a landmark qualitative study of women of many races and socioeconomic backgrounds to understand "women's ways of knowing." *Women's Ways of Knowing* has become a highly cited piece of feminist work, and offers important insights that can be related to women's negative attitudes toward science. The researchers interviewed extensively 135 adult women students of all ages, backgrounds, and races. The participants included students of a local health department's new mothers program, adult education students, traditional undergraduate students, and traditional graduate students.

The researchers analyzed the women's words, and developed a schema of five ways of knowing: silence (or not knowing), received knowing, subjective knowing, procedural knowing, and constructed knowing. These five categorizations were conceived to represent a continuum in the development of knowledge.

Silent women did not have answers when they were asked about themselves or their futures. They lacked language for talking about their experiences. Their experiences told them that words represented weapons or problems. These women were nearly always abused physically, verbally, sexually, and/or psychologically.

The next group consisted of "received knowers." These women got their knowledge from what authority figures told them. They did not consider their own feelings or thoughts about what they were told. People in authority gave them knowledge and they took it at face value.

A third group consisted of "subjective knowers." Nearly half of the women interviewed fit this category. These women trusted only their feelings or "inner voices." They were not swayed by authorities or logic. These women often had once been received knowers, but had changed their ways when they were let down in some way by an authority figure. Many times, they had been abused by the authority figure, or the advice given to them from an authority figure resulted in disaster. These women rejected authority and trusted their own intuitions. Many of the stereotypes of women as emotional and illogical fit with this way of knowing.

> The fervor with which subjectivist women draw sharp lines between intuitive knowledge and what they assume to be the impersonality of abstract thought harks back to the dogmatism and either/or thinking characteristics of the [silent and received knowers] women. … It is not that these women have become familiar with logic and theory as tools for knowing and have chosen to reject them; they have only vague and untested prejudices against a mode of thought that they sense is unfeminine and inhuman and may be detrimental to their capacity for feeling. (Belenky et al., 1986, p. 71)

The fourth set of women gained knowledge through procedures. Procedural knowers used either the scientific method, called "separate knowing," or social construction, called the "connected mode," (p. 114) to decipher truths. Separate knowing has much in common with traditional science, especially in its values of doubt, reason, and self-extrication. Separate knowing is basic to the sciences because those fields rely on logic and experiments to expand their knowledge base. Women who were procedural knowers faced the same criticisms that male scientists face. They were seen as unfeeling, but wholly logical.

Some procedural knowers used what Belenky et al. (1986) called the "connected mode." Connected knowers used procedures for connecting to other people and their experiences. These women's procedures included conversation, sharing, refusing to judge, collaborating, and using their own subjective knowledge.

The fifth and most evolved way of knowing was constructed knowing. Constructed knowers combined the information they received from authority figures, from their own intuitions, from logic, and from other people's input to construct their unique voices. By basing their beliefs on this range of inputs, they sought to solve problems holistically.

The five ways of knowing described by Belenky and her colleagues (1986) can be distilled to different combinations of cognitive, affective, and behavioral components of knowledge. In silent knowers, none of the components is present. Received knowers do what they are told; behavioral components are dominant. Subjective knowers trust their intuitions; the affective domain is most important. Procedural knowers rely on cognitive components. Finally, constructed knowers use a balance of all three domains.

(It is important to note that *Women's Ways of Knowing* is not about differences between women's and men's ways of knowing. The researchers interviewed only women in an attempt to understand their experiences. They made few claims on the relevance of their findings to men. Men may have ways of knowing that are very different or very similar to the ways identified by these researchers.)

Instructional Design for Women

Traditional, masculine teaching methodologies are adversarial and competitive, with debates and competition for the "best" grade. A number of guidelines for developing woman-friendly instructional methodologies have been proposed based on quantitative and qualitative data, classroom experience, and feminist theoretical foundations. Some of these guidelines are for any instruction for women, and some are specific to science instruction.

Many researchers have studied gender differences in aesthetics and visual imagery (Couch, 1995; Rogers, 1995). Rogers found that girls generally prefer colorful images, detailed images, female characters, and peaceful images. However, she cautioned against using these preferences in instructional design because of the risk of "institutionalized sexism." Couch (1995) includes the recommendation of avoiding use of gender-biased imagery in his list of recommendations for schools to help improve gender equity.

Researchers conducted a focus group to answer the question, "What might a computer look like, aesthetically, if a woman had designed it?" (Carr-Chellman, Marra, & Roberts, 2002). Their research was inspired by the general ugliness of early computers as boxes with blinking lights and wires. "The basic metaphor of many boxes wired together seems to be less than appealing to some women" (p. 7). They found that women were concerned with aesthetics, and would design computers to be rounded and colorful. (The authors allow that much of their data was collected prior to 1995, when computers *did* become curvier and colorful.) The new computer would be designed for cooperative exercises. Participants suggested that "it should be like a glass orb" and should have a picture that "can be seen by everyone and would move with the viewer" (Carr-Chellman et al., 2002, p. 8). These results point to two additional suggestions common in recommendations for teaching women: (a) teach with aesthetics in mind, and (b) employ group-based, collaborative, or cooperative learning. Linda Sax conducted a regression analysis to identify factors that correlate with men and women's persistence in science majors (Sax, 1994). She found that working on a professor's research was one of the few factors that professors control that positively correlated with women's persistence in science. She also found that women were "more concerned with the 'social good' of their career choice" (p. 59), and recommended that science instruction focus on social concerns. Her findings point to two common recommendations for science instruction for women. First, instructors should include role models and mentors (see also Boswell, 1985; Bozeman & Hughes, 1997; Brown, 2001; Couch, 1995; Mathis, 2002). Second, teachers should also incorporate socially relevant problems into the instruction (see also AAUW Educational Foundation, 2000; Boswell, 1985; Brown, 2001; Couch, 1995;

Damarin, 1991; Kaiser-Messmer, 1993; Lockwood, 1994; Mathis, 2002; Meyer & Koehler, 1990; L. B. Smith, 2000).

Much feminist theory is based on women's preference for social interaction and interpersonal development. Many researchers recommend using group-based, collaborative, or cooperative learning in the classroom to make the classroom friendlier to women (Bozeman & Hughes, 1997; Brown, 2001; Couch, 1995; Lockwood, 1994; Mathis, 2002; Sax, 1994).

These guidelines represent years of research on instruction for women. The guidelines can also guide instruction for attitude change in women.

Instructional Strategies for Improving Women's Attitudes toward Science

Four basic fields of research have been discussed in the previous pages: (a) women in science, (b) attitudes and attitude change, (c) instructional design for attitude change, and (d) instructional design for women. These areas intersect where women in the classroom form attitudes toward science. Three themes recur in the discussion that can guide instructional designers in strategies for improving women's attitudes toward science: (a) emotion, (b) modeling and role models, and (c) attitude function. The three themes are discussed here in terms of the four fields of research.

Emotion

The presence or absence of feeling, emotion, and subjectivity is a defining factor for all four of the research bases discussed previously.

Women in Science

The head-on collision between scientific and feminist thought is well documented (e.g., Damarin, 1991; Hubbard, 2001; Schiebinger, 1999). A major source of difference between the two philosophies is the subject of emotion. Science seeks objectivity and freedom from emotion. Feminism embraces and encourages emotion, and encourages subjectivity. Feminism acknowledges that the scientist creates knowledge; science acknowledges that knowledge is created. The use of active voice in feminist writing and passive voice in scientific writing is nearly ubiquitous.

Attitudes and Attitude Change

Although most attitude researchers acknowledge some connection between emotion and attitude, "the treatment of affective and emotional processes has been relatively narrow and largely neglected in attitude research" (Breckler & Wiggins, 1989, p. 409). There also exists a body of literature on emotion research, but this body and attitude research "rarely make contact" (Breckler & Wiggins, 1989, p. 412). The attitude change studies described previously reveal an emphasis on attitude change by persuasion, with notable exceptions (Millar & Millar, 1990; Millar & Tesser, 1986). The elaboration likelihood model (Petty & Cacioppo, 1986) is a major theory of attitude change, and is based solely on persuasion. (In fact, the full title of the model is "the elaboration likelihood model of persuasion.") Persuasion is attitude change through cognitive means. More technically, to persuade is "to move by argument, entreaty, or expostulation to a belief, position, or course of action" (*Webster's new collegiate dictionary*, 1987, p. 878). Notice the absence of words related to *emotion* in the definition. Kamradt and Kamradt (1999) called this the "debate champion" approach. They criticized this approach (and several others, see previous discussion) for focusing entirely on only one of the three components of attitudes.

Instructional Design for Attitude Change

Instructional design guidelines for attitude change are vague at best with regard to emotion. Some theorists seem to equate attitude with emotion, and therefore assume that instruction about any component of attitudes satisfies the need for inclusion of emotion. While they tend to agree that emotion should be considered, they are silent or vague when it comes to specific techniques for including it in instructional design. For example, compare the following quotations from documents written to help instructional designers design for attitude change.

Bednar and Levie recommended that designers "structure attitude-change lessons so that attention is paid to the cognitive (information), affective (feeling), and behavioral (acting) elements of the attitude" (1993, p. 300). No more specific guidelines for treating emotional elements are given.

Driscoll acknowledged the importance of including all three components, but also failed to elaborate on the inclusion of emotion. "All three components are important to consider when designing instruction to teach or influence attitudes" (2000, p. 355). Several pages later, she went into more detail: "For any attitude to be learned and *expressed*, learners must … possess … *information*" (2000, p. 362, italics added). The emotional component is not discussed. Notice the contradiction between what is "important to consider" in the previous item (all three components) and what is necessary for attitude change (information and expression, not emotion).

Dick and Carey made the same omission. "The substance of the instruction for an attitude consists of teaching the *behavior* that is to demonstrated … as well as supporting *information* about why this is important" (1996, p. 196, italics added). Again, emotion is not mentioned.

Kamradt and Kamradt noticed the omission of the emotional component, and summed up the problem as such: "After expertly teaching two of the three attitudinal components, we allow ourselves to blame low-performing learners for *their* attitude deficiencies" (1999, p. 574, italics in original).

What is illustrated by these quotations is the rift between the accepted definition of *attitude*, which includes emotion, and instruction for attitude change, which seems largely to ignore the emotional component (with the notable exception of Kamradt and Kamradt's structured design technique).

Instructional Design for Women

The deficiency of these approaches is especially important if women tend to value emotions (Belenky et al., 1986; Boler, 1999). Attitude change approaches that ignore emotional components are theoretically less likely to be effective for women.

The research foundations laid out in *Women's Ways of Knowing* (Belenky et al., 1986) lend support to this idea. The importance of emotion to women is a source of both feminist philosophy and negative stereotypes about women. In the research of Belenky et al. (1986), the presence or absence of emotion (affect, subjectivity, feeling) helped to define the five categories of knowing.

With silent women, received knowers, and separate knowers, emotion was left out of the equation for new knowledge. Separate knowers, those most aligned with traditional science values, purposefully omitted feeling from their knowledge building, in order to be more logical. Feminists call women who think this way "honorary males" (Pattatucci, 1998). Subjective and constructed knowers *do* factor emotions into their knowledge building. In fact, subjective knowers base their entire knowledge on their intuitions, or emotions. Constructed knowers incorporate received knowledge, intuitive knowledge, and procedural knowledge to construct their understandings.

Subjectivity is especially important in light of the large fraction of women in Belenky et al.'s (1986) study who based *all* their knowledge, including their strong negative attitudes toward science, on subjective information. Nearly 50% of the 135 women interviewed were subjective knowers. Recall the following quotations from participants in the *Women's Ways of Knowing* study (Belenky et al., 1986).

> I'm having a hard time with the premise that truth is scientific knowledge, because for me it isn't that at all. For me, truth is internal knowledge. I don't think we need scientific methods to ascertain what's right at all. I think we need internal exploration and knowledge of self to know what's right and what is true. (Belenky et al., 1986, p. 71-72).

> I think women have been cowed by science. We've been told, 'That's unlogical, that's unscientific. Anything you can't prove is not worth talking about.' They're saying if you can't prove your sensations, you don't got 'em. Our society is trying to suppress the senses in favor of what goes on from the eyes up. That's so destructive. (Belenky et al., 1986, p. 72)

These women were subjective knowers, basing their knowledge solely on their internal voices and emotions. Their words highlight the difficulty instructional designers may have in trying to *persuade* them that they should have positive attitudes toward science. If many of the women whose attitudes toward science should be improved fall into this category, it follows that no quantity of fact-based argument will change their attitudes.

Megan Boler's book, *Feeling Power* (1999), includes a discussion of the absence of emotion in educational settings. "The classroom community … is not a place where emotional epistemology or literacy are part of the educational agenda" (Boler, 1999, p. 148-149). "Emotion defies language, and education discursively denies language to emotion" (p. 150). Boler recommends "an integration of structures of feeling with the work of education" (p. 150).

In a study considering the relationships between science and emotion, forty-seven eighth graders (about half boys and half girls) learned about food webs using a graphic video from the African Savannah (Alsop, 2001). After seeing the video, the students discussed and wrote about how they felt about food webs and chains. The researcher grouped the feelings as “hot,” “mild,” or “cool.” Fourteen girls expressed “hot” emotions, as compared to seven boys, leading to the conclusion that “emotional display appeared to be gender-sensitive” (Alsop, 2001, p. 66). Some of the students’ comments raised important philosophical questions about the value of science. For example, one boy wrote, “Personal feelings should not be part of science since then they undermine the factual evidence presented” (Alsop, 2001, p. 66). The comment demonstrates the traditional devaluing of emotion in science.

Emotion is clearly part of femininity and feminism (Belenky et al., 1986; Boler, 1999), and cannot be ignored in instruction for women, especially in instruction for attitude change. The importance of emotion leads to the first major recommendation for instructional designers: address the emotions that are associated with existing negative attitudes toward science.

Role Models and Modeling

A second important theme is present throughout the previous discussion: role models. Women role models in science fields alleviate the masculine image of the fields, and can address reservations girls and young women have about the relevance of science to women’s interests. Modeling is a recommended instructional technique for attitude change.

Women in Science

The lack of women role models in science-related fields is documented (AAUW Educational Foundation, 2000; National Center for Education Studies, 2000; National Science Foundation, 2002). Four studies described below show the effect of women role models on women in science and women’s attitudes toward science (Canes & Rosen, 1995; Evans & Whigham, 1995; Hill et al., 1990; W. S. Smith & Erb, 1986).

Two researchers conducted a correlation study to determine whether there was a significant positive correlation between the number of women faculty in a department and the number of women students who chose the major (Canes & Rosen, 1995). They studied the academic departments at three universities that were different in size, geographic location, and academic reputation. They conducted a longitudinal study using data from 1974-1988. They concluded that there was no evidence that having more women faculty would lead to more women majors in any discipline. They did not study the attitudes of women students in the departments, nor did they control for student-faculty contact variables.

In a study of the effect of women role models on the attitudes of high school science students, 1,616 students (921 girls and 695 boys) participated in a study in which female role models met with ninth grade science classes (Evans & Whigham, 1995). The role models stressed such points as "You don't have to be a brain to succeed in technical fields," "You sometimes have failure that you must overcome," "You also have successes for which you should take credit," and so on. Six components, including attitudes toward science, were measured before and after the intervention in experimental and control groups. The components were liking science, liking math, valuing recognition for work in technical fields, valuing science and math for future utility, being seen as a nerd if in a technical job, and knowing what scientists and engineers do all day. Girls had positive, significant attitude changes in all components except perceptions of "nerdiness." Boys also had positive, significant attitude changes in liking science, utility, and understanding of jobs.

Hill, Pettus, and Hedin (1990) conducted a correlational study to determine factors associated with success in science. The researchers analyzed factors of gender, race, location (rural vs. urban), and knowing a scientist. They correlated these factors to dependent measures of science activities, perceived relevance of science, interest in science, parental support, science ability, teacher support, self-image, and numbers of science and math courses taken. They found that students who know a scientist, mathematician, or engineer scored significantly higher on all the dependent measures except relevance.

Smith and Erb (1986) conducted another study about role models on 286 middle school science students. Fifth through eighth grade students participated in the study in which about half of the students were exposed to women role models and the other half were not. The same teachers taught both the experimental and control groups. The students responded to an attitude test on the "Image of Science and Scientists" before and after the instruction. Those who were exposed to the women role models had a significantly better attitude toward science after the instruction. There was no significant difference in attitudes of boys and girls.

Attitudes and Attitude Change

Attitude change researchers stressed the importance of a credible, attractive source (Chaiken & Maheswaran, 1994; DeBono & Harnish, 1988; DeBono & Telesca, 1990).

Instructional Design for Attitude Change

Modeling is one of the specific recommended methods for attitude instruction (Bandura, 1977, 1997; Dick et al., 2001; Driscoll, 2000; Gagne et al., 1988). Modeling works to change attitudes because "people tend to want to 'be like' those whom they respect or with whom they identify" (Driscoll, 2000, p. 362).

Instructional Design for Women

Many researchers have recommended involving more role models for women in instructional processes (Boswell, 1985; Bozeman & Hughes, 1997; Brown, 2001; Couch, 1995; Mathis, 2002).

The research cited above leads to the second major recommendation for improving women's attitudes toward science: involve credible, attractive women role models. The role models should exhibit a positive attitude toward science and should be positively reinforced for it.

Functional Attitude Theory

The third major theme that should guide attitude change instruction is functional attitude theory.

Women in Science

Women participants in qualitative studies described herein did not talk about their attitudes toward science in the language of attitude function theory, but some of their words can be translated.

Negative attitudes toward science may hold a social-identity function. If people perceive that scientists are brainy, nerdy, hurtful, crazy, or anti-social (e.g., Matthews, 1996), they may hold negative attitudes toward science in order to prevent others from associating them with such characteristics. Girls in Lockwood's (1994) study were surprised to find scientists to be normal people.

1. "He was so normal, like a dad" (p. 244).
2. "This guy was <u>human</u>!!" (p. 244).
3. "[Another girl] was surprised that [a scientist] was so young. Scientists are in their middle 30s to 40s" (p. 244).

Some students, especially girls, hold negative views of science for value-expressive functions. High school girls in focus groups talked about the reasons they were not interested in computers and computer-related careers (AAUW Educational Foundation, 2000). They perceived engagement with computers as diametrically opposed to engagement with the world, and they clearly valued engagement with the world (AAUW Educational Foundation, 2000). Comments from girls in Lockwood's (1994) journal analysis also reveal this function.

1. "What's more important, human welfare or the stars?" (p. 242).
2. "I can't help wondering if that money (the Mirror Lab) could've been better spent on the homeless women and children and those starving elsewhere" (p. 242).
3. "Counting volcanoes is not exactly saving mankind or anything, but I guess we're continuing human-kind [*sic*] search for knowledge" (p. 242).
4. "NASA doesn't seem too important next to the population explosion" (p. 243).

Other value-expressive attitude functions are reflected in some social sciences, where women are the majority. According to Carla Howery of the American Sociological Association, women are attracted to these fields because they deal with “issues central to women’s lives, like … mothering, rape, or marriage” (quoted in Holden, 1996, p. 1919).

Attitudes toward science clearly hold defensive functions. Girls and women perceive that science and related subjects are hard. (Remember the talking Barbie doll in the 1990s that said, “Math class is tough.”) To avoid feeling stupid, the girls avoid the subjects altogether or denigrate boys’ interest in those subjects. Journal entries from the Lockwood (1994) study and quotations from the AAUW focus group (2000) attest to this.

1. “I’m not positive I will do well [in a science class] because of my lack of knowledge in math” (Lockwood, 1994, p. 246).
2. “I feel stupid in this class” (Lockwood, 1994, p. 246).
3. “I’m totally afraid to ask for help because I’m afraid you’ll think I’m <u>very</u> stupid” (Lockwood, 1994, p. 246).
4. “I know for sure that I want to be a doctor. The only thing that holds me back is my lack of confidence” (Lockwood, 1994, p. 245).
5. “Girls have other priorities. Guys are just more computer type people” (AAUW Educational Foundation, 2000, p. 8).
6. About boys’ interactions with computers: “Immature. They just get worked up … they spend all their time on computers and they just never grow” (AAUW Educational Foundation, 2000, p. 8).

Strong evidence for women’s attitudes toward science holding utilitarian functions was not found, with one exception. One girl in a focus group said about a technology-related career that she might “think about doing it as a starting off thing, just to get some money,” but later would “go into something that I actually enjoy” (AAUW Educational Foundation, 2000, p. 8). Her utilitarian attitude toward a career in computer science was positive (based on perceived salary); however, her utilitarian positive attitude was outweighed by a value-expressive negative attitude toward the same object.

Attitudes and Attitude Change

The underlying theme of functional attitude theory is that attitudes serve functions. Research has shown that to change attitudes one must address the functions that the old attitudes serve. For example, "Appeals that were relevant to an attitude's primary function were more persuasive than appeals that were relevant to another function" (Shavitt, 1989, p. 325).

Therefore, the first step in changing attitudes should be to determine what functions the existing attitudes serve. Functions of negative attitudes toward science have not been studied specifically. However, it is possible to hypothesize those functions based on prior research on attitudes toward science.

Research has shown that it is not necessary to know exactly the function the target attitude holds for each person in the target audience. Rather, one can identify audience members as high or low self-monitors in general and target instruction to those general groups (social-identity function instruction for high self-monitors and value-expressive function for low self-monitors) (Clary et al., 1994; DeBono, 1987; DeBono & Harnish, 1988; DeBono & Rubin, 1995; DeBono & Telesca, 1990; Lavine & Snyder, 1996; Maio & Olson, 1994). It is also possible to deliver instruction for both the value-expressive functions and the social-identity functions. Lavine and Snyder (1996) found this technique to be less effective than complete functional matching, but more effective than complete mismatching.

Instructional Design for Attitude Change

Instructional designers who have published attitude change guidelines have largely ignored the functions of attitudes (Bednar & Levie, 1993; Dick & Carey, 1996; Driscoll, 2000), perhaps because, like emotions (Boler, 1999), the functions of attitudes might be thought to be private, individual, and unknowable or at least difficult to know. Kamradt and Kamradt's (1999) structured design approach to attitude change is based on the human needs that attitudes serve. Although the language is slightly different, the parallel between *function* and *need* is clear.

Instructional Design for Women

The instructional design guidelines for women do not specifically deal with attitude function. However, some of the recommendations inherently treat the functions of women's negative attitudes toward science. For example, group-based, collaborative, or cooperative learning could help students with social-expressive negative attitudes understand that science is based on social interactions. Role models who do not fit negative scientist stereotypes may also treat the social-expressive negative attitudes. For the value-expressive negative attitudes, presenting science in terms of holistic, real-world, and social problems may improve attitudes toward science.

Women's negative attitudes toward science majors and fields hold social-expressive, value-expressive, and defensive functions. The research cited above leads to the third major recommendation for improving women's attitudes toward science: Address the functions of the existing attitudes.

Conclusions

As described and supported in the above, attitude change instruction to improve women's attitudes toward science must:

1. Address the emotions that are associated with existing attitudes,
2. Involve credible, attractive women role models, and
3. Address the functions of the existing attitudes.

Specific instructional strategies to address each recommendation are given below. These guidelines are ideas that follow logically from the literature review, and do not make up an exhaustive list. Other techniques that follow the three recommendations could be developed and implemented.

The first recommendation is to address the emotions that are associated with existing attitudes. Four strategies could help to implement this recommendation.

1. Activate existing attitudes toward science early in the instruction (Kamradt & Kamradt, 1999).
2. Encourage learners to think about how they feel about science (Boler, 1999; Kamradt & Kamradt, 1999).

3. Encourage learners to discuss, perhaps in same-sex groups, their feelings about science (or the field associated with the instruction) (Boler, 1999).
4. Include language for discussing emotion in the instruction (Boler, 1999).

The second recommendation is to involve credible, attractive women role models. The six strategies below would help instructors meet this recommendation.

5. Hire women narrators for audio and video segments.
6. Choose images and language carefully to avoid masculine gender bias.
7. Actively include relevant contributions of women professionals in science.
8. Leave room in the curriculum for live and/or face-to-face meetings with successful women in science fields.
9. Include opportunities for learners to see models receive positive reinforcement for their attitudes toward science.

The third recommendation is to address the functions, especially the social-identity and value-expressive functions, of the existing attitudes. These strategies include three for social-identity functions of negative attitudes, and three more for value-expressive functions.

10. To address social-expressive functions, allow for cooperative, collaborative learning in science classrooms to illustrate the social nature of science.
11. Incorporate examples of collaboration among members of science.
12. Include in those examples discussion of the [generally positive] nature of collaboration in science.
13. To address value-expressive concerns, such as beliefs that science has no value to society, incorporate examples of innovations and techniques developed by members of the science community that address social issues important to women.
14. Incorporate elements of the subject that are relevant to women.
15. Incorporate examples of career options that allow for solving social problems.

The guidelines presented here are ideas, hypotheses. They are based on theories and quantitative and qualitative research on attitude change, feminism, and the nature of science. The next steps in the research were to design or modify existing instruction to incorporate these guidelines, implement the instruction in a science classroom, and test for attitude change. These steps are described in the following chapters.

Research Questions

The present research sought to answer five basic research questions. These questions are:

1. Will the incorporation of the recommended instructional strategies improve college students' attitudes toward science, as measured by the Test of Science Related Attitudes (TOSRA)?
2. Will the incorporation of the recommended instructional strategies improve women's attitudes more than men's, as measured by the TOSRA?
3. What is the process for attitude change, as reported by the learners, and does that process match Kamradt and Kamradt's (1999) Structured Design model for attitude change?
4. What are the conditions that inhibit attitude change, as reported by the learners?
5. Are there qualitative differences between processes and conditions of attitude change between men and women, as reported by the learners?

Methodology

This section describes the methods employed for answering the research questions posed above. It includes descriptions of the research design, study participants, the instructional and testing materials, the procedures, and the data analysis techniques used in the study.

Research Design

Because the research questions are both quantitative and qualitative in nature, the study design had to allow for the collection of relevant data of both types. The first two research questions are quantitative in nature. To answer these questions, a classic pretest-posttest control group design was used. Using standard notation (Campbell & Stanley, 1963), the basic study is summarized as such:

Treatment:	O	X	O (R)
Control:	O	X_{alt}	O (R)

Participants were randomly assigned to the treatment or control groups ("R" for random). Both groups received the pretest and posttest ("O" for observation). Only the treatment group received the treatment ("X"). The control group received an alternate treatment ("X_{alt}"). Measurement of the control group allowed for the identification and statistical removal of effects on attitude toward science that occurred for reasons external to the study (such as exposure to the subject, exposure to the pretest, or input from an excellent teacher).

Some attitude researchers discourage pretesting because the pretest itself can activate the attitude and cause attitude change, regardless of the treatment. The nature of the research questions of this study required a pretest because the objective was to discover attitude *change*, which can only be measured by finding the difference, or gain score, between scores on two tests. By conducting the pretest on both the experimental and control groups, the effects of the pretest could be statistically removed. Comparisons were made between the control and experimental groups, not between pre- and post-intervention attitudes.

Comparison of gain scores on the attitude tests provided the answer to the first research question, which is, "Will the incorporation of the recommended instructional strategies improve college students' attitudes toward science?"

Comparison of gain scores, in conjunction with demographic information collected from the participants, provided the answer to the second research question, which is "Will the incorporation of the recommended instructional strategies improve women's attitudes more than men's?"

The remaining three research questions are qualitative in nature, and required a content analysis of learners' journals gathered during the study. The first of these questions addresses the process for attitude change. Kamradt and Kamradt (1999) described their Structured Design model of attitude change. They provided theoretical support for their model, but practical research has not validated the attitude change process they outlined. This part of the content analysis sought evidence from the responses of learners whose negative attitudes improved the most to determine whether the process of attitude change matched, or failed to match, the Structured Design model. The analysis involved a search for ideas related to cognitive dissonance and the emotional, cognitive, and behavioral components of attitudes.

The second qualitative question addresses the conditions that inhibit attitude change. In spite of the incorporation of the recommendations for promoting attitude change, some learners with negative attitudes did not change their attitudes. The purpose of this analysis was to find out why. This part of the content analysis involved a search in the responses of learners whose negative attitudes did not change for conditions that seemed to preclude attitude change in the learners.

The final qualitative research question asks whether there were differences in the responses of men and women that are related to the process of attitude change or the conditions that inhibit it. Data analyzed to answer the previous two questions were separated by gender of the learner. The data from the two groups were then compared to answer the final question.

Participants

Participants were selected from a number of sections of introductory science classes at Radford University and Virginia Tech. At Radford University, two geology professors and three chemistry professors encouraged their students to participate. At Virginia Tech, one chemistry professor encouraged students to participate. All the students were enrolled in introductory physical geology, introductory chemistry, or introductory physical science. All the professors but one offered some form of grade credit for participating, up to an additional 2% on their final class grade. Participants could drop out of the study at any point; however, if they dropped out, they were not recommended for receiving credit.

All the participants electronically signed an informed consent form that was approved by the Institutional Review Boards (IRBs) of both Virginia Tech and Radford University. The IRB approvals and informed consent form are included in Appendix A.

There were 281 participants in the study who completed all the steps. Of those, 40.3% were men and 59.7% were women. The majority of the participants were typical students in introductory science classes: single college freshmen under the age of 22 who were taking the course because it was required. Single people made up 96.1% of the sample. Eight participants (2.8%) were married; one (0.4%) was divorced. College freshmen made up 53.7% of the sample. The rest of the participants were about evenly divided among the sophomore (18.6%), junior (16.6%), and senior (10.2%) levels, except for two participants (0.7%) who were not seeking degrees. Nearly all the participants (98.2%) were under age 22. Two participants (0.7%) were in their thirties, and three (1.1%) were in their forties. As expected, most of the participants (84.8%) were enrolled in a science class because it was required; 14.0% considered the class an elective. Three participants (1.1%) did not answer the survey question about why they were taking the class.

None of the participants expected to fail the science class in which they were enrolled. Most of the participants (52.9%) expected to make a B. The rest expected to make an A (22.3%), a C (20.9%), or a D (4.0%)

Sixty-two percent of the participants were students at Virginia Tech; the rest were students at Radford University. Most of the students (70.3%) were in chemistry classes; the rest (29.7%) were enrolled in geology classes. All of the geology students went to Radford University. Of the chemistry students, 88.9% were students at Virginia Tech; the rest (11.1%) went to Radford University.

Because some participants dropped out of the study, the experimental and control groups were not exactly the same size. The experimental group included 139 participants (49.1%), whereas the control group included 143 participants (50.1%).

Data Collection Materials

Materials for the study included a demographics questionnaire, the attitude assessment called the Test of Science Related Attitudes, and the instructional materials used in the modules. These materials are described in more detail below.

Demographics Questionnaire

Demographic information about participants was collected in a short questionnaire at the beginning of the study. Participants were asked to give their gender, age range, marital status, year in school, major, professor, reason for taking the class (required or elective), and grade expected in the class. Data were collected using the online survey program *survey.vt.edu*.

Test of Science Related Attitudes

The Test of Science Related Attitudes (TOSRA, Fraser, 1978, 1981) was used as the measurement tool in this study. It is "one of the most frequently used instruments to measure science-related attitudes" (Laforgia, 1988, p. 415). In a meta-analysis of studies of attitudes toward science, researchers evaluated the TOSRA as "particularly outstanding" because of its "sound theoretical basis" (Haladyna & Shaughnessy, 1982, p. 549). The test measures "science-related attitude" by assessing attitudes toward the following seven concepts:

1. Social implications of science,

2. Normality of scientists,
3. Attitude toward scientific inquiry,
4. Adoption of scientific attitudes,
5. Enjoyment of science lessons,
6. Leisure interest in science, and
7. Career interest in science.

The concepts were derived from attitude objectives important to science identified by Klopfer (1971) in a chapter in the *Handbook on Formative and Summative Evaluation of Student Learning* (Bloom, Hastings, & Madaus, 1971). Klopfer created his list of "attitudes and interests" from the "categorization of aimed-for or hoped-for attitudes and interests that are frequently stated by science teachers and curriculum builders" (1971, p. 576). Klopfer cited Krathwohl and others' (1964) well known hierarchy of affective objectives, but did not base his organizational scheme on it. Klopfer's six scales "do not pretend to be a complete taxonomy of the affective domain as it pertains to the student's learning of science" (1971, p. 576). Rather, the concepts identified are ones for which "probably every teacher of science hopes" (p. 577).

Klopfer defined his six categories as follows:

1. Manifestation of favorable attitudes toward science and scientists.
2. Acceptance of scientific inquiry as a way of thought.
3. Adoption of "scientific attitudes."
4. Enjoyment of science learning experiences.
5. Development of interests in science and science-related activities.
6. Development of interest in pursuing science as a career.

During the development of the TOSRA, Fraser divided one of Klopfer's objectives, "manifestation of favorable attitudes toward science and scientists," into two separate concepts in the TOSRA, "social implications of science" and "normality of scientists." Fraser's table (1978) illustrating the parallels between his subscales and Klopfer's (1971) categories subscales is presented as Figure 5.

Scale (Fraser, 1978)	Classification (Klopfer, 1971)
Social implications of science	Manifestation of favorable attitudes toward science and scientists.
Normality of scientists	
Attitude toward scientific inquiry	Acceptance of scientific inquiry as a way of thought
Adoption of scientific attitudes	Adoption of “scientific attitudes”
Enjoyment of science lessons	Enjoyment of science learning experiences
Leisure interest in science	Development of interests in science and science-related activities
Career interest in science	Development of interest in pursuing a career in science

Figure 5. Comparison of Fraser's subscales and Klopfer’s classification.

The test was initially used for secondary school students in Australia in 1977. The author of the test measured the reliability of the seven subscales of the TOSRA for Australian high school students (Fraser, 1981). Attitude researchers recommend a reliability of .70 or higher (Henerson, Morris, & Fitz-Gibbon, 1978). The average reliability of the seven subscales was α = .84 for students in Year 10 (high school), meaning 84% of the variance in scores can be attributed to systematic variance, leaving only 16% attributed to error. Reliability of the seven subscales ranged from α = .67 for “adoption of scientific attitudes” to α = .91 for “career interest in science.” These reliability values represent an acceptable level for tests in social science. The average test-retest reliability of the seven subscales was .78; scores for individual subscales ranged from α = .69 for “normality of scientists” to .84 for “career interest in science.”

These relatively high reliability values indicate that the test is sufficiently reliable for the purposes of this research.

In 1982, the test was given to high school girls in Philadelphia (Fraser & Butts, 1982). Reliability measurements from the United States were very similar to Australian results, leading Fraser to conclude that the data “support the cross-cultural validity of TOSRA for use in the United States” (Fraser, 1981, p. 6). Other researchers found similar reliability values for the test when they studied high school students in the United States (Khalili, 1987; Smist et al., 1994). Cronbach’s alpha was also calculated based on the data collected in this study.

The distinctiveness of constructs, often called discriminant validity, is based on correlations between scores on the different subscales (Pedhazur & Schmelkin, 1991). If correlations between two subscales are too high, it can be argued that the two subscales actually measure the same thing. For each of the seven subscales of the TOSRA, Fraser (1981) found the mean of the correlations with the other subscales. The average of these means was .33. The subscale with the highest of these means was “career interest in science” which averaged a .40 correlation with the other subscales. The lowest was “attitude toward inquiry,” which averaged a .13 correlation with the other subscales. The low correlation values indicate acceptable discriminant validity, meaning that the subscales measure different things, as they were intended.

Later research on the TOSRA found that the discriminant validity among the seven scales was not so low as Fraser found. These studies were conducted on older high school students in the United States. Khalili (1987) and Smist et al. (1994) conducted factor analyses on data from the test. Both studies found that “leisure interest in science” and “career interest in science” loaded together. Khalili’s study also found that “enjoyment of science lessons” loaded on the same factor. Both studies found that “social implications,” “normality of scientists,” and “attitude toward inquiry” loaded on separate factors as expected. The last scale, “adoption of scientific attitudes” did not load on any factor in either study. In Khalili’s study, discriminant validity of the scales ranged from a low of .22 (“normality of scientists” scale) to a high of .65 (“enjoyment of science” scale). Khalili found the average discriminant validity across the scales to be .50, much higher than Fraser's .33.

For the purposes of this study, the TOSRA was split in half for a pre- and post-testing to measure attitude change. This application of the instrument was recommended by its author (Fraser, 1981).

A pilot test of the TOSRA was run on members of the target population for this study. Forty undergraduate students enrolled in introductory geology classes responded to both the pre-test and post-test halves of the TOSRA. The information collected from this test was used to field check the reliability of the TOSRA on the target population of undergraduate students in science classes, because earlier work with the instrument was done on high school students.

From the pilot test data, the reliability was calculated using Cronbach's alpha, and was found to be $\alpha = .82$, which is very close to the reliability estimate ($\alpha = .84$) that the author of the TOSRA found for the oldest group of high school students he studied in the early uses of the test (Fraser, 1981). From this comparison, the researcher concluded that the TOSRA was a viable test for college students in introductory science classes.

Instructional Materials

The instructional materials for the study consisted of four web-based, asynchronous modules. Two modules were developed based on the design recommendations identified in the literature review. These modules were used for the experimental group. The other two modules, developed for the control group, were neutral and not based on the recommendations. The instructional design process for the experimental modules is discussed in this section. Following that discussion, the experimental and control modules are described.

Instructional Design

The three design recommendations identified in the literature review drove the development of the instruction. Those recommendations are:

1. Address the emotions that are associated with existing attitudes,

2. Involve credible, attractive women role models, and
3. Address the functions of the existing attitudes.

Structured Design (Kamradt & Kamradt, 1999) inherently incorporated recommendations 1 and 3, which are concerned with existing attitudes. Emotions associated with existing attitudes were the emotional component of attitudes as described by Kamradt and Kamradt because learners were asked how they felt. The functions of existing attitudes were both activated and addressed in the technique. For example, assume that a learner does not want to be perceived as a social outcast, and therefore objects to socializing with scientists, whom she believes are social outcasts. Her attitude serves a social expressive function. To change the attitude, the instructor would address the learner's cognitive belief that scientists are social outcasts by introducing her to scientists with healthy, substantial social structures. By addressing the undesired attitudes in the domain that is the basis for the attitude's function, the attitude can be changed.

The remaining recommendation, the involvement of women role models, can be incorporated into nearly any instruction, including that based on Structured Design. In this instruction, the learners were introduced to professional women scientists as part of the instruction to change negative attitudes based on cognitive beliefs about who scientists are, what they look like, and what they do in their spare time.

Structured Design. In order to teach attitude change, Kamradt and Kamradt (1999) outlined a specific process. First, the instructor should activate the attitude by presenting a problem situation that calls for an attitude slightly different from the existing attitude of the target audience. The participants "solve" the problem. Then, the instructor asks students how the situation made them feel, what they thought, and what they did. These questions correspond to the emotional, cognitive, and behavioral components of the attitude. The instructor then begins instruction that corresponds to the most dissonant component, which may be anticipated during the design phase of the instruction. Following the instruction, the instructor uses a review and transfer technique to consolidate the attitude.

Structured Design requires the facilitator or instructional designer to anticipate and prepare for objections that learners will necessarily raise to tasks that are counter to their current attitudes. (Recall that raising objections is part of how the learner activates the attitude to be changed.) Three basic steps are essential to designing instruction based on this technique. First, the designer must identify a situation or task that would serve to activate existing attitudes by creating dissonance. Second, the designer must anticipate likely objections to the situation or task. Finally, the designer must develop domain-specific responses to the objections to help the participants to change their attitudes. A sample worksheet for the process is included as Figure 6. A more detailed description of the three steps is described in the paragraphs below.

Task	**Objection**	**Domain**	**Response**
Learn about a lot of scientists.	Scientists are nerds. I can't do it.	Cognitive Emotional	New information Reassurance

Figure 6. Sample worksheet for developing instruction based on Structured Design.

Instructional objectives. As with any instructional design project, an early step in the process was to define instructional objectives. The underlying objective was, of course, to improve women's attitudes toward science. To test the instructional design guidelines, however, the guidelines identified in the literature review had to be applied in conjunction with common instructional objectives. The guidelines would not be useful if they could only be used in instruction whose sole objective was to improve attitudes. Rather, they should be able to be incorporated with instructional objectives that are already part of introductory science classes.

For this study, two topics were chosen that were relevant to introductory geology and chemistry classes so that both types of classes could participate in the study. The topics were "Scientists" and "Minerals."

After completing the Scientists module, students were expected to be able to:

1. List at least three different types of jobs that scientists have.
2. Describe a "typical" scientist, including references to gender, value of work, and activities outside of work.

After completing the Minerals module, students were expected to be able to:

1. Describe the importance of minerals to our way of life.
2. List and define common physical and chemical properties used to identify minerals.
3. Give the uses of common rock-forming minerals.
4. Identify the specific physical and chemical properties that make common minerals useful.
5. Describe social and environmental issues associated with mineral exploration and mining.

Formative evaluation. Early testing of an instructional module, including testing apparent effectiveness and instructional logistics, is an important part of the instructional design process, and is referred to as formative evaluation.

The Scientists module was initially designed as a synchronous module to be delivered via video-teleconferencing technology for a course project. The module was produced for 13 graduate instructional technology students in two locations. The principal investigator and three other graduate students in the instructional technology program collaborated to develop the instruction. The students in the audience for this instruction were not members of the target population, but were subject matter experts in instructional design and technology.

The students were told that they should imagine themselves in the first day of an introductory geology class. Then they were presented with the following scenario, which was designed to activate their existing attitudes:

> Angela is a serious student who has been accepted to a college and has been given as choice of freshman dorms to live in for next year. She can live in a freshman study dorm or the science dorm. The science dorm is usually reserved for those students pursuing science studies, but this

year there are openings for students who have not yet declared a major. Both dorms are identical in space, décor, and amenities. In either case, she will not know who her roommate will be in advance of move-in. Put yourself in Angela's shoes and answer each of these three questions: How do you feel? What are you thinking? What will you do?

The students were asked to write their answers to the three questions. Following the response time, a researcher presented short biographies, photographs, and quotations from four scientists. Finally, the students responded to a survey that included the ten TOSRA statements relating to the normality of scientists, the statement "I was surprised by some of the information in the presentation," the statement "I enjoyed the instruction," and the statement, "My attitude toward scientists changed today." Students indicated whether they strongly agreed, agreed, were not sure, disagreed, or strongly disagreed with each statement. Finally the students were debriefed about the purpose of the instruction.

The formative evaluation produced two types of results: (a) data gathered through direct observation of the students interacting with the scenario and response and (b) concrete survey data and written responses. Both types are discussed below.

During the instructional period, students wanted to know more about the fictional student, Angela. They felt they needed more information to make the decision about where she was to live. Students also wanted to know more about the science dorm and the freshman study dorm. They wanted to know what the exercise had to do with geology. In conversations after the presentation of scientists, several students asked about the source of the information about the scientists. Several students doubted that the scientists presented were real people.

Thirteen students responded to the survey. When their scores on the ten TOSRA questions were averaged, their attitude toward the normality of scientists ranged from 2.7 to 4.9 (where 1 indicates a very negative attitude and 5 indicates a very positive attitude). All 13 students agreed or strongly agreed with the statement, "I was surprised by some of the information in the presentation." Nine students agreed or strongly agreed with the statement, “I enjoyed the instruction.” Eight students agreed or strongly agreed with the statement, “My attitude toward scientists changed today.”

Written responses varied widely. On the “How do you feel” question, one group wrote that they felt relieved that their similar class presentation was already over. Other feelings included *wary, baffled, anticipating*, and *good*. One group did not include any words that could be considered feeling words.

All of the groups wrote something relevant for the “What are you thinking” question. One group explicitly stated that they “need[ed] more information,” and another only wrote questions, such as “Which dorm works best for studying/social?” Another group wrote, “She is serious so she would want to be around people like her (thinking that science students are more serious).” The fourth group wrote, “Science dorm would be better if major is science or somewhat related.”

For the question of what they would do, one group chose not to make a decision, but to contact a Resident’s Assistant (RA) to get more information. The second group chose the freshman dorm, but also indicated a need for more information. The final two groups chose the science dorm. One of those explained, “because may have opportunity to share interests with students of similar interests.”

The formative evaluation revealed that the scenario was distracting to the learners and failed to activate their attitudes toward scientists. Learners did not put themselves in the shoes of the imaginary “Angela”; rather, they tried to imagine what she was like and what would be best for her. The participants spent considerable time dissecting the language of the scenario to determine what kind of person she was. Because of this response, the scenario was removed from the instructional module. The instruction was modified so that the counter-attitudinal task was completing an instructional module on a science topic.

Following the formative evaluation, the instructional module was redesigned for asynchronous web distribution. Using the information gathered from the formative evaluation, the second module was developed to describe the social benefits and issues related to minerals.

Asynchronous module development. Kamradt and Kamradt's Structured Design attitude change model (1999) was designed for face-to-face instruction. A major challenge in the development of this instruction was the adaptation of the process for mediated instruction.

The first step was to identify situations that would activate the existing attitude. The learners were asked to do a task that was in line with the desired attitude. In this case, the learner was asked to work through an instructional module on a science topic. If the learner had no problem with the task, his or her attitude did not need changing. However, if the learner did have a problem with the task, he or she would be likely to voice objections. In the mediated instruction designed for this research, no instructor was present to hear the objections. Therefore, the instruction included an opportunity for learners to journal their initial reaction, which was intended to activate the attitude.

In the study, the learners were informed of the learning objectives at the beginning of each module. Immediately after the objective presentation, the learners were asked to journal about how they felt (emotional) about studying the topic, what they thought (cognitive) or already knew about the topic, and what they thought they would do (behavioral) during the instructional module.

In face-to-face instruction, the next step would be to react to specific objections raised by the learners. In the mediated instruction, the instructional designer had to instead anticipate likely objections to the attitude-activating situations, and group those objections according to the attitude component they represent. Likely objections to science instruction were identified during the literature review for this study. Each potential objection was classified as emotional, cognitive, or behavioral.

Finally, component-specific responses were prepared for each common objection to the task. For example, an objection in the cognitive domain was held because it was based on a belief. The appropriate response was to introduce the learner, personally or in a mediated way, to new information that was counter to that belief.

The instructional strategy fit with Kamradt and Kamradt's model. Their model can be simplified into four steps: 1) activate the attitude; 2) diagnose the dissonant component; 3) address the most dissonant component; and 4) consolidate the attitude. A table showing how the steps in the instruction fit Kamradt and Kamradt's model is presented in Figure 7.

Kamradt & Kamradt's model	Instructional component
1. Activate the existing attitude.	The introduction, which let participants know they would be completing a science module, served to activate the existing attitude.
2. Diagnose the dissonant component.	The journal entry, which was prompted with specific questions to address the emotional, cognitive, and behavioral components of the attitude. The dissonant component was anticipated before the instruction. The journal entry was designed to help validate assumptions made and to activate the existing attitude.
3. Address the most dissonant component.	The "information presentation" of the instruction was designed to address the component assumed most dissonant.
4. Consolidate the attitude.	The final journal entry encouraged participants to reflect on changing attitudes.

Figure 7. Comparison of Kamradt and Kamradt's technique with instructional components.

Experimental Modules

The instruction consisted of two modules designed for asynchronous delivery via the World Wide Web. The instruction was asynchronous and web-based to ease the distribution of the instruction to diverse geographic locations and to promote objectivity.

Instructional materials for these modules are included as Appendices B and C. The modules are described below.

Each module targeted attitude change on a subscale on the Test of Science-Related Attitudes (TOSRA). Each began with an introduction, in which the participants learned the topic and instructional objectives for the module. The next page asked participants to journal their cognitive, emotional, and behavioral responses to the idea of studying the topic presented. A short page explaining the pages to come preceded the ten content pages. Following each content page, participants were asked to write (and submit online) three things they remembered from that page. After the tenth response, participants were tested on their ability to meet the instructional objectives using free recall questions, and then asked to respond to the module for a final journal entry.

The Scientists module (Appendix B) was designed to improve participants' attitudes toward the normality of scientists. The module included ten scientists who were chosen based on their appeal to the target population. They were young, normal, attractive people with interesting hobbies. The scientists included six women and four men chosen from the Planet Science website. Planet Science is a website for science students and teachers that is funded by the National Endowment for Science, Technology, and the Arts (NESTA), a British organization. Some information from each chosen scientist's interview page was used in a reformatted page for the module. British spelling and usage was edited out.

The Minerals module (Appendix C) was designed to improve participants' attitudes toward the social value of science. It was assembled from a variety of web, print, and electronic sources. Minerals were featured that benefit or otherwise affect society. They were also chosen based on their usefulness for teaching basic concepts, such as the physical and chemical properties used to identify minerals. Some content was chosen because of its local relevance. All the content was developed with the instructional guidelines for improving women's attitudes toward science in mind.

Control Modules

Two additional modules were developed for the control group. Instructional materials for the control group modules are included as Appendices D and E. The information from these modules came directly from existing web modules on water and acid rain published by the United States Geological Survey (USGS). These modules contained an introductory page, ten content pages, and ten response pages. There were no journaling activities before and after these modules. In addition, care was taken not to incorporate the instructional guidelines for improving women's attitudes toward science. For example, masculine gender bias in language and pictures was left in place. No women or social issues were included in the presentation. Participants in these modules were not asked to write about their emotions.

Procedures

The study procedures included a pilot test and data collection.

Pilot Test

The entire study was piloted by ten volunteers who were experts in geology, chemistry, or instructional technology. They were asked to review the materials, identify any problems with the interface, and enter something in each of the data fields so that the researcher could verify that the interface was working properly. No data were analyzed quantitatively or qualitatively from this part of the pilot test.

This test revealed a number of issues that were corrected prior to the study's implementation. For example, users who followed a web link to a list of feeling words were disappointed to find that their previous entries were lost when they returned. This link was modified so that the page opened in a new window. Mistakes in the design, such as an omitted login prompt, were also identified and corrected.

Data Collection

Data were collected in October and November 2004. The professors who agreed to participate forwarded the link to begin the study to all their students. Those students who wished to participate did so by clicking on the link in the email from their professors.

The link took participants to the asynchronous modules' web pages stored on the principal investigator's online institutional "Filebox." Data collection pages were managed by the principal investigator using the online survey program provided by the institution (survey.vt.edu).

After signing an informed consent form, all participants initially signed in to the web interface using their email addresses. All participants then took the pretest and entered demographic information, including gender, age, marital status, year in school, major, professor, reason for taking the class, and grade expected in the class. At the end of the pretest, participants were informed that they would receive an email message the following week with additional instructions. The texts of all the routine email messages sent during the study are included as Appendix F.

As participants entered the study, they were randomly assigned to either the experimental group or the control group. Experimental group members were randomly divided in half again. Group A completed the Scientists module first, whereas Group B completed the Minerals module first. This grouping was made to eliminate any order effects in the two modules. The control group was labeled Group C.

In the following two weeks, each participant received an email message that included a link to the next module he or she should complete. In the fourth week of the study, participants received an email message with a link to the TOSRA posttest. A table of the study schedule is presented as Figure 8.

	Group A (exp)	Group B (exp)	Group C (control)
Week 1	Pretest	Pretest	Pretest
Week 2	Minerals	Scientists	Water
Week 3	Scientists	Minerals	Acid rain
Week 4	Posttest	Posttest	Posttest

Figure 8. Study schedule

Participants never came face to face with the project investigator; their entire interaction in the study was via the web, email, and their own professor. For the most part, email messages to the participants were simply instructions, reminders, and confirmations. Because of the course credit involved, participants were always encouraged to email the principal investigator if they encountered technical problems. Figure 9 lists each week's tasks for the principal investigator.

The data were managed using the online survey program *survey.vt.edu* and using several Microsoft™ Excel spreadsheets. One spreadsheet was used to manage the demographic, pretest, posttest, and module completion data. Separate spreadsheets were used to manage the journal and response data from each module. Because of limitations of the online survey program, responses to each page in the study were recorded as separate surveys. The principal investigator used the participants' email addresses to align responses from each question.

Pre-study	Contact chemistry and geology professors at Radford University and Virginia Tech. Send information sheet.
Week 1	Send informed consent link to all professors who agreed to participate.
	Download and organize pretest data as participants begin the study.
	Assign participants to experimental or control groups.
Week 2	Send link for appropriate module to all three groups. Set deadline for Friday at 5:00 p.m.
	Wednesday: Send reminder email with Friday 5:00 p.m. deadline to all who have not completed module. Send confirmation email to all who have.
	Thursday: Continue sending confirmation emails as participants finish.
	Friday after 5:00: Send link for week 3 module to all who have completed week 2. Send "last chance" email to those who have not finished. Extend deadline to Sunday at 5:00 p.m.
Week 3	Continue sending link for week 3 as participants complete work for week 2.
	Wednesday: Send reminder email with Friday 5:00 p.m. deadline to all who have not completed module. Send confirmation email to all who have.
	Thursday: Continue sending confirmation emails as participants finish.
	Friday after 5:00: Send link for postttest to all who have completed week 3. Send "last chance" email to those who have not finished. Extend deadline to Sunday at 5:00 p.m.
Week 4	Continue sending link for week 4 as participants complete work for week 3.
	Wednesday: Send reminder email with Friday 5:00 p.m. deadline to all who have not completed posttest. Send confirmation email to all who have.
	Thursday: Continue sending confirmation emails as participants finish.
	Friday after 5:00: Continue sending confirmation emails as participants finish. Send "last chance" email to those who have not finished. Extend deadline to Sunday at 5:00 p.m.
Post-study	Email participants who did not list their professor in pretest to find out who should get their data.
	Email participants who used a commercial email address to learn their school addresses.
	Send lists of participants by professor to participating professors for extra credit assignment.

Figure 9. Task list of principal investigator by week.

Data Analysis

Quantitative Data Analysis

The following quantitative information was collected for each participant: demographic information, group membership (control or experimental), pretest attitude score, and posttest attitude score. The primary purpose of the quantitative analysis was to answer the first two research questions of the study:

1. Will the incorporation of the recommended instructional strategies improve college students' attitudes toward science?
2. Will the incorporation of the recommended instructional strategies improve women's attitudes more than men's?

The first question was answered by using an independent t-test to compare the gain scores of the experimental group with the gain scores of the control group. The statistics program SPSS was used for the quantitative data analysis. Pretest TOSRA scores were first subtracted from posttest TOSRA scores to compute a gain score for each participant. Then the gain scores of the two groups were compared using an independent t-test.

To answer the second question, the analysis included conducting an independent t-test on the gain scores to compare how men's attitudes changed as compared with how women's attitudes changed. If this hypothesis were correct, women's gain scores should be higher than men's.

Qualitative Analysis

During the course of the study, each participant in the experimental group wrote responsive journals. Some of these journals were analyzed qualitatively to find the answers to the three remaining research questions:

3. What is the process for attitude change, as reported by the learners, and does that process match Kamradt and Kamradt's (1999) Structured Design model for attitude change?

4. What are the conditions that inhibit attitude change, as reported by the learners?
5. Are there qualitative differences between processes and conditions of attitude change between men and women, as reported by the learners?

Twice during each module presentation, learners in the experimental group were asked to respond to the instruction by writing a journal entry. Immediately after being exposed to the instructional objectives, learners were prompted to write a journal on their response to the idea of learning about the science topic. Learners responded to prompts designed to elicit answers to the three questions identified by Kamradt and Kamradt (1999): how you feel, what you think, and what you do. These questions correspond to the three components of attitudes.

For example, the three journal prompts for the Scientists module were:

1. How does knowing that you are about to learn about scientists make you feel? Write a paragraph or two about your feelings below. (At a loss? Click for a list of feeling words.)
2. What do you already know about scientists? Can you already list three types of jobs scientists do? How would you describe a typical scientist? Write a paragraph or two about your thoughts below.
3. How do you think you will approach this module? What will you do? Will you go through it as fast as possible or will you do it slowly? Will you work on it by itself or will there be other distractions? Write a paragraph or two about what you think you will do during the module.

Following the module presentation, the learners wrote another journal entry, this time on their responses to the information presentation. For the Scientists module, the prompt read:

4. Take a minute to reflect on the scientists you just ‘met.’ Were you surprised? Why or why not? Are they people you would like to meet in person? Why or why not? Write a few paragraphs to respond to this module.

The qualitative data analysis included both inductive and deductive techniques. The first of the qualitative research questions was answered using analytic induction. That is, the journals were examined for theoretical concepts related to Kamradt and Kamradt's (1999) theory of attitude change. Analytic induction is a "strategy for engaging in qualitative inquiry … that includes examining preconceived hypotheses, that is, without the pretense of the mental blank slate" that is required by other forms of qualitative research (Patton, 2001, p. 493). The remaining two research questions were answered using deductive content analysis.

In conducting any content analysis, it is important to define clearly what the data are, from what population they are drawn, from what context are they drawn, what the boundaries of the analysis are, and what purpose is served by the inferences made (Stemler, 2001). In this research, the data were journals solicited during the administration of the instructional modules. They were drawn from the population of all the study participants. The method for selecting the samples is described below. The boundaries of analysis are the natural boundaries of the journal entries themselves; although participants wrote other things as part of the study, only responses to journal prompting questions were considered. The purpose of the content analysis was to identify the processes of attitude change, validate or invalidate Kamradt and Kamradt's (1999) Structured Design model for attitude change, to identify conditions that impede attitude change, and to determine whether there were qualitative differences between men's and women's responses.

Journals for qualitative data analysis were selected based on preliminary analysis of the quantitative data. The control group was omitted, because participants in this group did not write journals. Then participants whose initial attitude scores on the Normality of Scientists subscale were equal to or higher than the midpoint of 15 were omitted to concentrate on participants who began the study with relatively negative attitudes toward the normality of scientists. From the 50 participants who remained, those with the highest nine gain scores (gain scores of 10 points or higher) were selected for qualitative journal analysis. Those with the nine gain scores closest to zero (5 points or lower) were selected for analysis of participants whose attitudes did not change.

Initially, the investigator also planned to use data from participants with the 25 lowest and highest gain scores. If those participants had been included in the qualitative analysis, there would have been no difference in gain scores between the lowest of the high and the highest of the low. By using data from participants with the nine lowest and highest gain scores, the difference was increased to 5 points. The range of gain scores for this group was from 0 to 12 points. The 5-point difference between the two halves, then, represents 42% of the maximum difference in this group.

The data were coded using an emergent coding system. First, the investigator read all the journals to identify recurring themes. A preliminary list of coding themes was generated from this reading. Then the journals were read again and compared to the coding theme list to identify additional themes so that the coding scheme would meet the criteria that it be exhaustive. Additional themes were added to the list, and coding rules were refined. During the third reading, the investigator marked meaning units with the code identifications. Finally, for a fourth reading, the investigator used spreadsheet software to cut and paste meaning units into categories defined by the coding scheme. Data in the spreadsheet were then checked to ensure that they were coded properly.

To ensure the reliability of the coding scheme, the coding scheme and data were given to another researcher following complete coding by the principal investigator. That researcher coded the data, and the results were compared to ensure that another person would code the data the same way. After the first iteration of the other researcher coding the data, the coding scheme was revised, simplified, and clarified. Then the coding process was repeated by both researchers. In this iteration, the two researchers coded 92% of the qualitative data in the same way.

The validity of the coding process was tested by comparison to the learners' TOSRA score. If the journal entries seemed to indicate a positive attitude toward science while the learners' score indicated a negative attitude, the data from that participant were deemed not valid, and was omitted from the analysis. This validity check was intended to remove participants who do not give consistent answers. No participants were removed during the validity check.

Research question 3, the first of the qualitative questions, asked what the process was for attitude change and whether that process fit the theoretical process described by Kamradt and Kamradt. To answer this question, the post-module journals from participants whose attitudes *did* change were analyzed for themes that matched the Structured Design theory. Four premises of Structured Design were used for the analysis: (a) attitudes fulfill human needs, (b) attitudes exist along a continuum from the most positive to the most negative, (c) attitudes are made up of emotional, cognitive, and behavioral components, and (d) shifts in the emotional, cognitive, and behavioral components occur in parallel with the other components.

In answering research question 4, the researcher hoped to identify conditions that preclude or hinder attitude change. To answer this question, content analysis data from pre-module journals of the changed-attitudes group were compared with data from the unchanged-attitudes group. The participants who mentioned specific themes in each group (changed attitudes and unchanged attitudes) were counted. These counts were compared between the two groups to see where differences occurred. If the difference in counts was three or greater (out of the nine possible), that theme was examined in depth. For example, if three people in the changed group mentioned a theme, and six people in the unchanged group mentioned the same theme (a difference of three), that theme was considered for further analysis. For some themes, data were coded differently by the two researchers. These themes were only considered for analysis if the difference was three or greater in both researchers' coding.

To answer the final question, the coded information was separated by the gender of the learners. Each gender's coded information was then analyzed separately to identify the prevalent themes for the gender. Three groupings of participants were used in the comparison of data by gender: the changed attitude group, the unchanged attitude group, and all the participants whose data were analyzed qualitatively. Because of differences in the numbers of men and women in each group, percentages of participants responding were compared across the genders. For all three groups, if the difference between genders in number responding was greater than 50%, the coded idea was considered for further analysis.

Results

The purpose of this study was to determine whether implementing certain instructional guidelines in introductory college-level science classes would improve women's attitudes toward science. Results of the study are both quantitative and qualitative in nature. Quantitative results are gleaned from participants' responses to a pre-test and post-test that measured their attitudes toward science. Qualitative results come from participants' journals that they wrote during each instructional module. The results of the study are summarized in this section.

Quantitative Results

The first two research questions lent themselves to quantitative data analysis. They are:

1. Will the incorporation of the recommended instructional strategies improve college students' attitudes toward science, as measured by the Test of Science Related Attitudes (TOSRA)?
2. Will the incorporation of the recommended instructional strategies improve women's attitudes more than men's, as measured by the TOSRA?

Results regarding initial attitudes toward science and order effects, as well as results for these two research questions, are discussed in this section.

Initial Attitudes toward Science

Participants' initial attitudes toward science were assessed using the Test of Science Related Attitudes (TOSRA). The TOSRA pretest is a Likert test consisting of 35 questions. On each question, subjects indicate their level of agreement with statements on seven subscales related to science attitudes. Scores for each question range from 1 to 5, with lower values indicating more negative attitudes toward science. TOSRA pretest scores could range from 35 to 175, a range of 140 points. A score higher than the midpoint of 105 indicated a relatively positive attitude toward science; lower than 105 indicated a relatively negative attitude.

The mean of the TOSRA pretest scores for all participants was 116.75, eleven points higher than the midpoint of the test. The maximum pretest score was 149; the minimum was 80. The range of pretest scores varied over 69 points, which translates to about 49% of the possible range. Frequency data from TOSRA pretest scores are presented in Figure 10. The mean of women’s pretest scores was 116.07. The mean of men’s pretest scores was 117.78. There was no significant difference in attitudes toward science between men and women at the beginning of the study.

On each of the seven subscales of the TOSRA, scores could range from 5 to 25; therefore, a score below the midpoint of 15 indicated a generally negative attitude for that subscale. The participants gave overall positive responses toward the social value of science (mean subscale score of 19.55), scientific attitudes (m=18.62), attitudes toward inquiry (m=17.81), attitudes toward science classes (m=16.46), and attitudes toward careers in science (m=16.18). The participants had overall negative attitudes regarding the normality of scientists (m=14.90) and leisure interest in science (m=13.23).

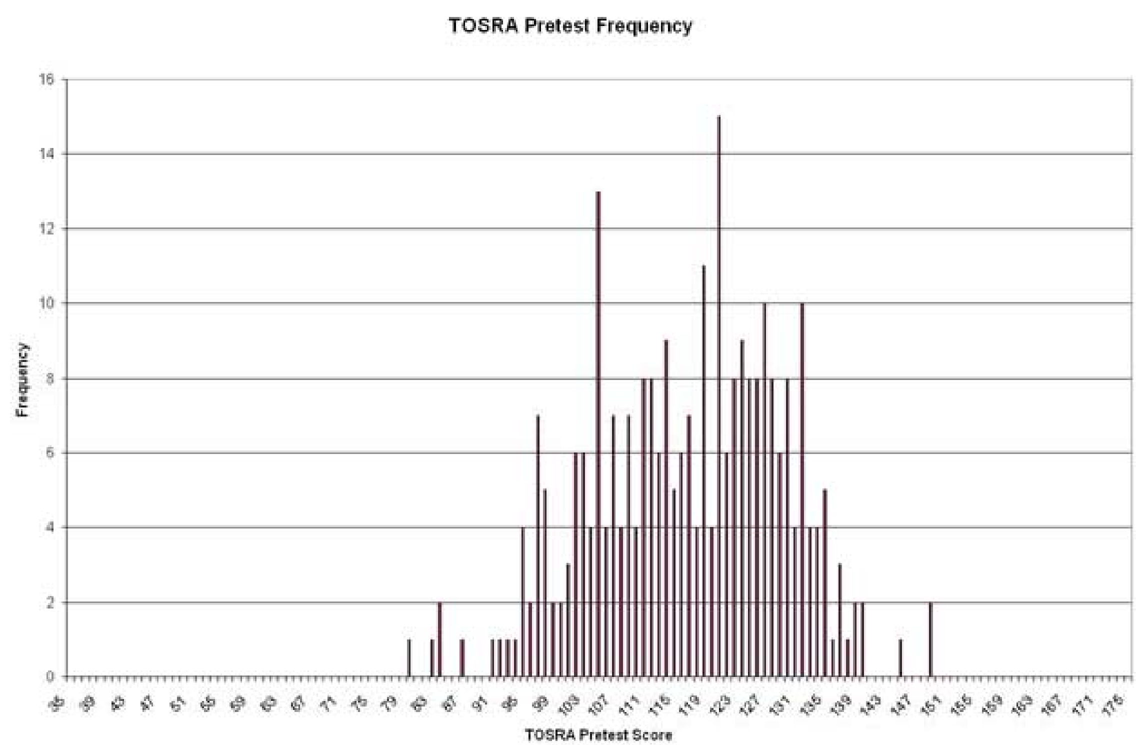

Figure 10. Pretest frequency data plot

There was no significant difference in initial attitudes toward science between the experimental and control groups, $t(280) = 0.406$, $p > .05$. (This t-test failed Levene's test for equality of variances; therefore, values for "equal variances not assumed" were used in this report.)

Most of the participants started the study with positive attitudes toward science, as defined by a score of 105 or higher on the TOSRA pretest. Because the objective of this study was to improve negative attitudes toward science, the researcher was most interested in the minority who began with negative attitudes toward science.

Sixty-three of the participants (22.4%) began the study with a negative attitude toward science, as defined by a score of 105 or lower on the TOSRA pretest. They included 22 men (34.9%) and 41 women (65.1%). All of them were age 22 or younger. Nearly all of them (96.8%) were single. One was married, and one did not respond to the marital status question. They were mostly freshmen (54.0%), but included sophomores (25.4%), juniors (12.7%), and seniors (7.9%). More than half (54.0%) were students at Virginia Tech; the rest went to Radford University. Eighty-six percent were taking their science class because it was required; the rest considered it an elective. Eight of the participants (12.7%) expected to make an A in the class, 31 (49.2%) expected a B, 16 (25.4%) expected a C, and the remaining eight (12.7%) expected a D. Of the "bad attitude" group, 26 (41.3%) were in the experimental group and 37 (58.7%) were in the control group.

Order Effects

About half of the participants in the experimental group (51.8%) did the Minerals module first and the Scientists module second. The other half (48.2%) completed the modules in the opposite order. A t-test on the gain scores of the two groups revealed no significant order effects on attitude change, $t(137) = 0.137$, $p > .05$.

There were also no significant order effects in the group of participants who began the study with negative attitudes, $t(24) = -1.169$, $p > .05$. (Participants with positive attitudes were not examined because they were not of interest in the research.)

Research Question #1: Attitude Improvement

The first research question asked whether the instructional modules would improve participants' attitudes toward science. Except as otherwise noted, the following statistics include data from all the study participants, including those who began the study with positive attitudes toward science. There was no significant difference in attitude change between participants who received the experimental treatment and those who received the control treatment, $t(280) = 1.424$, $p > .05$. There was also no significant difference in attitude change between *women* who received the experimental treatment and women who received the control treatment, $t(167) = 0.894$, $p > .05$. In participants who began the study with negative attitudes, there was also no significant difference in attitude change between the experimental and control groups, $t(61) = 0.712$, $p > .05$. There was no significant difference in attitude change between women in the control and experimental groups who began the study with negative attitudes $t(39) = 0.735$, $p > .05$. Raw pretest and posttest scores are summarized in Table 1. T-test data are summarized in Table 2.

Table 1

Raw Pretest and Posttest Test of Science Related Attitudes (TOSRA) Score Means

	Pretest score		Posttest score	
Participants	Mean	SD	Mean	SD
All participants (n = 282)				
Experimental	117.06	11.39	126.01	13.50
Control	116.45	13.95	123.81	15.13
Women (n = 169)				
Experimental	116.59	11.89	126.77	13.65
Control	115.57	14.66	124.46	15.32
Negative attitudes (n = 63)				
Experimental	100.77	5.05	113.50	9.39
Control	97.86	6.38	108.73	11.83
Women with negative attitudes (n = 41)				
Experimental	99.56	5.91	114.19	8.87
Control	97.08	6.46	109.12	12.09

Table 2

T-test Summary Data for TOSRA, Control vs. Experimental Groups

	Mean gain score		df	t
Participants	Exper.	Control		
All participants (n = 282)	8.94	7.36	280	1.424
Women (n = 169)	10.18	8.89	167	0.894
Negative attitudes (n = 63)	12.73	10.86	61	0.712
Women with negative attitudes (n = 41)	14.63	12.04	39	0.735

* $p < .05$

Gain scores were also analyzed by subscale. On one of the subscales, the normality of scientists, attitudes improved significantly more for the participants in the experimental group than for those in the control group, $t(274) = 3.661$, $p < .05$. There were no significant differences between the control and experimental groups in attitude change on any of the other six subscales. Raw pretest and posttest scores are summarized in Table 3. A summary of the t-test data is presented in Table 4.

Table 3

Raw Pretest and Posttest TOSRA Score Means for All Participants by Subscale

Subscale	Pretest score		Posttest score	
	Mean	SD	Mean	SD
Social value				
Experimental	19.77	2.16	20.23	2.40
Control	19.33	1.99	19.78	2.18
Normality of scientists				
Experimental	14.96	1.55	21.41	2.35
Control	14.84	1.60	20.14	2.38
Inquiry				
Experimental	17.65	3.48	16.59	3.62
Control	17.97	3.93	16.98	3.80
Attitude				
Experimental	18.50	2.73	19.56	2.03
Control	18.75	2.40	19.39	1.99
Education				
Experimental	16.76	3.53	18.36	3.34
Control	16.17	4.65	18.24	3.74
Leisure interest				
Experimental	13.20	3.42	14.93	3.69
Control	13.26	3.85	14.94	3.86
Career interest				
Experimental	16.23	2.34	15.73	3.19
Control	16.14	2.52	15.22	3.39

Note. n = 283

Table 4

T-test Summary Data for TOSRA Subscales, Control vs. Experimental, All Participants

Test / Scale	Mean gain score		df	t
	Exper.	Control		
Social value	0.48	0.45	272	0.099
Normality of scientists	6.45	5.32	274	3.661*
Inquiry	-1.08	-1.03	272	-0.128
Attitude	1.07	0.62	275	1.486
Education	1.65	1.83	266	-0.545
Leisure interest	1.71	1.71	275	0.003
Career interest	-0.49	-0.91	272	1.284

Note. $n = 283$

* $p < .05$

Research Question #2: Gender Differences

The second research question asked if there was a difference in attitude change between men and women. For the experimental group, there was a significant difference, $t(137) = 2.016$, $p < .05$, with women's attitudes improving more than men's. However, there was also a significant difference in attitude change between men and women in the control group, $t(141) = 2.355$, $p < .05$, also with women's attitudes improving more than men's. The difference between men's and women's scores was not significant for either the experimental group, $t(24) = 1.463$, $p > .05$, or control group, $t(35) = .913$, $p > .05$, when only the data of those participants who started the study with negative attitudes were included. Raw pretest and posttest data are summarized in Table 5. T-test data are summarized in Table 6.

Table 5

Raw Pretest and Posttest TOSRA Score Means for Women and Men

	Pretest score		Posttest score	
Participants	Mean	SD	Mean	SD
All experimental (n = 139)				
Women	116.59	11.89	126.77	13.65
Men	117.75	10.69	124.91	13.33
All control (n = 143)				
Women	115.57	14.66	124.46	15.32
Men	117.80	12.78	122.80	14.93
Negative attitude experimental (n = 26)				
Women	99.56	5.91	114.19	8.87
Men	102.70	2.45	112.40	10.55
Negative attitude control (n = 37)				
Women	97.08	6.46	109.12	12.09
Men	99.50	6.14	107.92	11.73

Table 6

T-test Summary Data for Test of Science Related Attitudes (TOSRA), Women vs. Men

	Mean gain score			
Participants	Women	Men	df	t
All experimental (n = 139)	10.18	7.16	137	2.016*
All control (n = 143)	8.89	5.00	141	2.355*
Negative attitude experimental (n = 26)	14.63	9.70	24	1.463
Negative attitude control (n = 37)	12.04	8.42	35	0.913

* $p < .05$

In the experimental group, there was no significant difference between men's and women's scores on any specific subscale. In the control group, however, there was a significant difference between men's and women's scores on the normality, $t(137) = 2.833$, $p < .05$, and leisure interest, $t(138) = 1.998$, $p < .05$ subscales. Women's attitudes improved significantly more than men's on both subscales. These data are summarized in Tables 7, 8, 9 and 10.

Table 7

Raw Pretest and Posttest TOSRA Subscale Score Means for Women and Men in the Experimental Group

	Pretest score		Posttest score	
Test / Scale	Mean	SD	Mean	SD
Social value				
Women	19.59	2.14	20.38	2.08
Men	20.04	2.18	20.02	2.79
Normality of scientists				
Women	15.11	1.50	21.59	2.38
Men	14.75	1.62	21.14	2.31
Inquiry				
Women	17.73	3.50	16.88	3.54
Men	17.53	3.49	16.18	3.71
Attitude				
Women	18.44	2.66	19.59	1.99
Men	18.58	2.86	19.52	2.10
Education				
Women	16.38	3.69	18.32	3.40
Men	17.30	3.23	18.43	3.29
Leisure interest				
Women	13.22	3.45	14.96	3.75
Men	13.18	3.40	14.88	3.64
Career interest				
Women	16.12	2.48	15.92	3.34
Men	16.39	2.15	15.46	2.98

Note. n = 139

Table 8

T-test Summary Data for TOSRA Subscales, Women vs. Men in Experimental Group

Test / Scale	Mean gain score		df	t
	Women	Men		
Social value	0.79	0.05	131	1.707
Normality of scientists	6.49	6.38	135	0.277
Inquiry	-0.88	-1.38	133	0.935
Attitude	1.21	0.88	135	0.729
Education	1.92	1.26	131	1.518
Leisure interest	1.73	1.68	135	0.096
Career interest	-0.14	-0.96	131	1.739

Note. n = 139

* p < .05

Table 9

Raw Pretest and Posttest TOSRA Subscale Score Means for Women and Men in the Control Group

	Pretest score		Posttest score	
Test / Scale	Mean	SD	Mean	SD
Social value				
Women	19.37	1.97	19.95	2.03
Men	19.27	2.03	19.51	2.38
Normality of scientists				
Women	14.75	1.57	20.51	2.29
Men	14.98	1.66	19.58	2.42
Inquiry				
Women	17.94	4.02	17.08	4.04
Men	18.00	3.82	16.82	3.44
Attitude				
Women	18.70	2.42	19.58	1.89
Men	18.82	2.38	19.09	2.12
Education				
Women	16.05	4.92	18.28	4.02
Men	16.36	4.24	18.17	3.32
Leisure interest				
Women	12.89	3.87	14.90	4.15
Men	13.84	3.79	14.98	3.41
Career interest				
Women	15.89	2.79	15.17	3.33
Men	16.54	1.97	15.29	3.51

Note. n = 145

Table 10

T-test Summary Data for TOSRA Subscales, Women vs. Men in Control Group

Test / Scale	Mean gain score: Women	Mean gain score: Men	df	t
Social value	0.59	0.24	139	0.989
Normality of scientists	5.82	4.56	137	2.833 *
Inquiry	-0.94	-1.17	137	0.498
Attitude	0.87	0.24	138	1.525
Education	2.04	1.51	133	1.081
Leisure interest	2.08	1.14	138	1.998 *
Career interest	-0.73	-1.20	139	0.974

Note. n = 145

* p < .05

Qualitative Results

The final three research questions lent themselves to qualitative data analysis. They are:

3. What is the process for attitude change, as reported by the learners, and does that process match Kamradt and Kamradt's (1999) Structured Design model for attitude change?
4. What are the conditions that inhibit attitude change, as reported by the learners?
5. Are there qualitative differences between processes and conditions of attitude change between men and women, as reported by the learners?

Eighteen participants from the experimental group were selected for qualitative journal analysis. These participants were selected in two groups. The nine participants whose attitudes toward the normality of scientists improved the most were selected, as were the nine participants whose attitudes changed the least. Attitude change was measured by the Normality subscale of the Test of Science Related Attitudes (TOSRA).

The unchanged attitudes group included four women and five men. All were single and under age 22. Seven were taking the course because it was required; the other two considered it an elective. Five were chemistry students at Virginia Tech. Four went to Radford University; one was a chemistry student, and the other two were geology students. Four expected to make an A, four expected a B, and one expected a C in the class they were taking. There were five freshmen, two sophomores, and two juniors. On the pretest administration of the TOSRA, three scored at or below the midpoint, indicating generally negative attitudes toward science. The rest scored higher than the midpoint. All scored below the midpoint on the subscale for the Normality of Scientists.

The changed attitudes group also included four women and five men. One of these students was married, in his forties, and enrolled in geology at Radford University. All the others were under age 22, single, and chemistry students at Virginia Tech. One considered the course an elective; the rest considered it a required course. Three expected an A and six expected a B in the class they were taking. There were seven freshmen and two seniors. On the pretest administration of the TOSRA, one participant scored at or below the midpoint, indicating generally negative attitudes toward science. The rest scored higher than the midpoint. All scored below the midpoint on the subscale for the Normality of Scientists.

As described in the Methods section, the qualitative research questions were answered using content analysis of journals written during the Scientists module. The emergent coding process produced a coding scheme, which is an exhaustive and mutually exclusive list of ideas treated in the participant journals. The complete coding scheme is included as Appendix G. Thirty-nine ideas were identified in the coding scheme. They included feelings, thoughts, and anticipated actions before the module, and positive and negative responses afterwards.

It is important to note here that the changed attitude participants did not answer the pre- and post-module journal prompts in drastically different ways from the unchanged group. Most of the ideas found in journals of “changed” participants were also present in the “unchanged” participant journals. It is also important to note that some of the responses reflect the participants' attitudes toward the module rather than toward scientists.

The coding scheme and the ideas coded to it were used to answer the three qualitative research questions. Results for these questions are discussed below.

Research Question #3: Processes of Attitude Change

The first qualitative research question was: what is the process for attitude change, as reported by the learners, and does that process match Kamradt and Kamradt's (1999) Structured Design model for attitude change?

To answer this research question, the coding scheme was analyzed for ideas that relate to Kamradt and Kamradt's notion of attitude change. Then the journals of participants whose attitudes changed were analyzed for their use of those ideas. Basic premises of Kamradt and Kamradt's attitude change theory include the following:

1. Attitudes fulfill human needs,
2. Attitudes exist along a continuum from the most positive to the most negative,
3. Attitudes are made up of emotional, cognitive, and behavioral components,
4. Attitudes change when one or more of the components is not aligned with the others, and
5. Shifts in the emotional, cognitive, and behavioral components occur in parallel with the other components.

Kamradt and Kamradt assumed that attitudes fulfill human needs, or serve functions. The coding scheme revealed a number of needs expressed by the participants. They expressed needs for knowledge, value expression, intellectual stimulation, feeling good about themselves, and social expression. Examples of attitudes fulfilling human needs from the participants' journals are presented as Figure 11.

Function	Examples
Knowledge	I also want to find out the things that I don't know. ... I think it will help me grow as a person to know more about scientists. I like to learn about people I am not familiar with, and it usually helps me if I know something about their personal life rather than just know what they do for a living. – Samantha (all names have been changed)
Value expression	… I feel that they should be so much more appreciated because they have made some [*sic*] many discoveries in this world that has led to a more happier and healthier living of the human race. Scientists have been willing to share their knowledge of the science field to help the world around them. So much of our life is based upon the discoveries made by scientists. – Jennifer I believe scientists are good people who can make a difference in this world. Many problems, such as disease exist in this country with no real cure. As long as scientists are trying new things, experimenting with materials we may already have, can really help our country. – Ethan
Intellectual stimulation	[It] depends on how interesting it all is. If it's actually something that matters to me or my life, I'll read it through. If not, I'll skim. – Franklin
Feeling good about self	I will approach it with the diligence that I approach every thing in my life. I will take the time necessary to do my best. – Jim
Social expression	To me a typical scientist is very work oriented and spends long hours on the job. They may be withdrawn and shy. …The typical scientist to me is a homely person that doesn't worry to much about their appearance or what other people think. – Samantha I think they would be very interesting [to] meet. I think they'd have interesting information to tell me, such as how they got to the job they have now. – Sara

Figure 11. Examples of functions served by attitudes.

The best evidence for a continuum of attitudes came from the participants' responses to the question, "Are [these scientists] people you would like to meet in person?" None of the participants in the qualitatively analyzed group, changed or unchanged, wrote that they would *not* want to meet the scientists, so the negative half of the continuum of attitudes is absent. The array of responses, listed below, shows the range of emotions associated with the specific behavior. Italics were added for emphasis.

1. I would *love* to meet them in person – Jessica (changed attitude)
2. I would *enjoy* meeting them. – Jim (changed)
3. These were more like people I would *like* to meet. – Seth (unchanged)
4. I think that it would *be interesting* to meet a scientist. – Jennifer (changed)
5. They'd *be interesting* to meet in person – Franklin (changed)
6. I *would* definitely meet these people in person. – Katie (unchanged)
7. I *would* definitely meet *some* of these people – Tim (unchanged)
8. I *wouldn't mind* meeting *some* of the scientists. – Thomas (changed)
9. I *guess I wouldn't mind* meeting them in person. – Martin (unchanged)

There was little evidence to support an individual's movement along the continuum as his or her attitude changed. However, Jennifer wrote:

> At first if I was told that I was going to meet a scientist I would probably see them as being really boring and too smart to have a normal conversation with but now I think that it would be interesting to meet a scientist. (Jennifer)

Jennifer's attitude changed, and her words represent a shift on the continuum from a slightly negative to a relatively positive attitude toward scientists.

Kamradt and Kamradt also maintained that every attitude has cognitive, emotional, and behavioral components. The pre-module journal prompts were based on this premise, because they asked, basically, how participants felt (emotional), what they knew (cognitive), and how they expected to behave (behavioral). The post-module prompt was more general. Overall, the participants responded to the questions with statements that corresponded to the emotional, cognitive, and behavioral components of their attitudes. However, not all participants included all three components of their attitudes, even with the prompts.

The cognitive component was surely the most dominant one in the responses. Participants were asked whether they were surprised. Many said they were, and went on to clarify that they were surprised by something they learned, such as the fact that scientists had social lives. Seven of the nine participants whose attitudes changed the most indicated that they were surprised by something they learned (cognitive) about scientists. For example:

1. I was surprised that so many of them had such vast social lives and so many interests outside their "laboratory." – Samantha
2. I was actually surprised at how young the scientists work [*sic*] and how much they looked like everyday people. – Jennifer
3. I guess I never really thought of scientist [*sic*] as being a lot of the younger generation either... Some of the scientists just seemed as if they were people that you would meet here at the college and hang out with in the clubs. – Thomas
4. They are normal people too despite what most may think, and have families and sufficient social lives. – Keith
5. I was surprised. Most of them seem like they aren't too different than normal people. – Franklin
6. I was surprised that most of them lived casual lives. I expected scientists to be more of an uptight and formal type person. – Ethan
7. I never realized that you could be a scientist but not wear the lab coat. – Sara

These statements represent shifts in the cognitive component of participants' attitude toward scientists. The surprise indicates that existing attitudes were activated, and the new information was dissonant with previously held beliefs. The participants' reiteration of the normality of scientists represents what Kamradt and Kamradt call "trying on" the new attitude (1999, p. 583).

Evidence for emotional components of attitudes toward scientists was scarce. As prompted in the pre-module journal, many participants wrote their feelings about doing the module, but those feelings had more to do with the educational exercise than the subject matter. Journals that did discuss emotions about scientists were limited to those ideas related to meeting scientists. As described above in the discussion of the attitude continuum, they included phrases such as “love to meet,” “like to meet,” and “enjoy meeting.”

The behavioral component was addressed better than the emotional component of attitudes toward scientists. The post-module journal prompt included the question, “Would you like to meet these scientists?” This question prompted participants to consider a behavior that was in line with the desired attitude. None of the participants whose journals were analyzed wrote that they would *not* like to meet the scientists. Eight of the nine participants in the changed attitudes group wrote that they would like to meet some or all of the scientists. Five of the nine in the unchanged group also wanted to meet the scientists. Most of the participants who elaborated said that they would like to talk to the scientists. One participant thought it would be fun “to do their hobbies with them” (Franklin). None of the journals described other behavioral ideas.

Most of the participants treated the three components separately, as prompted by the questions. However, there was limited evidence for Kamradt and Kamradt’s assertion that all attitudes contain all three components. The quotation below was the only statement in which all three components were present relatively near each other. The participant wrote:

> I was surprised. Most of them seem like they aren’t too different than normal people. They have hobbies, even though they don’t have much time for them. They seem like they’d be interesting to meet in person because while it would be fun to do their hobbies with them, they could tell you stuff about it you would have never known before, like surfing. Overall, I was surprised by how normal the lives they lead really are. (Franklin)

He *knew* (cognitive) things about scientists that made him *think* (cognitive) it would *be fun* (emotional) to *meet* them in person (behavioral).

Kamradt and Kamradt (1999) maintained that attitude change occurs when one of the components of the attitude is out of alignment with the others. Participants who changed their attitudes were more likely to say they were aware that their image of the typical scientist was a stereotype. This reaction can be explained using Structured Design. The people who called their ideas about scientists "stereotypes" were exhibiting attitude dissonance; that is, the emotional, cognitive, and behavioral components of their attitudes were not in alignment. Thomas, who changed his attitude, essentially said as much when he wrote the following:

> I guess now logically I know what scientist [*sic*] are like, but you always have that view of the crazy scientist that you see in movies and I think learning about things that you have a distorted point of view on will always help to get a better understanding. (Thomas)

Samantha, who also changed her attitude, wrote a similar statement: "I feel like my stereotypes of scientists are outdated and all together incorrect." The cognitive component of their attitudes (knowledge that the typical scientist is "homely" [Samantha] or "crazy" [Thomas]) was not in line with some other component, such as their emotional need to accept all kinds of people (or their social need to appear to accept all kinds of people). It was probably also not in line with their behavioral intention to treat people equally, regardless of their profession. Because Thomas and Samantha's attitudes were out of alignment at the beginning of the exercise, they were more likely to change their attitudes. Although just as many had negative views of scientists, members of the unchanged group generally did not mention the word *stereotype* in their descriptions of scientists. This may be interpreted to mean that they held just as negative views of scientists, but perhaps were comfortable with their negative views.

The final premise of Kamradt and Kamradt's theory discussed here is that shifts in the emotional, cognitive, and behavioral components occur in parallel with the other components. Very few statements in the journals represented attitude shifts in any component other than the cognitive. With such an absence of data, it is impossible to support or refute this part of the theory.

Research Question #4: Conditions Inhibiting Attitude Change

The fourth research question was: what are the conditions that inhibit attitude change, as reported by the learners? The answer to this research question was sought by looking for differences in responses between the unchanged and changed participants. Five themes from the coding scheme were identified as having differences: (a) statements of awareness of own stereotype, (b) statements about what scientists do, (c) statements of no distractions expected during the module, (d) statements that scientists are not "others" / stereotypes are wrong, and (e) statements indicating a desire to meet scientists. For all of these themes, fewer unchanged participants than changed participants included references to these ideas. Examples of journal statements that were coded to these themes are included below.

Four participants in the changed group mentioned that they were aware of their own stereotype, whereas only one in the unchanged group mentioned this idea. Katie, who did not change her attitude, wrote, "When I think of a typical scientist, I think of Bill Nye the science guy, but I know that's not always true!" Thomas, who did change his attitude, wrote:

> I guess now logically I know what scientist [*sic*] are like, but you always have that view of the crazy scientist that you see in movies and I think learning about things that you have a distorted point of view on will always help to get a better understanding.

Three other changed attitude participants mentioned the word *stereotype* or *stereotypical* in their description of a typical scientist.

For the theme "what scientists do," all the changed participants included the idea, as did six of the nine unchanged participants. Sara, whose attitude changed, wrote, "Three types of jobs that scientists do are: discover new information, study specific information in their field, and perform experiments to form new hypothesis [*sic*]." Heather, whose attitude did not change, wrote, "Scientists perform experiments, make conclusions, theorize, discuss laws or matter and do crazy kinds of technology."

Six changed attitude participants wrote about their intention to work on the module without distractions. Sara (changed) wrote, "I will work on it by myself without other distractions." Five other changed attitude participants also included this theme. Katie, whose attitude did not change, did not write anything for this theme, but did write, "There will most definitely be distractions, especially living in a dorm. I can also never focus on one thing for too long without losing my attention span." Two of the unchanged participants wrote that they would not have any distractions.

In the post-module journal, more changed than unchanged participants wrote that scientists were not the "others" they were expecting. Jennifer, whose attitude changed, wrote:

> I think scientists always are given this image of what they look like, old and geeky like. But after reading about all these different scientists it shows that they aren't devoted completely to science and they do come home and switch off from work mode to home mode.

Jennifer and six other changed participants included this theme in their journal. Martin, whose attitude did not change, wrote, "I was somewhat surprised to see that most of them are not geeks and they seems [*sic*] just like everyone else." Three other unchanged participants also included this theme.

Finally, eight changed participants included the theme "would like to meet scientists," whereas five of the unchanged participants did. Jim, whose attitude changed, wrote, "I would enjoy meeting them in person and discussing certain interests we have in common." Martin, whose attitude did not change, wrote, "I guess I wouldn't mind meeting them in person."

Research Question #5: Gender Differences

The fifth and final research question was: are there qualitative differences between processes and conditions of attitude change between men and women, as reported by the learners? The answer to this research question was sought by looking for differences in responses between men and women. Three groups were analyzed: the entire group of qualitatively analyzed participants, the changed attitudes group, and the unchanged attitudes group. When all the qualitatively analyzed journals were considered together, there were no appreciable differences between men's and women's responses.

For the changed attitude group, two coding themes were identified in which there were meaningful differences between how men and women responded. Those themes were (a) scientists are valuable to society, and (b) I don't know much about scientists and/or expect to learn. For both themes, women included these themes more often than men. For example, Sara wrote, "Scientists work to better the environment and society." Samantha wrote, "I know that I do not know very much, and there is a lot that I probably should know."

In addition, the character of the women's writing was different from the men's. A woman whose attitude improved after the module wrote this before the module:

> I feel that [scientists] should be so much more appreciated because they have made some [*sic*] many discoveries in this world that has led to a more happier and healthier living of the human race. Scientists have been willing to share their knowledge of the science field to help the world around them. So much of our life is based upon the discoveries made by scientists. (Jennifer)

On the other hand, a man whose attitude improved wrote:

> I believe scientists are good people who can make a difference in this world. Many problems, such as disease exist in this country with no real cure. As long as scientists are trying new things, experimenting with materials we may already have, can really help our country. (Ethan)

Jennifer's scientists "were willing" to help the world and "should be so much more appreciated," whereas Ethan's were "good people" who were "trying new things." The difference in treatment may reflect women's tendency to see scientists as authority figures rather than ordinary people. Women who saw scientists as unapproachable authority figures may have had their preconceived notions challenged by the presentation of likable, young scientists. In functional attitude theory terms, the instruction presented an attractive alternate attitude to women for whom their negative attitudes toward scientists served to protect them from social interactions with authority-figure scientists. As evidenced by Ethan's journal entry above, the men who wrote that scientists were valuable to society did not put scientists on such a pedestal. The women whose attitudes did *not* change may have had other, unknown reasons for their negative attitudes, which were not treated by the presentation.

In the changed attitude group, women were also more likely to say that they did not know much about scientists. However, there was no appreciable difference between men and women's responses in the themes related to what scientists actually do. This finding supports previous research that found that women lack self-confidence in science and related fields (Adhikari et al., 1997; Adhikari & Nolan, 1997; Libarkin & Kurdziel, 2003; Meyer & Koehler, 1990). The participants were prompted with the following: "What do you already know about scientists? Can you already list three types of jobs scientists do? How would you describe a typical scientist? Write a paragraph or two about your thoughts below." At this prompt, Katie wrote:

> I don't know much about scientists. I did learn in my chemistry class this semester that there are two different types: some that do science for the purpose of finding a specific result or applied goal, and some that just do science for the thrill of it. I know that scientists work in the fields of medicine, pharmacy and chemistry, although I do not know much past that. (Katie)

Notice that Katie wrote twice that she did not know much about the topic, but showed that she actually did. Luke, on the other hand, wrote his response without any qualifiers about how much he knew: "Scientists are researchers who study and analyze the earth as well as perform experiments and tests to improve our daily quality of life." It is unclear why this difference is only present among the participants whose attitudes changed, but may be related to differences in the quantity of writing between the two groups.

In the unchanged attitude group, two themes were identified in which the two genders responded differently. Those themes were (a) statements that distractions would be present during the module, and (b) statements indicating plans to work through the module as fast as possible or not carefully. For both themes, women in this group were more likely than men include the ideas in their journal entries. For example, Katie wrote, “There may be a couple other distractions.” Heather wrote, “I will try to complete this module as fast as I can because I am in the Corps of cadets and my time is limited. We move with a sense of urgency.”

Post Hoc Analyses

During the analysis of journals to determine conditions that inhibit attitude change, the fact that all the themes with differences were included by more of the changed participants begged the question of whether the participants who changed their attitudes simply wrote more. Analysis of the word counts for the two groups revealed that this was the case, $t(16) = 3.600$, $p < .005$. Those who changed their attitudes wrote an average of 148 words more than those who did not. Those who changed their attitude wrote an average of 338 words; those who did not averaged 188 words.

In a parallel analysis, the fact that more women included all of these ideas brought up the question of whether women simply wrote more than men did overall. A word count analysis revealed that women wrote an average of 279 words, and men wrote an average of 252. In a sample of this small size (18 people), the difference was not significant, $t(16) = .490$, $p > .05$.

Discussion

This study tested a number of instructional strategies to determine whether they were effective in improving women's attitudes toward science. The strategies focused essentially on including emotion in instruction, using role models, and addressing the functions that existing negative attitudes served. This section summarizes main findings, discusses limitations of the study, and outlines directions for further research.

Although there was no significant difference between the experimental and control groups in the overall attitude gains, the experimental group did have significantly higher gains for the component of attitudes related to the normality of scientists. The experimental modules were designed for two of the subscales, normality of scientists and social value of science. The Scientists module was specifically designed to challenge stereotypes about scientists as nerds. The Minerals module was designed to show one of the ways that science benefits society.

Results on the normality of scientists subscale indicate that the intervention was successful. Participants who did the Scientists module did improve their attitudes significantly more than participants in the control group, who completed modules on acid rain and the water cycle. These results show that teaching about science in general is not effective in combating stereotypes about scientists. To change attitudes about scientists, teachers and curriculum designers should include specific instruction about scientists.

The Minerals module was targeted at the subscale that dealt with the social value of science. The success with the Scientists module begs the question of why there were not also significant increases for the social value subscale. However, pretest scores on the social value subscale were the highest of all the subscales. Only two participants had negative attitudes about the social value of science at the beginning of the study; therefore, it was difficult to improve those attitudes. Future instruction for attitude change in introductory college science classes probably need not focus on this aspect of the attitude.

The other subscales were not treated specifically, and instructional modules may or may not be the best treatment for them.

Attitudes changed more for women than for men. In short, the study was successful, because attitudes improved overall, and women's attitudes improved significantly more than men's did. However, women's attitude improvement was significantly better than men's in *both* the experimental and control groups. This was not the expected result, but it does give rise to additional questions for future research.

Researchers have long known that pretests can effect attitude change all by themselves (Willson & Putnam, 1982). A repeat administration of this study comparing attitude improvement between participants who received a pretest and participants who did not could determine whether the pretest inadvertently "activated existing attitudes toward science early in the instruction." If pretests do cause attitude change, then activating existing attitudes may be a very important strategy in women's attitude change.

Future research could examine the effect of the gender, or other qualities, of the principal investigator. Such research might reveal that women role models, source credibility, and source gender are very important factors in women's attitude change. Attitude research has pointed to the importance of source credibility and attractiveness as a factor in attitude change (Chaiken & Maheswaran, 1994; DeBono & Harnish, 1988; DeBono & Telesca, 1990). Although the researcher in this study never met face to face with the participants, they did know her name, and that she was a woman. From their professors' introduction of the study, they probably also knew the principal investigator was a geologist, a social scientist working on her dissertation, a former student or colleague of their professor's, and/or a friend of their professor's. Depending on how much the participants knew about the principal investigator, they might have even considered her a role model. For example, one woman whose attitude improved somewhat wrote, "I would not mind meeting any of them. I'm sure I could gain a lot of knowledge from each of them and not just in the field of science. I may ask them questions about obtaining their PhD" (Karen). For this woman, knowledge that the principal investigator was a woman obtaining her PhD might have made some difference in her willingness to change her attitude.

Alternatively, future research might reveal that participating in attitude studies or being enrolled in science classes improves attitudes. In any case, women were more willing to change their attitudes than men. It could be that simply asking women to consider changing their attitudes toward science would improve those attitudes. This finding warrants more research.

Post hoc analysis revealed another difference between the people whose attitudes changed and those whose attitudes did not change. The changed attitude group wrote more. Two possible areas for further research relate to the level of engagement and to the learner types.

Teachers know that students with negative attitudes are less engaged in all types of classroom activities. Attempts to draw these students into exercises are met with grudging one-word answers. They do the bare minimum. If the unchanged attitude participants are like these students, their reluctance to fully engage in the activity may have prevented the attitude change strategies to work on them. Future research could examine this finding in more detail by comparing word counts for all parts of the exercise to the change in TOSRA scores. By virtue of being online and a non-social activity, this exercise separates the "bad attitude" students from the shy students who sometimes also refuse to engage during class.

The module may have been most effective for linguistic learners. Students learn in different ways, and have different strengths (e.g., Gardner, 1983). If the changed attitude group as a whole was made up of people who have higher linguistic intelligence, it would stand to reason that these learners might respond best to this type of instructional module, which emphasizes reading and writing. Learners who are not as strong in linguistic intelligence might not enjoy the reading and writing aspects of the module and would write less. It could be that the strategies employed here work best for strong linguistic learners. Future research could examine this hypothesis.

Limitations

Several factors likely limited the generalizability of the study, including factors related to the participants and to the study design. They are discussed here.

More than half of the participants in the study were enrolled in the same class with the same teacher. That teacher already implemented most of the suggestions for improving women's attitudes toward science in her classes. She is a dynamic, enthusiastic teacher who is already a woman scientist role model. Effects thought to be from the study could instead be a result of her influence on the participants. To control for this phenomenon, participants were randomly assigned to the control and experimental groups. Random assignment removed the factor from the quantitative analysis. Qualitative data were chosen based on responses to the quantitative parts of the study, and included data from many participants in the same class.

Participants were self-selected. They participated in the study because they wanted to or wanted extra credit. Some participants dropped out of the study after the pre-test; others dropped out after the first or second module.

Qualitative findings were based on the journals of eighteen participants. These journals were chosen purposefully, but may not have represented the majority of students well. When the journals were separated by gender and attitude change, the groups were very small, with four or five members. Therefore, one or two participants' eccentricities could affect the counts of results considerably. Table 6 shows how the numbers were distributed.

Table 11

Numbers of Participants in Qualitative Analysis

	Women	Men	Total
Changed	4	5	9
Unchanged	4	5	9
Total	8	10	18

Because of study design limitations, not all of the recommended strategies identified in the literature review were incorporated. To ensure that the experimental and control groups had comparable experiences, social involvement recommendations were not included. For example, participants in the study did not discuss their feelings in groups, meet face-to-face with successful women in sciences, or participate in cooperative, collaborative learning. If in future research, these guidelines were incorporated, the results may be different. Second, the participants were exposed to the guidelines in two short modules in two weeks. Future research involving the thorough application of guidelines in a semester-long science course may give different results.

The nature of the initial prompt used to activate learners' attitudes toward science prevented the collection of appropriate data to test the viability of Kamradt and Kamradt's approach to attitude change. Initially, the Scientists module was designed with a scenario that was designed to activate the learners' attitudes toward the normality of scientists. During the formative evaluation, in which Instructional Technology graduate students participated in the module, the scenario proved ineffective. The graduate students spent all their time trying to learn more about the fictional character and to determine what was best for her. They never activated their own attitudes towards the normality of scientists. Following the formative evaluation, the scenario was dropped from the module, and the statement of learning objectives replaced the scenario for the purpose of activating attitudes.

The shift to using the learning objectives accomplished the goal of activating attitudes without unnecessary distractions. However, the attitudes that were activated were towards *completing a module* about scientists, not the normality of scientists. The attitude activation tool was "once removed" from the desired attitude.

The effect was not devastating. Participants still managed to activate their attitudes toward the normality of scientists, and many did improve their attitudes. However, the attitude activation occurred after they began the instructional module, and their initial attitudes were not captured well in the pre-module journal. The absence of relevant qualitative data in the pre-module journals makes it impossible to answer the research question with conviction. The process for attitude change outlined in the Structured Design theory is not refuted, but is not particularly supported either.

In spite of the limitations cited above, there are practical suggestions for classroom teachers and instructional designers that can be taken from the study.

Practical Implications

If we agree that attitudes toward science include attitude toward scientists, we have a lot of work to do. While participants in this study believed that scientists were good for society, they did not believe they were normal people. Students described typical scientists as strange-looking, strange-acting people with no social lives. Their comments can be summarized as, “We need them, but I don’t want to be one or know one.” Participants were surprised to learn that scientists had hobbies, families, and other interests. Many wrote they were surprised scientists could be young. The participants in the control group did not improve their attitudes toward scientists as much because they did not “meet” the scientists. To improve attitudes toward scientists, we should include opportunities in our curricula for students to meet real scientists, virtually or in person. We should plan time for scientists to let students know about their lives, not just their jobs. These scientists could serve as role models and, in certain situations, mentors. The results of this study indicate that learning about science is not enough to improve attitudes toward scientists.

Although the precise reasons are unclear, women’s attitudes toward science improved more than men’s did for both the experimental and control groups. Some women’s attitudes improved considerably. From this we can conclude that women are willing to change their attitudes.

Consider Tara’s story. She was a sophomore psychology major enrolled in a general education chemistry class. At the beginning of the study, she had an overall negative attitude toward science. She did the Scientists module first. Before the Scientists module, she wrote:

> The thought of I’m about to learn about scientists make me feel bored and unenthusiastic. I spent twelve years of my life already studying about

> different scientists and what they discovered. So now in college, I really see no need in learning about scientists even more. (Tara)

When asked how she would approach the module, she wrote, “I think I'll approach this module with an attitude of, ‘I could be doing something else right now.’” At the end of the Scientists module, she wrote, “I must admit I was very pleasantly surprised by the people I just met. It also made me feel slightly embarrassed because I had such narrow and stereotypical view of scientists as a whole.”

The next week, Tara completed the Minerals module. Before this module, she wrote, “I think I'll approach with a little more open mind than previous module.” In the module, she learned about a number of minerals, but was most moved by the story of diamond wars in Africa. That page included a photograph of a young girl whose arm had been amputated as a result of the wars. Tara wrote after the module, “The picture of that little girl absolutely broke my heart. Diamonds is [*sic*] not worth killing innocent lives, nevertheless, innocent children. Preserve their innocence, not take it.” In the final week of the study, Tara’s attitude toward science was measured again. Her attitude score gained 32 points, and put her well into the “positive attitudes toward science” category.

Including role models, emotion, and treatment of attitude function will not improve all women’s attitudes toward science. However, it was just the ticket for Tara. She responded to all three components essentially as expected. This study suggests that the strategies work for certain students. They are easy to implement and should be added to teachers’ lists of techniques for improving science classes.

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Appendix A: IRB Approvals and Informed Consent Form

Honors Academy

RU
RADFORD
UNIVERSITY

P.O. Box 6971
Radford, VA 24142

(540) 831-6125
(540) 831-5004 FAX

www.radford.edu

April 2, 2004

Ms. Phyllis Newbill
Department of Geology
Box 6939
Radford University

Ms. Newbill:

I have determined that the project, "An investigation of attitudes toward science," for which you and Dr. Katherine Cennamo requested exemption from review meets the criteria for such exemption as set out in the relevant Federal and State guidelines. I am therefore exempting the project from review by the Radford University Institutional Review Board for the Review of Human Subjects Research.

Please remember that all work involving human subjects, whether exempt from review or not, is subject to the standards for the protection of human subjects established by the IRB. Don't hesitate to contact me or Janet Hahn in the Office of Sponsored Programs & Grants Management if you have any questions regarding these standards.

Best of luck in your study.

Sincerely,

[redacted]

Joseph S. King, Ph.D.
Chair, Radford University Institutional Review Board
for the Review of Human Subjects Research

cc: Janet Hahn, Katherine Cennamo

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Rec'd 3/24

Institutional Review Board

Dr. David M. Moore
IRB (Human Subjects)Chair
Assistant Vice Provost for Research Compliance
CVM Phase II- Duckpond Dr., Blacksburg, VA 24061-0442
Office: 540/231-4991; FAX: 540/231-6033
email: moored@vt.edu

DATE: February 26, 2004

MEMORANDUM

TO: Katherine S. Cennamo Teaching and Learning 0313
Phyllis Newbill EDCI 0313

FROM: David Moore

SUBJECT: **IRB Exempt Approval:** "An Investigation of attitudes toward science" IRB # 04-095

I have reviewed your request to the IRB for exemption for the above referenced project. I concur that the research falls within the exempt status. Approval is granted effective as of February 26, 2004.

cc: File
Department Reviewer Barbara Locke T&L 0313

Informed Consent

This page tells you about the study so that you may make an informed decision about participating in it.

Title of study: An investigation of attitudes toward science

Investigators: Phyllis Leary Newbill, Principal Investigator and Katherine S. Cennamo, Advisor

I. The Purpose of the Study

This study examines college students' attitudes toward science.

II. Procedures

During the study, you will respond to two 35-item surveys. You will also work through two instructional modules about science and scientists. During each module, you will write journal entries about your thoughts and feelings related to the topic. Electronically signing this form constitutes agreement to participate in the project.

III. Risks

There are no anticipated risks to you as a participant. Participation in the study will require a total of about 3 hours of your time, spread over four weeks.

IV. Benefits of this Project

This project will contribute to our understanding of college students' attitudes toward science.

V. Anonymity and Confidentiality

The results of this study will be kept confidential. Anonymity is not guaranteed.

Your name and other personal identifiers will not be associated with the information you provide. Any publications from the research will use pseudonyms and mask personal identifiers.

VI. Compensation

There is no compensation from the project investigators for participating in this project.

VII. Freedom to Withdraw

You are free to withdraw from this study at any time.

VIII. Participant's Responsibilities

You are responsible for completing each task in the study within the specified time frame. You are also responsible for giving truthful information on the surveys and journals.

X. Participant's Permission

I have read and understand the Informed Consent Form for Participants and the conditions of this project. I have had any questions I had about the project answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I may withdraw at any time without penalty. I indicate my agreement by entering my email address and clicking "submit" below.

Should I have questions about this research project, I may contact:

Phyllis Newbill, Principal Investigator (pnewbill@vt.edu, 540/633-2465)

Dr. Katherine Cennamo, Advisor (cennamo@vt.edu, 540/231-5587)
Dr. Barbara Lockee, Dept. of Teaching and Learning IRB Representative (barbara.lockee@vt.edu, 540/231-5587)
Dr. David Moore, Chair, Virginia Tech Institutional Review Board (moored@vt.edu, 540/231-4991)

Type your email address here if you wish to participate in the study. Use this same email address throughout the study.

By clicking the "submit" button, I agree to participate in the study.

SUBMIT

Appendix B: Scientists Module

The experimental group went through this module during either week 2 or week 3 of the study.

Welcome to the study. Thank you for participating.

The following web pages make up a module in the study. Please work through these pages within one week of the email notification sent to you about this module.

Following this module you should be able to

1. List at least three different types of jobs that scientists have.
2. Describe a "typical" scientist.

During this lesson, you will

1. write a journal entry about what you already know, feel, and do;
2. read about some scientists and write about what you remember; and
3. write a response journal.

Begin

Journaling Activity

Recall the objectives of this module. They are:
1. List at least three different types of jobs that scientists have.
2. Describe a "typical" scientist.

Take a minute to think about how you feel about scientists, what you already know about scientists, and what you will do as you work through the module. In the spaces below, record your responses.

Type your email address here. Use the same email address for all parts of the study.

How does knowing that you are about to learn about scientists make you feel? Write a paragraph or two about your feelings below. (At a loss? Click for a list of feeling words.)

What do you already know about scientists? Can you already list three types of jobs scientists do? How would you describe a typical scientist? Write a paragraph or two about your thoughts below.

How do you think you will approach this module? What will you do? Will you go through it as fast as possible or will you do it slowly? Will you work on it by itself or will there be other distractions? Write a paragraph or two about what you think you will do during the module.

<u>SUBMIT</u>

Meet some scientists

In the next few pages, you will meet some real scientists who work in a variety of environments. Take a few minutes to read about each one - you will be asked to write about what you remember.

Continue

Laura Grant
Science Communicator

Q. Can you describe your job?

I am studying for a PhD in Science Communication at the University of Liverpool. I am looking at innovative ways of promoting Physics. Alongside this I run the Physics Department outreach program, which involves giving lectures and running events at local Schools, Museums and Science Centers.

Q. Your family background?

My mom is a Physiotherapist and my dad is a management consultant, so neither have a background in the Physical Sciences. This has the advantage that they don't really understand my work so they think I'm dead clever! I have two younger brothers, one works in finance and the other is studying for a degree in media studies.

Q. Who or what inspired you to become a scientist?

I have always been fascinated with the way things worked so I think that Science was a natural choice for me. I was actually put off by pure Science a lot at school because we had to do such boring experiments and rubbish calculations that had nothing to do with real life, or anything interesting. I think that this problem is currently being addressed and efforts are being made to liven up the curriculum a bit. Physics became really exciting for me at the university level where I was able to study interesting problems and current research was included in our course material and projects.

Q. What do you love about your job?

I love the fact that my research may have a positive impact on people's lives. I was put off Physics at school and my research is looking at why that is and how the negative trend can be reversed. My outreach work is also very rewarding because I get to show school students a side to Science that they wouldn't normally see in the classroom, plus I get to play around with Liquid Nitrogen which is always good fun, if a little dangerous...!

Q. Where can I learn more about you?

Be Yourself!
My personal profile online

Q. How do you spend your free time?

Life outside work is pretty hectic, going to the university gives you the chance to meet people from all over the country, so lots of my weekends are spent going out with friends or my boyfriend.

I am a self-confessed shopaholic so I love going into Liverpool and scouting out some good bargains. Until recently I used to do a bit of modelling in my spare time to fund my shopping habit, which was fun but hard work and not as glamorous as you'd think.

I love horse-riding but unfortunately don't have my own horse any more, but I'm sometimes able to scrounge rides off my friends which is always a good laugh because I'm invariably out of practice and in agony the next day!

As well as this, I try and get some exercise salsa dancing or going out to clubs! To relax I do Tai Chi at my gym and chill out in the sauna.

Next

Type your email address here. Use the same email address for all parts of the study.

What do you remember about the scientist you just read about? List at least three things.

Submit and continue to next scientist.

Page 2 of 10

Julie McManus
Scientific Adviser at L'Oreal

Q. What is your job?

I am a scientific adviser for the world leading cosmetics company, L'Oreal. I am the link between the laboratories in France/US and the UK business, advising the business teams, public relations and even the UK media on any technical questions or queries.

Q. Can you briefly describe your job path?

I was really lucky to happen upon my current job at L'Oreal. I spent the first year in the laboratories based in Paris, France, in order to develop an in depth understanding of L'Oreal's research, the culture and the French language. I am now based in the UK, advising the business teams, Public Relations, and the UK media on scientific and technical matters. I still travel to Paris, and sometimes Brussels and Ireland. I attend product launches where I meet journalists and then later help them when they write magazine articles on cosmetics, particularly sun care. I have been here for 5 years and I love it! **Q. Your family background?**

I guess that my background was scientific, as my mom was a nurse and my dad a physicist; however, they did not try and persuade me to go into science. I was really into sports at school, which they encouraged and I just happened to find biology the most interesting academic subject. I also loved languages - my mom is Dutch, so working at L'Oreal gave me a language and science.

Q. What do you love about your job?

I find the subjects really interesting. I am responsible for the technical understanding of a huge variety of products. I learn something new everyday as our understanding of the skin, hair and damage from UV rays increases. I really enjoy making science interesting (and important) for other people whether it be my colleagues, journalists or even my friends and family.

Q. Would you say you had a good standard of living / work life balance?

I believe that I have reached a very happy and rewarding stage in my life. I have a really interesting career, and have a wonderful husband and little baby boy. I work hard, but I travel less now so I am able to spend a lot of time with my family. I am also well paid for a scientist.

Q. How do you switch off from work?

I have always been really into sports, so before I had my baby (Callum) I played netball, squash, went running and swimming. I also traveled a lot, took French, Dutch and Japanese language courses and went to several Grand Prix races in Europe (another passion of mine). Callum is 8 months old and I now spend my spare time with my family, but fortunately he loves swimming too so we can all do that together.

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Type your email address here. Use the same email address for all parts of the study.

What do you remember about the scientist you just read about? List at least three things.

Submit and continue to next scientist.

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Mike McCartney
Games Programmer & Astronomy Lecturer

Q. Can you briefly describe your job and your job path?

I'm designing and programming games for the newest generation of mobile phones. My most recent project has been to create a space game where you get to hunt and destroy enemy spacecraft in a true 3D environment on a phone display.

I really wanted to take a year off after college, but wanted to make sure it was something useful that I'd be able to sell to future employers. I spoke to my professors and through luck and effort managed to get a 7-month job working as 'student help' at a mountain observatory in Hawaii. That helped me get my PhD position and now I'm trying out different lines of work. Right now I'm programming games during the day and serving as a part-time evening lecturer in astronomy.

Q. Where can I learn more about your work?

Click here: http://www.kuju.com **Q. Your family background?**

My parents wanted me to go into a traditional stable career path like banking but I've always followed my own interests, and that's pretty much led me in the right direction.

Q. Who or what inspired you to become a scientist?

I've always been fascinated by the subject. Reading Sci-fi at a young age probably started my imagination off in that direction. Apart from that, just looking at the night sky and trying to imagine what's out there is often inspiration enough.

Q. What do you love about your job?

It's extremely creative. You get given a vague idea of a game design but using your imagination, combined with an ability to problem solve, produces exciting games and effects you would never have imagined you could create. When creating a soccer game, you can end up watching the players running around and trying to understand what they're doing from being given a simple set of rules. Before you know it, they're behaving like they are alive and you can't always figure out why! **Q. Would you say you have a good standard of living, or work life balance?**

My working hours are flexible and company dress is casual. This leads to a relaxed working environment where people can be themselves. The work can be extremely interesting. I've had mornings when I couldn't wait to get into work to try out some cool explosion effect that I'd been thinking about on the way back from work. The pay could be better, but is very good for a job this interesting.

Q. How do you switch off from work?

On weekends or on holidays I like to go hang-gliding. Flying up to cloud base or along alpine ridges with birds of prey is an amazing experience.

Next

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Submit and continue to next scientist.

Page 4 of 10

Miles Pebody
Robot Programmer

Q. What is his job all about?

Scientists want to find out what's happening under the ice at the Antarctic. They want to know what the seabed and submerged glaciers look like, how fast the ice is melting, if there's any sea life there and how it survives. But there's a major problem; how do you get to the Antarctic without ruining the environment you want to investigate? You can't cut through the ice with a ship because that'll damage the environment you want to investigate. You need to send something under the ice, get it to take measurements and make sure it comes back again.

The answer is a 7-meter-long robot submarine designed by a team of scientists at Southampton Oceanography Centre. Autosub's a robot submarine designed to explore deep into the oceans where people can't go. Dr. Miles Pebody is on the team of scientists developing the "Autosub." He's responsible for programming it to chart these virgin waters, carrying instruments to take water samples and monitor conditions. As a software engineer he designs programs that enable the sub to use on-board sonar to detect floating ice and the shape of the seabed so that it can navigate itself around obstacles.

Q. What do you love about your job?

The best thing about my job is earning a living by doing something interesting, varied, and fun. Also, living near the sea, and being able to go windsurfing when I look out of the window and see that the wind is blowing, is great.

Q. How important is the work of Autosub?

Autosub is increasingly important, there's no other way to get under the ice to find out how currents are changing, to monitor global warming and so on...

Q. Can you describe your work on the Autosub?

Some Autosub expeditions are land-based - we launch Autosub and tow it with a small boat - while others are ship-based. Expeditions can last up to 5 weeks and we work as a team with ship crews, marine scientists and other engineers. This involves setting up all the support equipment for launch and recovery of Autosub and then, once underway, programming Autosub for a particular mission.

We've had many successes. The most memorable was our expedition to the Weddell Sea in the Antarctic with the British Antarctic Survey. Our task was to send Autosub on missions under the sea ice to collect information about the animals that live there and how thick the ice is. This was the first time anyone in the world was able to explore under Antarctic sea ice, apart from short dips by divers etc. But we only went about 30 km or so, and we want to go back.

I want to be able to make Autosubs that can get to the bottom of the deepest ocean trenches (nearly 12km down) and spend all their time at sea recharging batteries and communicating with engineers and scientists via satellites.

Q. What was your ambition when you left school?

To be a farmer. We had friends who lived on a farm so I was always into the idea of working on one. I worked on various farms around Britain for 2 years, which was great fun until I had to sort potatoes for two years. It gave me a bit of thinking time about what I wanted to do. I liked the big tractors but didn't like the early mornings! Eventually I couldn't face any more potato sorting and didn't have a farm of my own so couldn't see a future in it."

Q. How do you spend your free time?

My wife and I windsurf whenever we can. We used to scuba dive a lot but since moving to

Southampton we've become windsurf addicts. We enjoy traveling, too. We enjoy hiking and mountain climbing and I ride a motorbike, so we sometimes travel around on that.

Q. Where can I learn more about you and your work?

Snapshots
My profile online

Next

Type your email address here. Use the same email address for all parts of the study.

What do you remember about the scientist you just read about? List at least three things.

Submit and continue to next scientist.

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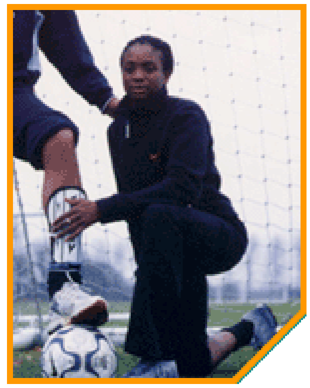
Stephanie Ankrah
Sports Materials Engineer

Q. How do you describe your job when you meet people at a party?

When I say I'm doing a PhD in Soccer Shin Guards, usually I get a weird look and have to explain a little more about the materials and stuff. Most people think it's really interesting though.

Q. How do you switch off from work?

I do a lot of sports in my spare time. I play hockey for a local club and I go to excerise classes (boxercise, khai bo, circuit training), gym, spinning, and running. At the university there is a wide range of sports available and I even took golf lessons last term. I also enjoy the student life, going out to restaurants, clubs, and of course the bars.



Q. What do you do as a sports materials engineer?

I look at how the materials in equipment behave when they are impacted, and potential materials that may improve the protection levels. I am studying at the University of Birmingham in the Department of Metallurgy and Materials Science.

Q. Where can I learn more about your work?

My homepage
Also find more material people here.

The performance of soccer shin guards
My recent research project

Shinpad change could prevent soccer injuries
News report of my research

Q. What do you love about your job?

I love interacting with people to get their opinions, on the products. I have met a few professional players, which was exciting as I am an avid soccer fan as well as a scientist. In everyday things I love having to build and design equipment for my tests. It is interesting knowing how things actually work and very satisfying when something you have made actually works and collects results. I also enjoy going to conferences and presenting at them. This September I am going to the 4th Engineering of Sport Conference in Kyoto in Japan to present some of my work, which I am really looking forward to.

Q. Your family background?

My family are very active although not particularly scientific. We are quite a sporty family. My mom and dad were both nurses when I was younger and now they both own their own businesses. My brother is also more business minded, I am the only scientist in my family really. My parents are very proud of me and have supported me throughout.

Q. Can you briefly describe your job path?

My first year at the university was quite hard as the course was hard work. We had a lot of hours compared to other departments. However the hours got easier the further into the degree I got. My grades improved year after year and I decided to do the Masters Degree. I then went on a 6 month placement in British Steel (as it was then!) as part of my final year. I also decided in my final year that I wanted to continue studying. I am a very keen sportswoman and wanted to combine my interest into my research. The perfect PhD for me was on offer so I took it and stayed.

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Submit and continue to next scientist.

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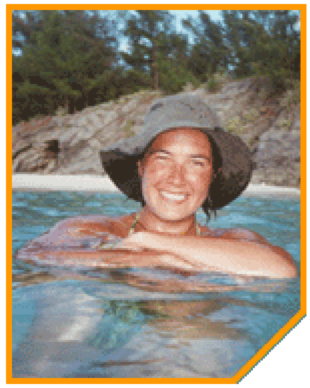
Christine Pequignet
Physical/Chemical Oceanographer



Q. Would you say you had a good standard of living / work life balance?

I live on an island where flowers bloom all year long. I walk to my office, and look at turquoise waters from my office window. I can wear whatever I want. Most of the time, it's shorts and flipflops. After work or at lunchtime, I get to enjoy these turquoise waters (sometimes I even do it for work!). If you are in the right place, the life style that comes with an oceanography job is great. Here at the Bermuda biological station, there is a really great social life, and it makes work much more enjoyable. Personally, my work is not too stressful (apart from deadline times, but it's not that frequent), at least I don't feel stress at all. A lot of my friends in different jobs envy my way of living, so I guess I must have a good standard of living, and I feel like I do. I am not rich, but I can afford to live decently even in an expensive country, I can travel a few times a year, my work hours are flexible and I like what I do. So the answer to the question is definitely yes.

Q. How do you describe your job when you meet people at a party?

I study carbon cycle, the fate of CO2 once it goes in the ocean and the consequences for the global climate.

Q. How can we know more about you and your work?

My Homepage More pictures! And my life and research in the middle of oceans.

Q. Your family background?

There wasn't any scientist in my family. My mom was a secretary in a hospital and my dad was a taxi driver.

Q. What would you like people to remember about your life as a scientist?

I see science as a big wall to the sky, that we are all building together, every one bringing his/her own little brick, some people bring more bricks than others, but the wall will never be finished anyway. I'm not in it to be remembered, I'm just glad to be part of the team.


Q. How do you switch off from work?

When I was studying waves, I found it hard to switch off from work, because my work was too close to my hobby, and often while surfing I would visualize waves as equations. I found that now that I work in a field related to what I like but not so close, I can switch off more easily. I still spend most of my free time in the ocean (sailing, kayaking, fishing, diving, surfing...) but when I am not at work, I just don't think about it. Sometimes when you are at sea for work for weeks, the fine line between work and life outside work disappear, but I like it sometimes.

Next

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What do you remember about the scientist you just read about? List at least three things.

Submit and continue to next scientist.

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Helen Fielding
Chemical Physicist

Q. How do you describe your job?

I work in the Chemistry Department at King's College London. My research involves using state-of-the-art ultrafast laser techniques to observe and control electronic and molecular processes in small molecules. I am the only person in UK working in this area.I also teach spectroscopy to chemistry undergraduates.

Q. How do you treat the balance between your family and work?

It's never easy balancing work and family, but I seem to manage. I have 2 young children so I spend my spare time playing, walking, visiting parks, zoos and museums.

Q. What is the most fascinating part of your work?

I love designing a new experiment and getting it to work for the first time. I always get an immense buzz when my experiment allows me to discover something new that no one else knows yet.

Q. Where can I learn more about your work?

My Homepage
at UCL

Double Success for Young King's Chemist
News report of my research.

Q. Is there anything along your professional history that you are proud of?

In 1997 I won the country's most prestigious prize for young physical and theoretical chemists, the Harrison Memorial Prize, awarded annually by the Royal Society of Chemistry. This was the first and only time a woman has won this prize.

Q. What are the highest achievements in your work?

I have won the prestigious Marlow Medal from the Royal Society of Chemistry and have been awarded an Advanced Fellowship from the EPSRC, as an outstanding young researcher. The Engineering and Physical Sciences Research Council (EPSRC) is the UK Government's leading funding agency for research and training in engineering and the physical sciences. Up to the year 2001 I have already attracted over 1 million into King's College London. Previous winners of the Medal include Nobel Prize winners John A Pople and John C Polanyi.

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What do you remember about the scientist you just read about? List at least three things.

Submit and continue to next scientist.

Sue Nelson
Science Correspondent

Q. How do you describe your job?

I am a science and environment correspondent for BBC TV News - mostly for the One o'clock News and Breakfast. My job is to report science news stories on air, usually in less than two minutes (which is an art in itself!).

Q. What do you love about your job?

I enjoy the whole process of putting a report together: the research, filming, writing, professional make up artists when you've had a late night, editing and finally seeing it on air happy that you've got the basics across without losing sight of the story under - often - extremely stressful conditions.

Q. How do you balance your family and work?

I had my first child in my late thirties. Up until then I worked long hours and occasionally at weekends.

I believe that getting the work life balance right is difficult - but I am lucky in that my managers have gone out of their way to help me balancing my work and my family. Even then, it's not always easy.

I work part-time, Tues-Fridays, and child friendly hours. Working on the One o'clock News means I can leave early afternoon for the nursery run and then work from home once my son's asleep. Tough sometimes, but this way I get to see him and get my work done. I'm not sure I could cope with full time or long hours as you'd never see your child. And who can afford a nanny? I know I can't.

BBC news on Portable and wearable PC

Q. How do you switch off from work?

Glass of wine, watching Buffy, pushing my son on a swing in the park, laughing with husband. No time to pursue any hobbies.

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Type your email address here. Use the same email address for all parts of the study.

What do you remember about the scientist you just read about? List at least three things.

Submit and continue to next scientist.

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Gareth Mitchell
Science Journalist

Q. Can you briefly describe your job and your job path?

At present, I produce and contribute to radio programs about science. I am also a part-time lecturer in broadcast communication and Science Communication at London's Imperial College.

I started out with an Electrical Engineering degree at Imperial College and then studied Science Communication. After graduating, I landed a 9-month contract to produce and present weekly science programs in English but based in Holland, and later I was picked to present regular science programs for young people on the BBC World Service. I had various broadcasting and journalistic 'gigs' and have discovered that it's possible to make a living without it feeling like 'work'!

Q. Your family background?

Dad is not a scientist himself but was keen to see his little boy end up in something 'sensible' like engineering. Mom wasn't fussy about it as long as her offspring was happy and not into drugs or car-jacking. As it's turned out, Mom likes hearing my stuff on the radio and Dad wonders how much more money I'd be making if I'd done a 'sensible' job.

Q. Where can I learn more about your work?

Click here:
http://www.scicom.hu.ic.ac.uk/
Where I work

Science for a skeptical audience
assessing the state of science and science broadcasting

Q. What do you love about your job?

Lucky me, I wake up in the morning and look forward to going to work! For me each day is different. I might be interviewing rock stars in downtown Boston (who says science reporters have to do only do science?!) or I might be trying out the Space Shuttle simulator at NASA's space centre in Houston (yes, I did crash it the first time round!) By and large my so-called job is great fun and really rewarding. I still love it when mom tells me she's just heard me on the radio! Equally rewarding is my teaching - we have some bright students who love to learn. Seeing them pick things up quickly is great and when they challenge me in class, it keeps me on my toes.

Q. Would you say you had a good standard of living, or work life balance?

I think I have a great standard of living. But it's not a money thing, believe me. I'm lucky because I have a regular teaching job. If you're 100 per cent freelance, you're constantly worried about running out of work and wondering how you're going to pay the rent if you do. There are few 'staff' jobs in science radio - so don't even consider it as a career unless you're prepared to take the highs and the many lows of being freelance for much of your working life. Money-wise, I have a 'comfortable' life. When I say I have a great standard of living, I'm referring to the sheer variety of what I get to do. I think my standard of living equates to someone who earns ten times as much as I do!

Q. How do you switch off from work?

Believe it or not, I switch off by switching on to the radio. The hard thing is to tune in as a 'normal' listener though. As I work in radio, it's hard to listen recreationally without thinking how I'd do it differently. Hmmm doesn't sound very well rounded does it? Hobby-wise then, I like listening to good music and playing very bad music (on my guitar). I like going to the cinema and hang out with my many friends -- both of them. I like motorcycling but I'm trying to save money, so am now selling my bike (all offers considered!).

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Submit and continue to next scientist.

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Simon Torok
External Communications Manager

Q. How do you describe your job when you meet people at a party?

I tell people I am a science journalist or editor, as writing is the most common part of my work. When I worked as a CSIRO communicator, I produced a soap opera on the Web about scientists.

Q. What do you love about your job?

I love seeing people come to an understanding about what I am talking about and enjoy people telling me after a presentation that they have learned something and will change their behavior as a result. I gain similar satisfaction receiving comments about articles I've written. I'm particularly keen on the area of science I am now working in, as I see climate change as an urgent and real problem that we must do something about.

Q. Would you say you had a good standard of living or work life balance?

I find the pressure at work is not too great, so I can switch off at the end of the day. Hours can sometimes be long due to the number of inquiries I receive, but these can be managed. The fun nature of the job makes the hours fly by. The pay in science communication is on a par with science in the early stages of a career, although you can move up through the ranks faster.

Q. How do you switch off from work?

I play guitar, take any opportunity to travel around the UK and to Europe, enjoy going to gigs to see local bands, and writing.

Can you briefly describe your job and your job path?

I talk to people about climate change and what we can do about it, write articles and send out press releases to ensure the research at the Tyndall Centre for Climate Change Research is discussed in the community.

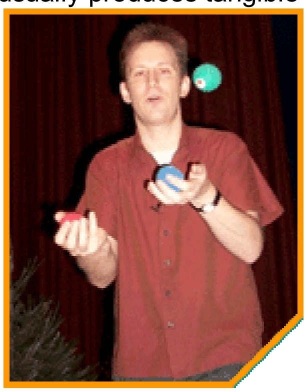
I realized during my work in science research that I enjoyed presenting my work in lectures and general articles more than I actually enjoyed the research. So I looked around for careers in communication, and found an entire field dedicated to communicating science. I spent a year traveling Australia presenting science shows with Australia's National Science and Technology Centre and the Australian National University, and then landed a job communicating science with CSIRO, Australia's research organization. I've since been editor of a science magazine, written many articles and a few books, and now communicate climate change results in the UK.

Are your parents scientists?

Science isn't in the family, but presentation to audiences is -- one of my brothers is a comedian, the other is an actor. So my job of presenting science isn't too far removed from what my two brothers do. But my parents don't know where we get this from!

Who or what inspired you to become a scientist?

My teachers recognized that I had a preference and flair for math and the sciences, but I kept up with languages through school and at the university. I was always interested in the way science usually produces tangible results and concrete answers.



Q. How can we know more of your work?

Click here:
My Homepage

CSIRO Atmospheric Research

Tyndall Centre for Climate Change Research

The Web Science SOAP OPERA

The stories in this soap opera take a humorous look at the social lives of six scientists, played by young scientists from CSIRO. The social action parallels the scientific themes, and an interactive reality check section allows readers to obtain more information about the science.
Conceiver of the series, Simon Torok says, "As a scientist, I'm offended by the negative stereotypes usually portrayed in the media. Young people need to get more of an idea about what it's really like to be a scientist. [The soap is] really a trojan horse to attract people not usually interested in science to find out about current scientific issues. We are trying to make science fun, without making fun of science," Dr Torok said.

Next

Type your email address here. Use the same email address for all parts of the study.

What do you remember about the scientist you just read about? List at least three things.

That was the last scientist. Submit and continue to the post-lesson journal.

Journal activity

Type your email address here. Use the same email address for all parts of the study.

List three different types of jobs that scientists have.

Briefly describe a typical scientist.

Take a minute to reflect on the scientists you just "met." Were you surprised? Why or why not? Are they people you would like to meet in person? Why or why not? Write a few paragraphs to respond to this module.

Appendix C: Minerals Module

The experimental group went through this module during either week 2 or week 3 of the study.

Welcome to the study. Thank you for participating.

The following web pages make up a module in the study. Please work through these pages within one week of the email notification sent to you about this module.

Following this module you should be able to

1. Describe the importance of minerals to our way of life.
2. List and define common physical and chemical properties used to identify minerals.
3. Give the uses of common rock-forming minerals.
4. Identify the specific physical and chemical properties that make common minerals useful.
5. Describe social and environmental issues associated with mineral exploration and mining.

During this lesson, you will

1. write a journal entry about what you already know, feel, and do;
2. read about some minerals and write about what you remember; and
3. write a response journal.

Begin

Journaling Activity

Recall the objectives of this module. They are:
1. Describe the importance of minerals to our way of life.
2. List and define common physical and chemical properties used to identify minerals.
3. Give the uses of common rock-forming minerals.
4. Identify the specific physical and chemical properties that make common minerals useful.
5. Describe social and environmental issues associated with mineral exploration and mining.

Take a minute to think about how you feel about minerals, what you already know about minerals, and what you will do as you work through the module. In the spaces below, record your responses.

Type your email address here. Use the same email address for all parts of the study.

How does knowing that you are about to learn about minerals make you feel? Write a paragraph or two about your feelings below. (Need help? Click for a list of feeling words.)

What do you already know about minerals? Can you already meet some of the objectives? Do you expect to learn something new? Write a paragraph or two about your thoughts below.

How do you think you will approach this module? What will you do? Will you go through it as fast as possible or will you do it slowly? Will you work on it by itself or will there be other distractions? Write a paragraph or two about what you think you will do during the module.

SUBMIT

Meet some minerals

In the next few pages, you will learn about some common rock-forming minerals that are used in a variety of everyday materials. You will also learn about some of the issues surrounding mineral mining. Take a few minutes to learn about each one - you will be asked to write about what you remember.

Continue

Could you live without your car?

The importance of mineral resources

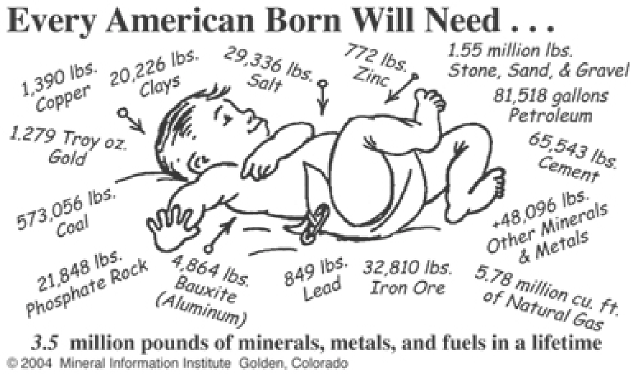
There are more than 130 million passenger cars in the United States alone. More than 8 million cars are made every year for use in the U.S. Do you have a car? Do you know where its components came from?

Q. Why do we mine?

Mined resources are important components of many of the necessities of modern life. In an MIT survey, 63% of Americans said they couldn't live without their cars. Automobiles are made up of at least **39** different minerals and metals, with each performing a special function when used in combination with others. The average weight of an automobile is 2,600 to 3,000 pounds.

There are at least 39 different minerals in this car.

This is why we mine. We mine minerals, metals, and petrochemicals to make the things we use every day. When you want something, you probably don't stop to think about the source of the materials necessary to make the product. If it wasn't grown, it had to be mined. To maintain our current standard of living in the United States, we must continue to mine at least 48,148 pounds of new minerals every year. Each American will use about 3.5 million pounds of minerals, metals, and fuels in his or her lifetime.



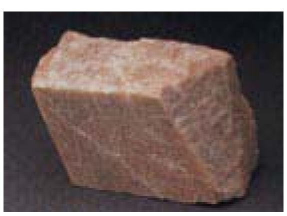
Q. What are mineral resources?

Mineral resources include anything that is mined, quarried, or pumped (in the case of crude oil) from the ground. Mineral resources include rocks and minerals.

Q. What is the difference between a mineral and a rock?

Minerals are the components that make up rocks. Any stone you pick up outside is a rock, and it is made up of one or more minerals. Minerals are naturally-occurring homogeneous solids, inorganically formed, with definite chemical composition and ordered internal atomic arrangement.

An analogy: Think about a granola bar. You can see oats, raisins, and chocolate chips in it. The granola bar is like a rock, and the oats, raisins, and chocolate chips are like minerals - single materials that make up the more complex solid.


The mineral potassium feldspar. Notice how the entire specimen looks the same.


The rock granite. This granite is made up of potassium feldspar (which gives it the characteristic salmon pink color), quartz, and biotite mica.

Geologists use computer models to estimate the quantities of mineral resources in deposits.

Q. How are minerals used in Virginia?

Roughly 12 tons of aggregate (sand, gravel, and crushed stone) are required annually for each Virginia citizen. A typical residential subdivision requires about 300 - 400 tons of aggregate per home.

Approximately 50% of all aggregate is used for publicly funded construction projects, such as highways, water and sewer systems, public buildings, airports and other county and municipal public works projects.

Q. Where can I learn more about the uses of mineral resources?

The Mineral Information Institute

Virginia Aggregates

Next

Type your email address here. Use the same email address for all parts of the study.

What do you remember about the mineral you just read about? List at least three things.

Submit and continue to next mineral.

Page 2 of 10

Cleaning the bathroom
Feldspar and quartz

Q. What does cleaning the bathroom have to do with minerals?

The answer is in the mineral property called hardness. Some minerals, like talc (baby powder) are so soft you can scratch them with your fingernail. On the other end of the scale is a diamond, which is so hard that it scratches nearly every other material. Bathroom cleaning powders are made up of soap and small abrasive particles for scouring. The particles can be made from most any mineral, but some work better than others.

Q. What's the connection between bathroom scouring products and feldspar and quartz?

During the 1880s a popular scouring soap, called Sapolio, was made from finely ground quartz and tallow soap. Quartz for the soap was obtained from mines in the Northeast. The quartz was always entwined with softer feldspar and the two minerals had to be separated by hand. The feldspar was discarded until someone suggested that this soft mineral might be combined with soap to create a less abrasive product to clean hard surfaces without scratching them. The feldspar was ground to a fine powder, mixed with liquid soap in wooden troughs, cured and cut into cakes, and Bon Ami soap was born.

You can still find Bon Ami soap powder in the cleaning aisle. Its slogan, “Hasn’t scratched yet!” has everything to do with the hardness of feldspar.

The primary use of mined feldspar is for the manufacturing of porcelain and glass products. The powder hasn’t scratched because it is not hard enough to scratch porcelain sinks and bathtubs. Quartz powders, on the other hand, are harder than porcelain and scratch it easily.

Hardness

A mineral's resistance to scratching is called its hardness. Hardness also tells how well a mineral will scratch another material. Hardness is described by using Moh's scale

 Glass plates, with a hardness of 5.5, are used to check the hardness of minerals. This quartz crystal is harder than the glass plate.

Moh's scale:

1 Talc
2 Gypsum
3 Calcite
4 Fluorite
5 Apatite
6 Orthoclase feldspar
7 Quartz
8 Topaz
9 Corundum
10 Diamond

Q. What are feldspar and quartz?

Feldspar and quartz are two of the minerals that make up granite, which is a very common rock at the earth's surface. Although both are silicate minerals (containing silicon and oxygen atoms), feldspar contains other elements as well that make it softer than quartz. On Moh's scale of hardness, feldspar has a hardness of 6, and quartz has a hardness of 7.

Q. Where can I learn more?
History of Bon Ami
Feldspar
Quartz

Identifying	**potassium feldspar**
Chemical class	silicate
Chemical formula	$KAlSi_3O_8$
Hardness	6
Luster	greasy to earthy
Specific gravity	2.6
Color	variable
Streak	white
Notes	salmon pink color is common

Identifying	**quartz**
Chemical class	silicate
Chemical formula	SiO_2
Hardness	7
Luster	nonmetallic
Specific gravity	2.7
Color	variable
Streak	white
Notes	very common

Next

Type your email address here. Use the same email address for all parts of the study.

What do you remember about the mineral you just read about? List at least three things.

Submit and continue to next mineral.

Page 3 of 10

Color the world
Hematite and limonite

Q. What do minerals have to do with "coloring the world"?
The color of a mineral might be helpful for identifying it, or it might not. Mineral colors are tricky because a single mineral can be a number of different colors. However, the color of a powdered sample of a mineral is much more useful for identifying minerals.

Powdered mineral samples can also be used to "color" paints, crayons, and other pigmented products.

Streak


A sample of limonite and its streak

The color of a powdered sample of a mineral is called its streak. A mineral's streak may or may not be the same color as the mineral itself, but it is about the same for all samples of a given mineral.

These products are pigmented with hematite and limonite from Pulaski County.

Q. What are some examples of minerals used for coloring?

Have you ever used the burnt sienna or raw umber crayon? If so, you have seen local hematite in action. Hematite and limonite are minerals mined in Pulaski County, Virginia, for the production of black, brown, yellow, and red pigments. All the burnt sienna mined in the United States for Crayola crayons comes from this mine.

 This photograph shows the area where pigments are mined. Do you see the yellow, brown, and red soil?

Q. What are hematite and limonite?
Hematite and limonite are closely related iron ore minerals that are relatively common. Most hematite and limonite mined is used for steel production. However, some is mined for its pigment properties.

Hematite and limonite are both easily identified by their streaks. Hematite has a blood red streak, and limonite has a dark yellow streak.

Q. Where can I learn more?

[Hoover Color]

Identifying	hematite
Chemical class	oxide
Chemical formula	Fe_2O_3
Hardness	5-6.5
Luster	metallic to earthy
Specific gravity	4.9-5.3
Color	silver, gray, or red
Streak	red-brown
Notes	streak is best identifier

Identifying	limonite
Chemical class	oxide
Chemical formula	$Fe_2O_3 * nH_2O$
Hardness	5-5.5
Luster	metallic to earthy
Specific gravity	4.1-4.3
Color	yellow to brown
Streak	yellow-brown
Notes	streak is best identifier

Next

Type your email address here. Use the same email address for all parts of the study.

What do you remember about the mineral you just read about? List at least three things.

Submit and continue to next mineral.

Page 4 of 10

Environmental problems and solutions
Pyrite and calcite

Q. What do minerals have to do with environmental problems?
Minerals are chemicals. In contact with air, water, or other materials, minerals can react, creating new chemicals that may help or hurt the immediate environment. Many environmental problems are associated with the mining of minerals.

The solutions to these problems often involve minerals as well.

Q. What is an example of a mineral that causes an environmental problem?

Pyrite is a sulfide mineral that is often found in association with coal. When exposed to air and water, it forms the acid in acid mine drainage.

Q. What is acid mine drainage?

Acid mine drainage is acidic water that drains from coal and metal mines. It occurs when sulfide minerals, including pyrite, are exposed to oxidizing conditions. The sulfur is released from the mineral and reacts with water to form sulfuric acid. The sulfuric acid creates acidic conditions in groundwater and surface water, severely damaging downstream ecosystems.

$$(1)\quad Fe^{+2} + \tfrac{1}{4} O_2 + H^{+} \rightarrow Fe^{+3} + \tfrac{1}{2} H_2O$$

$$(2)\quad FeS_2 + 7/2\ O_2 + H_2O \rightarrow 2SO_4^{-2} + Fe^{+2} + 2H^{+}$$

$$(3)\quad Fe^{+3} + 3H_2O \rightarrow Fe(OH)_3 + 3H^{+}$$

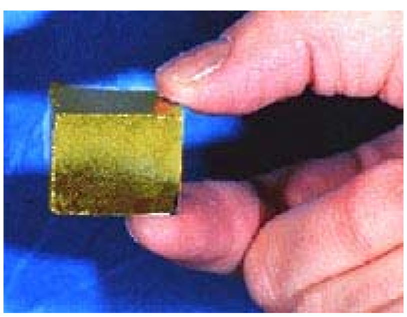
$$(4)\quad FeS_2 + 15/4\ O_2 + 7/2\ H_2O \rightarrow 2H_2SO_4 + Fe(OH)_3$$

This series of reactions shows how acid mine drainage forms from the oxidation of pyrite. Source.

Chemical formulas

Recall that minerals have a definite chemical composition. Each mineral is made up of many copies of the same molecule. Minerals are grouped by similarities in their chemical formulas. For example, sulfide minerals are made up of sulfur and at least one other element. Silicates are made up of silicon, oxygen, and one or more other elements. Carbonates are made up of carbon, oxygen, and one or more other elements.

Calcite $CaCO_3$



Pyrite FeS_2

Q. How can a mineral help clean up acid mine drainage?

Acids are neutralized by bases or alkaline materials. When another mineral, calcite, comes in contact with acidic water, it neutralizes the acid, leaving water and carbon dioxide. Calcite, a carbonate mineral, is the primary mineral in the rock limestone. In Appalachia, limestone is readily available, and is often used to remediate acid mine drainage.

Acid mine drainage on this West Virginia creek is remediated by adding finely ground limestone to the stream. Here, the treatment plant is visible at the bottom of the image, and the limestone is visible as a lighter-colored substance in the water.

After this system was installed, a formerly "dead" river became a high quality trout fishery.

(1) $CaCO_{3(s)} + H^+ \rightarrow HCO_3^- + Ca^{+2}$

(2) $HCO_3^- + H^+ \rightarrow H_2CO_3$

(3) $H_2CO_3 \rightarrow H_2O + CO_{2(g)}$

This series of reactions shows how the calcite in limestone neutralizes acids. Source

Q. Where can I learn more about acid mine drainage and remediation?

Acid mine drainage primer
Remediation story

Identifying	**pyrite**
Chemical class	sulfide
Chemical formula	FeS_2
Hardness	6-6.5
Luster	metallic
Specific gravity	5
Color	brass yellow
Streak	dark gray
Notes	"Fool's gold"

Identifying	**calcite**
Chemical class	carbonate
Chemical formula	$CaCO_3$
Hardness	3
Luster	nonmetallic
Specific gravity	2.7
Color	variable
Streak	white
Notes	fizzes in acid

Next

Type your email address here. Use the same email address for all parts of the study.

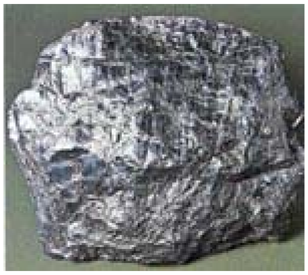
What do you remember about the mineral you just read about? List at least three things.

Submit and continue to next mineral.

Page 5 of 10

Writing and scratching
Graphite and diamond

Q. What do minerals have to do with writing?
Pencil leads are made from the mineral graphite.



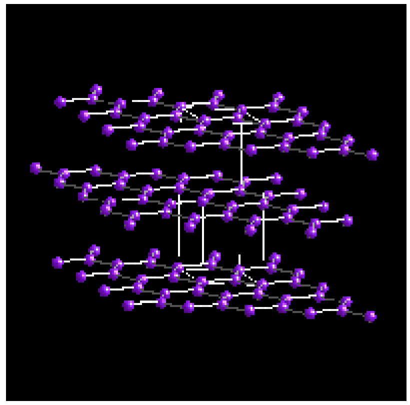
Q. What do minerals have to do with scratching?
Diamonds, another mineral, are the hardest of all known substances, can scratch anything else. Diamonds are used in abrasive materials, and, of course, as jewelry.

Q. What do graphite and diamond have to do with each other?
They are chemically identical - both are composed of carbon (C), but physically, they are very different.

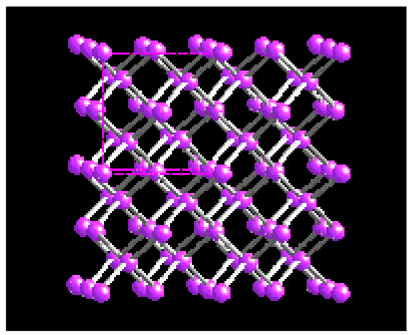
Q. How are graphite and diamond different?
When you look at graphite and diamond, it is hard to imagine that they are identical chemically, for they are so different physically. Graphite is opaque and metallic- to earthy-looking, whereas, diamonds are transparent and brilliant. Another important physical difference is their hardness. Graphite is very soft and has a hardness of 1 to 2 on Moh's scale of hardness. Diamonds are the hardest known natural substance and have a hardness of 10. The crystal structure of graphite yields physical properties that permit the use of graphite as a lubricant and as pencil lead. The gem and industrial properties of diamond, physical properties that we cherish and exploit, are also a result of diamond's crystal structure.

Crystal structure

Minerals have an ordered internal structure. This means that the molecules of the mineral are arranged in repeating patterns that are responsible for the beautiful crystals that some minerals form. Crystal forms are one way to identify minerals. Some minerals have the same chemical composition, but different crystal structures. These pairs are called polymorphs.



Graphite's crystal form is in sheets connected together by weak bonds.



Diamond's crystal form, shown by this model, contains the same atoms as graphite, but in a different ordered arrangement.

Q. How can the two minerals have the same chemistry and be so different?

The reason for the differences in hardness and other physical properties can be explained with molecular models. In graphite, the individual carbon atoms link up to form sheets of carbon atoms. Within each sheet every carbon atom is covalently bonded to three adjacent carbon atoms. The spacing between the sheets of carbon atoms is greater than the diameter of the individual atoms. Weak bonding forces called van der Waals forces hold the sheets together. Because these forces are weak, the sheets can easily slide past each other. The sliding of these sheets gives graphite its softness for writing and its lubricating properties.

In diamonds, each carbon atom is strongly bonded to four adjacent carbon atoms to form a three-sided pyramid. These bonds have the same strength in all directions. This gives diamonds their great hardness. The brilliance and "fire" of cut diamonds are also related to the structure of diamonds.

Q. Where can I learn more about diamonds and graphite?

Miles Mineral Museum

Jill Pasteris


Dr. Jill Pasteris, far right, got her start studying the microscopic features of diamonds. She now collaborates with Dr. Brigitte Wopenka (far left) and Dr. John Freeman (center) studying everything from volcanos to breast implants to bone chemistry.

Identifying	graphite
Chemical class	native element
Chemical formula	C
Hardness	1
Luster	metallic/ greasy
Specific gravity	2.1-2.3
Color	gray to black
Streak	dark gray
Notes	marks paper

Identifying	diamond
Chemical class	native element
Chemical formula	C
Hardness	10
Luster	adamantine
Specific gravity	3.52
Color	colorless and variable
Streak	no streak
Notes	very hard

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What do you remember about the mineral you just read about? List at least three things.

Submit and continue to next mineral.

Page 6 of 10

Girl's best friend?
Diamond

Q. Diamonds are a girl's best friend, right?
Decide for yourself. There are big issues surrounding diamond mining. Read two points of view below.

Two sides of the diamond debate

From www.adiamondisforever.com

"Unparalleled in its beauty, unmatched in its mythical lore, the diamond has evolved into the ultimate gift of love."

"The gift of a diamond is one of the few tangible ways to tell that certain someone that they mean the world to you."

This Is Your Moment
The instant two people decide to marry is probably the most intimate and important moment of their lives. It marks the moment two become one forever. As a gift of love, diamonds evoke the romance and magic of traditions that have spanned centuries.

The First Diamond
The diamond acquired its unique status as the ultimate gift of love as far back as the fifteenth century. The tradition of giving a diamond engagement ring as a promise for marriage began in 1477 with Archduke Maximillian of Austria and Mary of Burgundy. At that time, diamonds were looked upon as talismans, or charms, that could enhance the love of a husband for his wife. Even Cupid's arrows were said to be tipped with diamonds, which had a magic that nothing else could equal. From this time forward, the royal tradition of giving a diamond engagement ring began to be embraced by people around the world, eventually becoming as much of a milestone in one's life as the engagement itself.

The Brilliance of a Diamond
When diamonds first began to be given as engagement rings, settings were elaborate and did not necessarily show the diamond in its best light. It actually wasn't until the discovery of diamond mines on the African continent in 1870 that diamonds became accessible to a wider public, increasing demand and influencing design.

The Mysterious Power of a Diamond
Wearing a diamond ring on the fourth finger of the left hand dates far back to ancient Egypt, where it was believed that the vena amoris (the vein of love) ran from that finger directly to the heart.


Amputee girl at the amputee camp in Freetown, Sierra Leone. © AI

From Amnesty International

"Conflict diamonds," the diamonds that are sold to fund conflicts, have been at the heart of some of Africa's most protracted and bloody wars. Diamonds have fuelled conflicts in Angola, Democratic Republic of Congo, Liberia and Sierra Leone, destroying nations and costing an estimated 3.7 million lives.

Illicit diamonds make fabulous profits for terrorists and corporations alike.

In Sierra Leone, a war is being fought for control of one of the world's most precious commodities: a fortune in raw diamonds that have made their way from the deadly jungles of Sierra Leone onto the rings and necklaces of happy lovers the world over.

Arms merchants, feeding on the diamond trade, bankrolled local armies and made fortunes for transnational corporations. The profits also filled the coffers of Al Qaeda, and possibly

Hezbollah—terrorist organizations notorious for committing human rights violations, including crimes against humanity.

Few who eventually wear the gems could even locate Sierra Leone. And fewer still could find the Parrot's Beak, a small wedge of land that juts between the borders of neighboring Liberia and Guinea, directly into the line of fire between warring rebel factions in those countries. Rebel forces of all three nations fought with one another, as well as with the legitimate governments of all three countries and with an unknown number of local indigenous militias that were fighting for reasons of their own.

In Sierra Leone, the Revolutionary United Front (RUF) began its jewelry heist in 1991, using the support of neighboring Liberia to capture Sierra Leone's vast wealth of diamond mines. The RUF's signature tactic was amputation of civilians: Over the course of the decade-long war, the rebels have mutilated some 20,000 people, hacking off their arms, legs, lips, and ears with machetes and axes. Another 50,000 to 75,000 have been killed. The RUF's goal was to terrorize the population and enjoy uncontested dominion over the diamond fields.

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What do you remember about the mineral you just read about? List at least three things.

Submit and continue to next mineral.

Page 7 of 10

Minerals and your health
Halite and iodine

Q. What do minerals have to do with my health?
You know that getting your vitamins and minerals is important to your nutrition. How do nutritional minerals relate to the minerals in rocks? They are the same thing. We get most of our vitamins and minerals through eating plants and animals that contain them. Some, however, come straight from the rocks.

Q. What is an example of a mineral I need for my nutrition?
You probably get plenty of sodium if you eat a typical American diet. Sodium is an element you get from salt. In the mineral world, common table salt is known as halite.

Q. Where does halite come from?
Halite is found in sediments formed from the evaporation of lakes or seas. Because it dissolves in water, it is usually mined by pumping hot water into the ground, allowing it to dissolve the salt, and bringing the brine back to the surface. The water is evaporated away, leaving the salt crystals.


Halite is an evaporite mineral with cubic cleavage. Notice the 90-degree angles

The salt industry has cooperated with world health leaders to add iodine.


This woman's swollen neck indicates an iodine deficiency.

Q. What is another mineral I need for my nutrition?
Have you noticed that your salt is "iodized"? A quarter teaspoon of salt (1.5 grams) provides 67 micrograms of iodine, which is about half of the U.S. Recommended Daily Allowance for iodine. Like salt, iodine is "mined" by evaporating brines that contain it. It also comes from certain seaweeds.

Q. Why do I need iodine?
The main reason that you need iodine is because of a gland in your neck called the thyroid gland. The thyroid gland produces hormones that your body uses during metabolism. Without these hormones you start to feel tired, depressed, cold, weak, etc. Iodine is an important element in these hormones, so without iodine your thyroid gland cannot produce them. When starved for iodine, the thyroid gland also swells, and when it does it is called *goiter*.

Iodine deficiency disorders (IDD) are a bigger problem for children. Problems start before birth. Serious iodine deficiency during pregnancy may result in stillbirths, abortions, and congenital abnormalities such as cretinism, a grave, irreversible form of mental retardation that affects people living in iodine-deficient areas of Africa and Asia. However, of far greater global and economic significance is IDD's less visible, yet more pervasive, level of mental impairment that lowers intellectual prowess at home, at school and at work. Iodine deficient people may forfeit 15 IQ points.

Q. What is being done to fight iodine deficiency disorders?

Progress has been dramatic since the primary intervention strategy for IDD control – Universal Salt Iodization (USI) – was adopted by the World Health Organization in 1993. Salt was chosen because it is widely available and consumed in regular amounts throughout the year, and because the costs of iodizing it are extremely low – only about a nickel per person per year.

Where salt iodization has been in place for over five years, improvement in iodine status has been overwhelming.Over the last decade, the number of countries with salt iodization programmes doubled, rising from 46 to 93. As a result, today 68% of the 5 billion people living in countries with IDD have access to iodized salt, and the global rates of goiter, mental retardation and cretinism are falling fast.

Q. Where can I learn more about iodized salt?

[About iodine]

[Iodized salt and world health]

Identifying	**halite**
Chemical class	halide
Chemical formula	NaCl
Hardness	2.5
Luster	nonmetallic
Specific gravity	2.1-2.6
Color	colorless or white
Streak	white
Notes	salty taste

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Type your email address here. Use the same email address for all parts of the study.

What do you remember about the mineral you just read about? List at least three things.

Submit and continue to next mineral.

Page 8 of 10

Monumental buildings

Calcite

Q. What do minerals have to do with buildings?

Some very pretty buildings are made of stone. Remember that minerals make up rocks. Certain minerals give rocks the color and strength needed for building construction. An example is the mineral calcite, the same mineral that was used to neutralize acid mine drainage.

Q. How is calcite used in buildings?

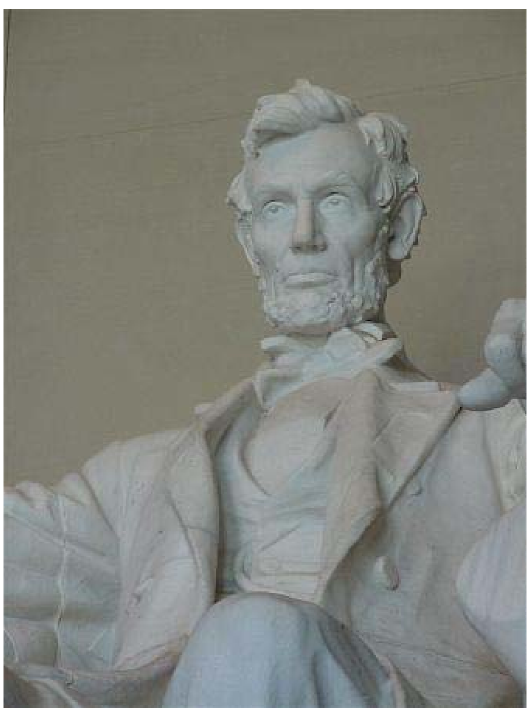
Calcite is a very common rock-forming mineral. It comes in a wide variety of colors, including white, pink, green, and black. However, the vast majority of calcite is white or colorless. Calcite is the primary mineral in two common rocks: limestone and marble. Limestones and marbles that contain nearly pure calcite are often beautiful white rocks, and make beautiful building stones.

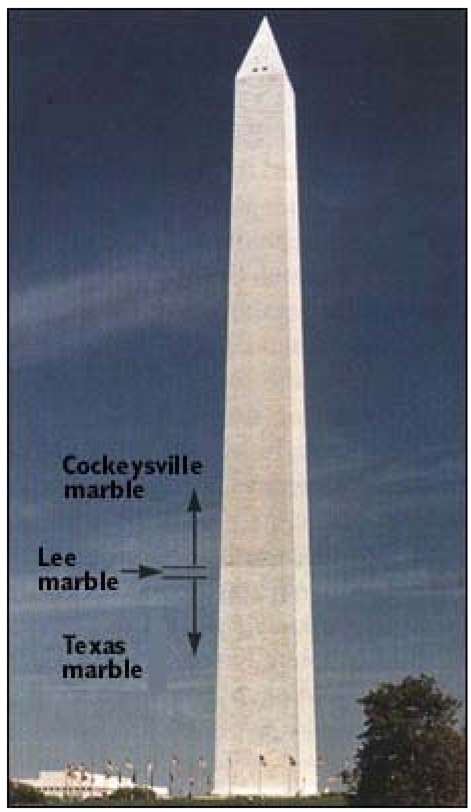
Q. What are some buildings that are made with limestone or marble?

The cityscape of Washington DC includes several great examples, including the Lincoln Memorial, the Washington Monument, and the White House.

The Lincoln Memorial

The Lincoln Memorial includes the monument building, a statue of Lincoln, and a reflecting pool. The exterior of the building is made from Indiana limestone and Colorado marble. The statue is carved of marble from Georgia. The base of the statue and the monument floor are made from Tennessee marble. The reflecting pool is made of North Carolina granite. Steps leading into the building are made of granite from Massachusetts. All the rocks had to be quarried, transported, and shaped. Together they form a major structure in Washington DC's memorial landscape.





The Washington Monument

Three different kinds of marble were used in the construction of the Washington Monument, which was delayed by several problems. The first 152 feet of the monument, built between 1848 and 1854, is faced with marble from the town of Texas in Maryland. Work stopped when funds ran out. When construction was about to resume in 1876, the builders discovered that the foundations were inadequate and the monument was sinking and tilting. To stabilize and straighten the monument, wider subfoundations were constructed to a depth of nearly 37 feet.

In 1879 work began again on the upward projection of the monument, and four courses or rows of white marble from Lee, Massachusetts, were laid above the Texas marble. However, Lee marble proved too costly, so the upper part of the monument was finished with Cockeysville marble from Maryland. The three marbles used in the monument can be distinguished by color differences.

The White House is white because it is covered with white marble, some of which came from Maryland. Under the marble, the structure is the Aquia Creek sandstone, quarried from near Fredericksburg, Virginia.

Q. Where can I learn more about the geology of Washington DC buildings?

United States Geological Survey Booklet

Identifying	**calcite**
Chemical class	carbonate
Chemical formula	$CaCO_3$
Hardness	3
Luster	nonmetallic
Specific gravity	2.7
Color	variable
Streak	white
Notes	fizzes in acid

Next

Type your email address here. Use the same email address for all parts of the study.

What do you remember about the mineral you just read about? List at least three things.

Submit and continue to next mineral.

Page 9 of 10

Making makeup
Talc, mica, and kaolinite

Q. What do minerals have to do with makeup?
Have you ever read the ingredients in makeup, shampoo, or toothpaste? It might surprise you. Many personal-care products contain a wealth of mineral materials taken from the earth. Take, for example, eye shadow.

Q. What are the minerals in eye shadow?
One of the first ingredients listed in eye shadow is usually talc - a magnesium silicate mineral. Its platy crystal habit is in part the reason why talc has been an important ingredient in cosmetics since 3500 B.C. The plates glide smoothly across each other, allowing makeup to be applied easily. They lie across the pores in the skin and lessen the chance of clogging pores, while providing texture to the skin. Yet they are translucent enough not to be seen. Talc is resistant to acids, bases, and heat and tends to repel water. In addition to eye shadows, talc is used in loose and pressed powders and blushes, is a filler in some deodorants, and is added to lotions and creams. Talc can also be found in chewing gum and pharmaceuticals.

Mica, a mineral widely used in eye shadows, powder, lipstick, and nail polish, is added to give luster or pearlescence to a product. Mica is resistant to ultraviolet light, heat, weather and chemical attack and adheres to the skin. Like talc, it has excellent slip characteristics and may be used to replace talc in a makeup. When coated with iron oxide, mica flakes sparkle with a gold tint.

Kaolin, a clay, is added to makeup to absorb moisture. It covers the skin well, will stay on the skin, and is resistant to oil. Kaolin and another clay, bentonite, are added to the earth-based face masks or packs predominately for their cleansing effects. Clays are also used as fillers in different products.

What minerals are in her eye shadow?

Talc, powdered and natural; Muscovite, a type of mica; Kaolin is a clay mineral (penny for scale)

Q. Where can I learn more about minerals in cosmetics? Women in Mining

Identifying	talc
Chemical class	silicate
Chemical formula	$Mg_3Si_4O_{10}(OH)_2$
Hardness	1
Luster	greasy
Specific gravity	2.7-.2.8
Color	light colored
Streak	white
Notes	soapy feel

Identifying	kaolinite
Chemical class	silicate
Chemical formula	$Al_4(Si_4O_{10})(OH)_8$
Hardness	1-2
Luster	earthy
Specific gravity	2.6
Color	white
Streak	white
Notes	soft and smooth

Identifying	biotite
Chemical class	silicate
Chemical formula	complex
Hardness	2.5
Luster	nonmetallic
Specific gravity	2.7-3.1
Color	brown to black
Streak	gray-brown
Notes	sheets

Identifying	muscovite
Chemical class	silicate
Chemical formula	complex
Hardness	2-2.5
Luster	nonmetallic
Specific gravity	2.7-3.0
Color	colorless
Streak	white
Notes	sheets

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What do you remember about the mineral you just read about? List at least three things.

Submit and continue to next mineral.

Page 10 of 10

Cleaning up mined out lands
Mine reclamation

Q. What happens to mines and quarries after all the minerals have been removed?
Cleaning up mined out lands is a big environmental issue. In some cases, irresponsible mining companies just leave. The mine is left with no vegetation, or with a dangerous hole in the ground. In developed countries, abandoning mines and quarries is not legal. Consequently, mining companies have created beautiful places from old mines and quarries. Reclaimed mines and quarries are now golf courses, gardens, housing developments, and wildlife refuges.

Q. What is an example of a reclaimed mine?

Once a productive limestone quarry on Vancouver Island, Canada, the Butchart Gardens have been developed into fifty acres of floral finery. The quarry was the source of limestone for the Portland Cement company owned and operated by Mr. Robert Butchart in the late 1880's, whose home was also on the property.

When the quarry was exhausted in 1904, an unprecedented plan for refurbishing the pit was devised. Tons of topsoil from nearby farmland were used to line the floor of the pit. Under Mrs. Jennie Butchart's supervision, the former quarry bloomed as a spectacular Sunken Garden. Next the Butcharts created a Japanese Garden on the sea-side of their home, and later a symmetrical Italian Garden. The Rose Garden followed in 1929. By that time, more than fifty thousand people each year were coming to see their creation.

The plant stopped manufacturing cement in 1916, but continued to make tiles and flower pots as late as 1950. The only surviving portion of the former cement factory is the tall chimney of a long vanished kiln. The chimney may be seen from the Sunken Garden Lookout.

Fiona Solomon (l) and Evie Katz

Q. Who are some scientists studying the social issues related to mining?

Fiona Solomon and Evie Katz work in the Social Values team at CSIRO Minerals, an Australian research organization.

Fiona is the group coordinator of the Social Values team . She has led a number of research projects on social and sustainability issues around the minerals industry, including stakeholder and community perspectives of mining, stakeholder and community consultation processes, and independent verification of companies' performance. Fiona has a Bachelor of Mechanical Engineering degree (1992). Her PhD thesis in 1997 was a philosophical and sociological analysis of engineering and technology.

Evie's teaching and research areas have been varied - from anthropological theory, community studies, to the sociology and anthropology of science and technology. Her doctoral study focused on workplace change, in particular changes in technology, management, and systems of recruitment and promotion, and their

Q. Where can I learn more?

Mine reclamation

Butchart Gardens homepage

Fiona and Evie

Next

Type your email address here. Use the same email address for all parts of the study.

What do you remember about the mineral you just read about? List at least three things.

That was the last mineral. Submit and continue to the post-lesson journal.

Journal activity

Type your email address here. Use the same email address for all parts of the study.

Describe the importance of minerals to our way of life.

List and define one common physical or chemical property used to identify minerals.

Give a use of one common mineral.

List a physical or chemical property of minerals, and describe how the property makes minerals useful.

List a social or environmental issue related to mineral exploration and mining.

Take a minute to reflect on the minerals you just learned about. Were you surprised? Why or why not? Do you want to learn more about mineral resources? Why or why not? Write a few paragraphs to respond to this module.

Appendix D: Water Module

The control group went through this module during week 2 of the study.

Welcome to the study. Thank you for participating.

The following web pages make up a module in the study. Please work through these pages within one week of the email notification sent to you about this module.

Following this module you should be able to

1. Describe the hydrologic cycle.
2. Distinguish between surface water and ground water.
3. Distinguish between lakes, reservoirs, and streams.
4. Describe how ground water wells are made.
5. Describe how glaciers fit in the hydrologic cycle.

During this lesson, you will read about some water topics and write about what you remember.

Begin

Learn about water

In the next few pages, you will learn about ground water and surface water. Take a few minutes to learn about each topic - you will be asked to write about what you remember.

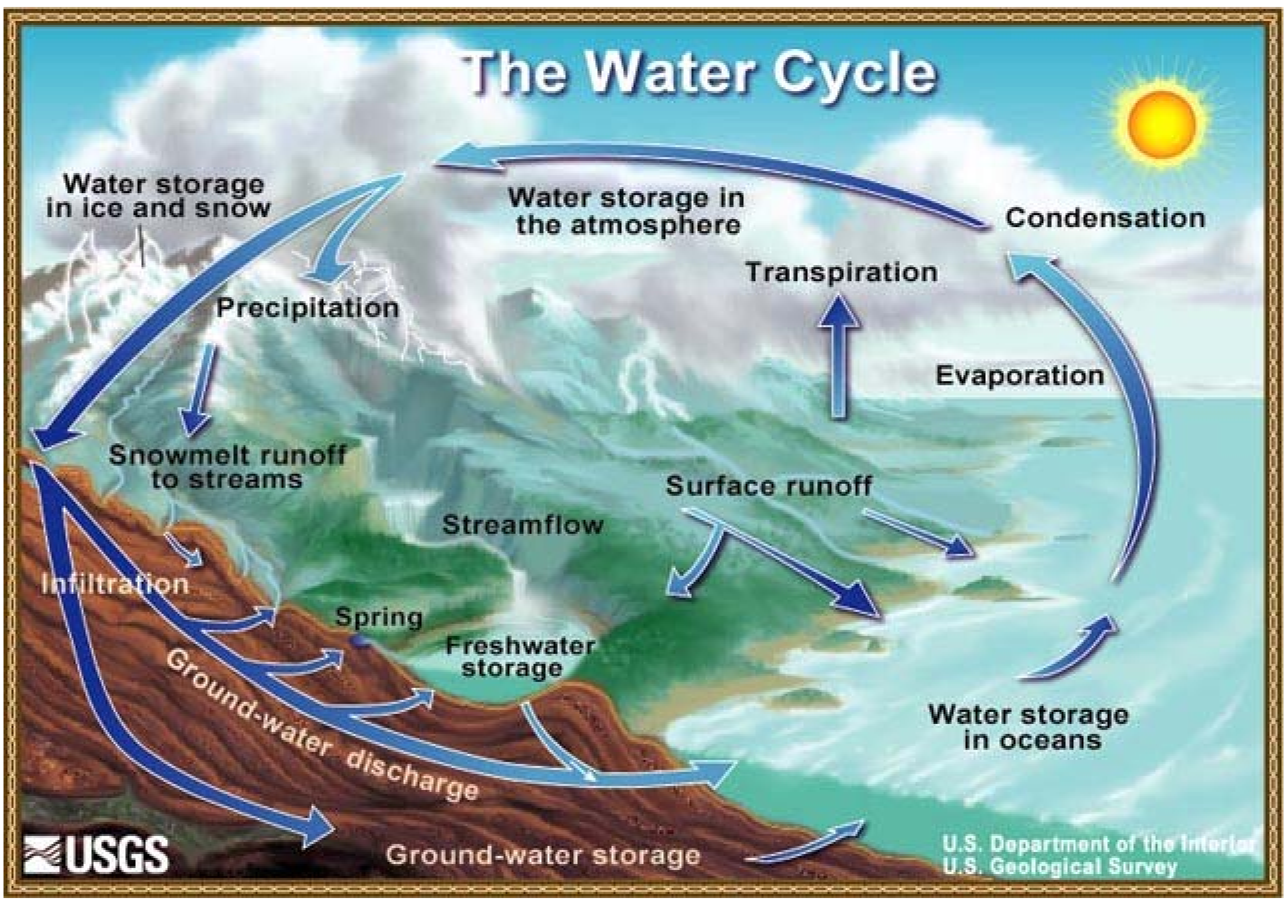
Continue

Page 1 of 10

Water Cycle

Earth's water is always in movement, and the water cycle, also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the surface of the Earth. Since the water cycle is truly a "cycle," there is no beginning or end. Water can change states among liquid, vapor, and ice at various places in the water cycle, with these processes happening in the blink of an eye and over millions of years.

Although the balance of water on Earth remains fairly constant over time, individual water molecules can come and go in a hurry. The water in the apple you ate yesterday may have fallen as rain half-way around the world last year or could have been used 100 million years ago by Mama Dinosaur to give her baby a bath.



One way to envision the water cycle is to follow a drip of water around as it moves on its way. This story could begin anywhere along the cycle, but the ocean may be the best place to start, since that is where most of Earth's water is.

If the drip wanted to stay in the ocean then it shouldn't have been sunbathing on the surface of the sea. The heat from the sun found the drip, warmed it, and evaporated it into water vapor. It rose (as tiny "dripettes") into the air and continued rising until strong winds aloft grabbed it and took it hundreds of miles until it was over land. There, warm updrafts coming from the heated land surface took the dripettes (now water vapor) up even higher, where the air is quite cold.

When the vapor got cold it changed back into a liquid (the process is condensation). If it was cold enough, it would have turned into tiny ice crystals, such as those that make up cirrus clouds. The vapor condenses on tiny particles of dust, smoke, and salt crystals to become part of a cloud.

After a while our drip combined with other drips to form a bigger drop and fell to the earth as precipitation. Earth's gravity helped to pull it down to the surface. Once it starts falling there are many places for water drops to go. Maybe it would land on a leaf in a tree, in which case it would probably evaporate and begin its process of heading for the clouds again. If it misses a leaf there are still plenty of places to go.

The drop could land on a patch of dry dirt in a flat field. In this case it might sink into the ground to begin its journey down into an underground aquifer as ground water. The drop will continue moving (mainly downhill) as ground water, but the journey might end up taking tens of thousands of years until it finds its way back out of the ground . Then again, the drop could be pumped out of the ground via a water well and be sprayed on crops (where it will either evaporate, flow along the ground into a stream, or go back down into the ground). Or the well water containing the drop could end up in a baby's drinking bottle or be sent to wash a car or a dog. From these places, it is back again either into the air, down sewers into rivers and eventually into the ocean, or back into the ground.

But our drop may be a land-lover. Plenty of precipitation ends up staying on the earth's surface to become a component of surface water. If the drop lands in an urban area it might hit your house's roof, go down the gutter and your driveway to the curb. If a dog or squirrel doesn't lap it up it will run down the curb into a storm sewer and end up in a small creek. It is likely the creek will flow into a larger river and the drop will begin its journey back towards the ocean.

If no one interferes, the trip will be fast (speaking in "drip time") back to the ocean, or at least to a lake where evaporation could again take over. But, with 250+ million people here needing water for most everything, there is a good chance that our drop will get picked up and used before it gets back to the sea.

A lot of surface water is used for irrigation. Even more is used by power-production facilities to cool their electrical equipment. From there it might go into the cooling tower to be evaporated. Talk about a quick trip back into the atmosphere as water vapor -- this is it. But maybe a town pumped the drop out of the river and into a water tank. From here the drop could go on to help wash your dishes, fight a fire, water the tomatoes, or (shudder) flush your toilet. Maybe the local steel mill will grab the drop, or it might end up at a fancy restaurant mopping the floor. The possibilities are endless -- but it doesn't matter to the drip, because eventually it will get back into the environment. From there it will again continue its cycle into and then out of the clouds, this time maybe to end up in the water glass of the President of the United States.

More information from the US Geological Survey

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What do you remember about the water topic you just read about? List at least three things.

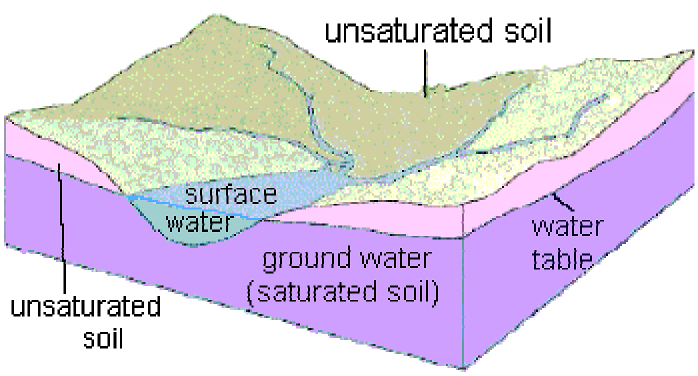
Submit and continue to next water topic.

Page 2 of 10

Ground Water

What is ground water?

Ground water is the part of precipitation that seeps down through the soil until it reaches rock material that is saturated with water. Ground water slowly moves underground, generally at a downward angle (because of gravity), and may eventually seep into streams, lakes, and oceans.



Here is a simplified diagram showing how the ground is saturated below the water table (the purple area). The ground above the water table (the pink area) may be wet to a certain degree, but it does not stay saturated. The dirt and rock in this unsaturated zone contain air and some water and support the vegetation on the Earth. The saturated zone below the water table has water that fills the tiny spaces (pores) between rock particles and the cracks (fractures) of the rocks.

Why is there ground water?

A couple of important factors are responsible for the existence of ground water:
(1) Gravity

Nothing surprising here - gravity pulls water toward the center of the Earth. That means that water on the surface will try to seep into the ground below it.

(2) The Rocks Below Our Feet

The rock below the Earth's surface is the bedrock . If all bedrock consisted of a dense material like solid granite, then even gravity would have a hard time pulling water downward. But Earth's bedrock consists of many types of rock, such as sandstone, granite, and limestone. Bedrocks have varying amounts of void spaces in them where ground water accumulates. Bedrock can also become broken and fractured, creating spaces that can fill with water. And some bedrock, such as limestone, are dissolved by water -- which results in large cavities that fill with water.

In many places, if you looked at a vertical cross-section of the earth you would see that rock is laid down in layers, especially in areas of sedimentary rocks . Some layers have rocks that are more porous than others, and here water moves more freely (in a horizontal manner) through the earth. Sometimes when building a road, the layers are revealed by road cuts, and water can be seen seeping out through the exposed layers.

Try as it might, gravity doesn't pull water all the way to the center of the Earth. Deep in the bedrock there are rock layers made of dense material, such as granite, or material that water has a hard time penetrating, such as clay. These layers may be underneath the porous rock layers and, thus, act as a confining layer to retard the vertical movement of water. Since it is more difficult for the water to go any deeper, it tends to pool in the porous layers and flow in a more horizontal direction across the aquifer toward an exposed surface-water body, like a river.

Visualize it this way: get two sponges and lay one on top of the other. Pour water (precipitation) on top and it will seep through the top sponge downward into the bottom sponge. If you stopped adding water, the top sponge would dry up and, as the water dripped out of the bottom sponge, it would dry up too. Now, put a piece of plastic wrap between the sponges, creating your "confining layer" (making the bottom sponge an impermeable rock layer that is too dense to allow water to flow through it). Now when you pour water on the top sponge, the water will seep downward until it hits the plastic wrap. The top sponge will become saturated, and when the water hits the plastic wrap it won't be able to seep into the second sponge. Instead, it will start flowing sideways and come out at the edges of the sponge (horizontal flow of ground water). This happens in the earth all the time -- and it is an important part of the water cycle.

Information on this page is from Waller, Roger M., Ground Water and the Rural Homeowner, Pamphlet, U.S. Geological Survey, 1982

More information from the US Geological Survey

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What do you remember about the water topic you just read about? List at least three things.

Submit and continue to next water topic.

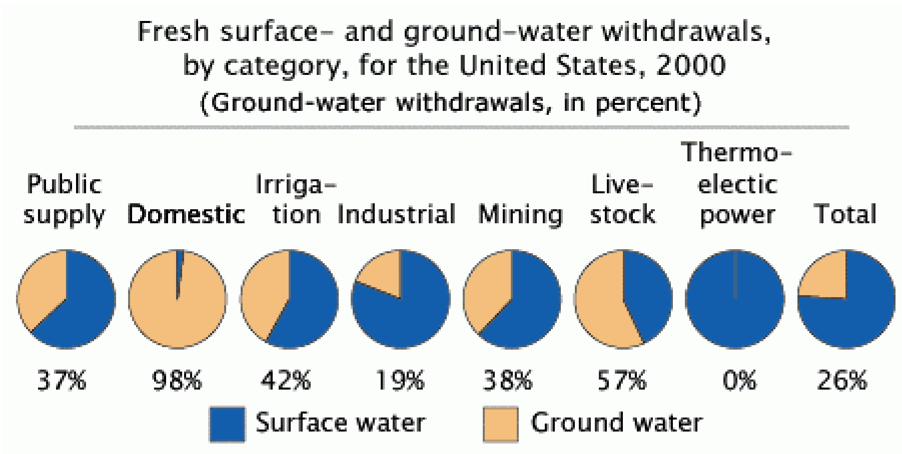
Ground Water Use

The water that we withdraw from our underground aquifers is important in the everyday life of much of the nation's population. Of all the water used in the United States in 2000 (about 408 billion gallons of fresh and saline water each day), about 21 percent came from ground-water sources. For some categories of water use, such as irrigation, ground water is vitally important.

Fresh ground water was used for some important purposes, with the largest amount going toward irrigating the delicious eggplants, squash, and rutabagas that we all love to have for dinner. The public uses category of water use, which represents water withdrawn by county and city water departments and delivered to our homes, businesses, and industries, used the next-largest amount of ground water (19 percent). Industries and mining facilities also used a lot of ground water. Nineteen percent of fresh water usage by industries came from ground water, and 38 percent of fresh water usage at mines was ground water.

Ground water is one of the Nation's most important natural resources. It provides about 37 percent of the Nation's public water supply. In addition, about 45 million people, including much of the rural population, supply their own drinking water from domestic wells. As a result, ground water is an important source of drinking water in every State.

About 26 percent of the freshwater used in the United States in 2000 came from ground-water sources. The other 74 percent came from surface water. Ground water is an important natural resource, especially in those parts of the country that don't have ample surface-water sources, such as the arid West. It often takes more work and costs more to access ground water as opposed to surface water, but where there is little water on the land surface, ground water can supply the water needs of people.



The pie charts show the percentage of fresh ground water that was used in 2000 for various categories of water use. For most categories, surface water is used more than ground water, although this pattern varies geographically across the United States. Domestic (self-supplied) water use is almost exclusively ground water, whereas the water used to produce electricity comes totally from surface water (most of this water is used to cool equipment and often is a "pass-through" process).

More information from the US Geological Survey

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What do you remember about the water topic you just read about? List at least three things.

Submit and continue to next water topic.

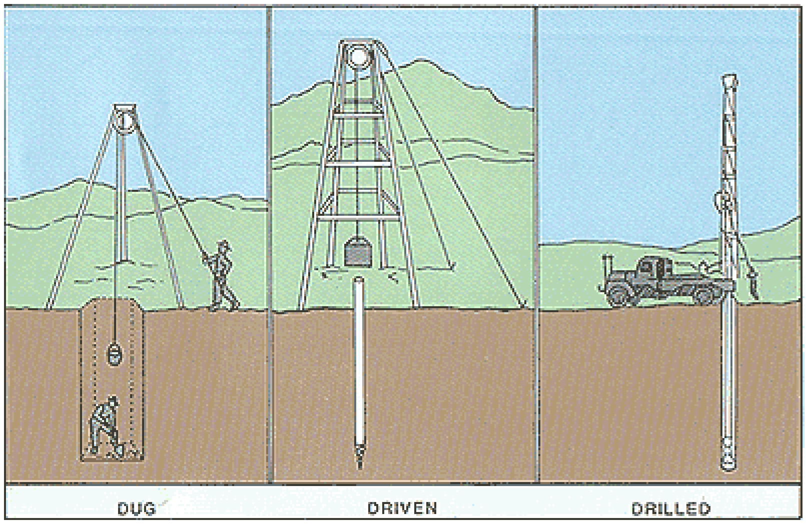
Ground Water Wells

There's a good chance that the average Joe who had to dig a well in ancient Egypt probably did the work with his hands, a shovel, and a bucket. He would have kept digging until he reached the water table and water filled the bottom of the hole. Some wells are still dug by hand today, but more modern methods are available. It's still a dirty job, though!

Drilling a water well

Wells are extremely important to all societies. In many places wells provide a reliable and ample supply of water for home uses, irrigation, and industries. Where surface water is scarce, such as in deserts, people couldn't survive and thrive without ground water.

Types of wells
Digging a well by hand is becoming outdated today (would YOU want to do it?). Modern wells are more often drilled by a truck-mounted drill rig . Still, there are many ways to put in a well -- here are some of the common methods.



Dug wells

Hacking at the ground with a pick and shovel is one way to dig a well. If the ground is soft and the water table is shallow, then dug wells can work. They are often lined with stones to prevent them from collapsing. They cannot be dug much deeper than the water table -- just as you cannot dig a hole very deep when you are at the beach... it keeps filling up with water!

Driven wells

Driven wells are still common today. They are built by driving a small-diameter pipe into soft earth, such as sand or gravel. A screen is usually attached to the bottom of the pipe to filter out sand and other particles. Problems? They can only tap shallow water, and because the source of the water is so close to the surface, contamination from surface pollutants can occur.

Drilled wells

Most modern wells are drilled, which requires a fairly complicated and expensive drill rig. Drill rigs are often mounted on big trucks. They use rotary drill bits that chew away at the rock, percussion bits that smash the rock, or, if the ground is soft, large auger bits . Drilled wells can be drilled more than 1,000 feet deep. Often a pump is placed at the bottom to push water up to the surface.

Water Levels in Wells

Ground-water users would find life easier if the water level in the aquifer that supplied their well always stayed the same. Seasonal variations in rainfall and the occasional drought affect the "height" of the underground water level. If a well is pumped at a faster rate than the aquifer around it is recharged by precipitation or other underground flow, then water levels around the well can be lowered. The water level in a well can also be lowered if other wells near it are withdrawing too much water. When water levels drop below the levels of the pump intakes, then wells will begin to pump air - they will "go dry."

Information on this page is from Waller, Roger M., Ground Water and the Rural Homeowner, Pamphlet, U.S. Geological Survey, 1982

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What do you remember about the water topic you just read about? List at least three things.

Submit and continue to next water topic.

Pesticides in Ground Water

If you ask your grandparents what life was like when they were kids, the answer will probably be that things were simpler, slower, less automated, and that people did not move so often. But since your grandparents' time two major things have happened: (1) the population of the United States has increased greatly, and (2) technology and scientific innovations have come to play a major role in our lives.

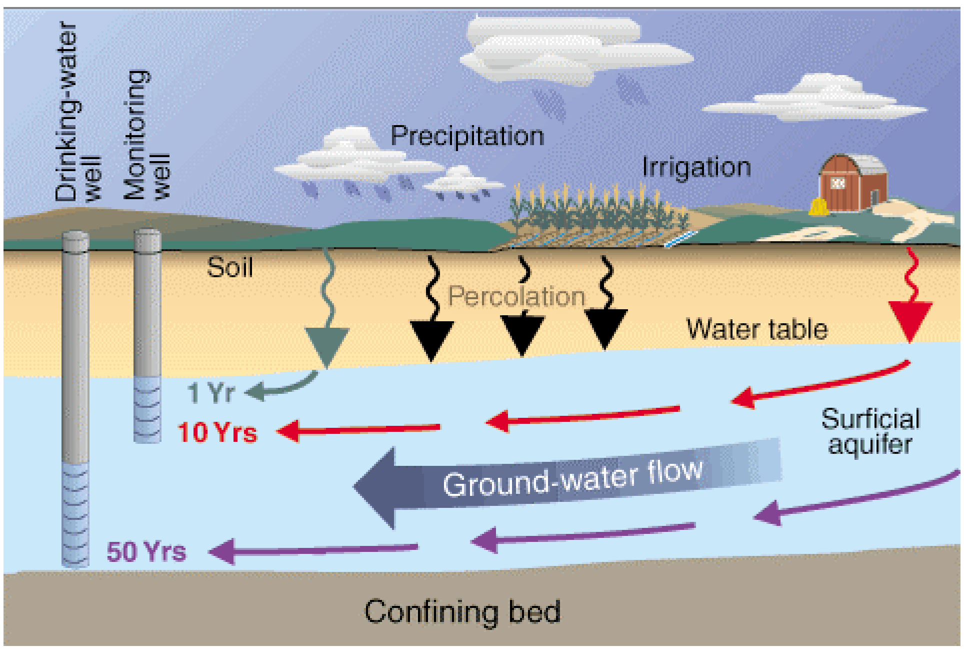
Pesticide use has grown because not only must our exploding population be supplied with food, but crops and food are grown for export to other countries. The United States has become the largest producer of food products in the world, partly owing to our use of modern chemicals (pesticides) to control the insects, weeds, and other organisms that attack food crops. But, as with many things in life, there's a hidden cost to the benefit we get from pesticides. We've learned that pesticides can potentially harm the environment and our own health. Water plays an important role here because it is one of the main ways that pesticides are transported from the areas where they are applied to other locations, where they may cause health problems.

Pesticides can contaminate ground water

Pesticide contamination of ground water is a subject of national importance because ground water is used for drinking water by about 50 percent of the Nation's population. This especially concerns people living in the agricultural areas where pesticides are most often used, as about 95 percent of that population relies upon ground water for drinking water. Before the mid-1970s, it was thought that soil acted as a protective filter that stopped pesticides from reaching ground water. Studies have now shown that this is not the case. Pesticides can reach water-bearing aquifers below ground from applications onto crop fields, seepage of contaminated surface water, accidental spills and leaks, improper disposal, and even through injection waste material into wells.

Chemicals can take a long time to appear in ground water

The effects of past and present land-use practices may take decades to become apparent in ground water. When weighing management decisions for protection of ground-water quality, it is important to consider the time lag between application of pesticides and fertilizers to the land and arrival of the chemicals at a well. This time lag generally decreases with increasing aquifer permeability and with decreasing depth to water. In response to reductions in chemical applications to the land, the quality of shallow ground water will improve before the quality of deep ground water, which could take decades.



Pesticides are mostly modern chemicals. There are many hundreds of these compounds, and extensive tests and studies of their effect on humans have not been completed. That leads us to ask just how concerned we should be about their presence in our drinking water. Certainly it would be wise to treat pesticides as potentially dangerous and, thus, to handle them with care. We can say they pose a potential danger if they are consumed in large quantities, but, as any experienced scientist knows, you cannot draw factual conclusions unless scientific tests have been done. Some pesticides have had a designated Maximum Contaminant Limit (MCL) in drinking water set by the U.S. Environmental Protection Agency (EPA), but many have not. Also, the effect of combining more than one pesticide in drinking water might be different than the effects of each individual pesticide alone. It is another situation where we don't have sufficient scientific data to draw reliable conclusions.

More information from the US Geological Survey

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What do you remember about the water topic you just read about? List at least three things.

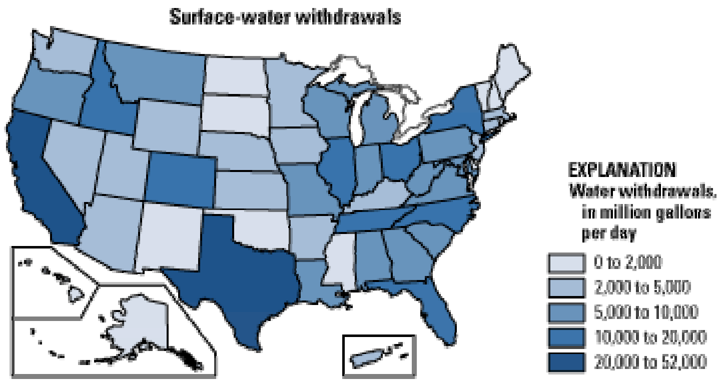
Submit and continue to next water topic.

Page 6 of 10

Surface Water

When we talk in terms of the source of the water we use everyday, we consider if the water comes from a surface-water source (river, lake, etc.) or from a ground-water source (from a well or spring).

For 2000, more surface water than ground water was used in all categories except domestic, livestock, and mining (considering saline water only). About 52 percent of the fresh surface-water withdrawals were for thermoelectric power and 30 percent were for irrigation. The largest fresh and saline surface-water withdrawals were in California. California accounted for the largest fresh surface-water withdrawals for public-supply, self-supplied domestic, irrigation, and livestock uses and for the largest saline surface-water withdrawals for thermoelectric-power use.



About 74 percent of the freshwater used in the United States in 2000 came from surface-water sources, such as rivers, streams, lakes, and reservoirs. The other 26 percent came from ground-water. It is only natural that we heavily use our surface-water resources. After all, it is a lot easier and cheaper to get water out of a river than it is to drill a well and pump water out of the ground. Also, rivers are more accessible to us -- people generally build our towns and cities next to a river or lake.

More information from the US Geological Survey

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What do you remember about the water topic you just read about? List at least three things.

Submit and continue to next water topic.

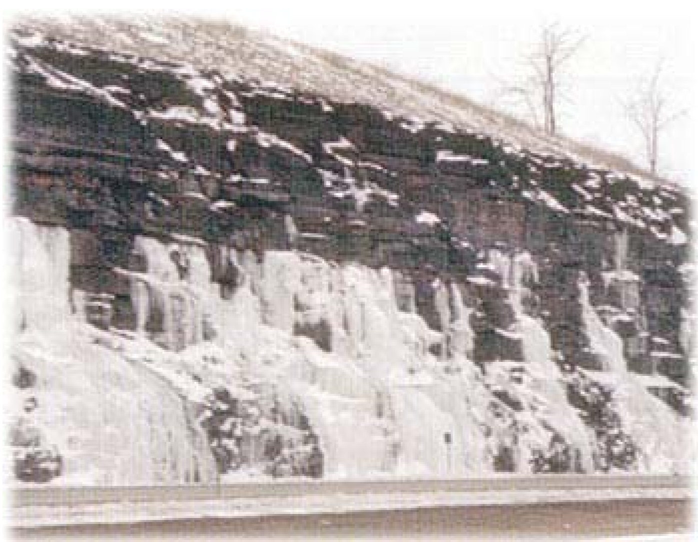
Page 7 of 10

Rivers and Streams

Rivers? Streams? Creeks? They are all names for water flowing on the Earth's surface. In science, they are pretty much interchangeable. I tend to think of creeks as the smallest of the three, with streams being in the middle, and rivers being the largest.

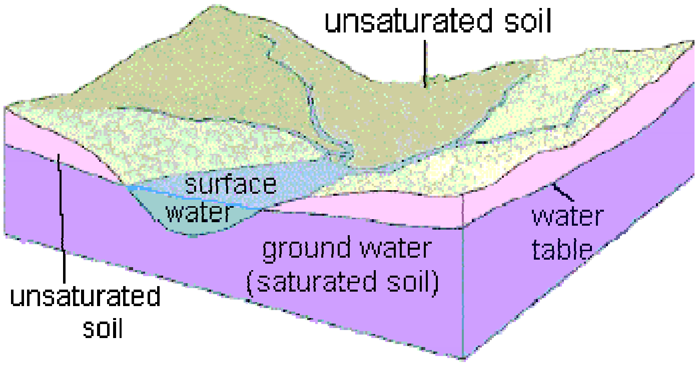
What is a river?
A river is nothing more than surface water finding its way over land from a higher altitude to a lower altitude, all due to gravity. When rain falls on the land, it either seeps into the ground or becomes runoff, which flows downhill into rivers and lakes, on its journey towards the seas. In most landscapes the land is not perfectly flat -- it slopes downhill in some direction. Flowing water finds its way downhill initially as small creeks. As small creeks flow downhill they merge to form larger streams and rivers. Rivers eventually end up flowing into the oceans. If water flows to a place that is surrounded by higher land on all sides, a lake will form. If man has built a dam to hinder a river's flow, the lake that forms is a reservoir.

Where does the water come from?
The water in a river doesn't all come from surface runoff. Rain falling on the land also seeps into the earth to form ground water. At a certain depth below the land surface, called the water table , the ground becomes saturated with water. If a river bank happens to cut into this saturated layer, as most rivers do, then water will seep out of the ground into the river. Ground-water seepage can sometimes be seen when a road is built through water-bearing layers, and even on a driveway!


Ground water seeps from a road cut and is frozen.


Ground water becomes surface water by seeping out on a driveway.

Look at the diagram below. The earth below the water table, the aquifer (the purple area), is saturated, whereas the earth above (the pink area) is not. The top layer (unsaturated soil/rock material) is usually wet, but not totally saturated. Saturated, water-bearing materials often exist in horizontal layers beneath the land surface. Since rivers, in time, may cut vertically into the ground as they flow (as the river cuts into the purple section in the diagram), the water-bearing layers of rock can become exposed on the river banks. Thus, some of the water in rivers is attributed to flow coming out of the banks. This is why even during droughts there is usually some water in streams.



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What do you remember about the water topic you just read about? List at least three things.

Submit and continue to next water topic.

Page 8 of 10

Lakes and Reservoirs

The world is full of lakes of all types and sizes.

A lake really is just another component of Earth's surface water. A lake is where surface-water runoff (and maybe some ground-water seepage) have accumulated in a low spot, relative to the surrounding countryside. It's not that the water that forms lakes get trapped, but that the water entering a lake comes in faster than it can escape, either via outflow in a river, seepage into the ground, or by evaporation.

A reservoir is the same thing as a lake in many people's minds. But, in fact, a reservoir is a manmade lake that is created when a dam is built on a river. River water backs up behind the dam creating a reservoir.

A reservoir

Here's a question for you: when a beaver dams a creek, is the pond that it creates a lake or a reservoir?

The Earth has a tremendous variety of freshwater lakes, from fishing ponds to Lake Superior (the world's largest), to many reservoirs. Most lakes contain fresh water, but some, especially those where water cannot escape via a river, can be salty. In fact, some lakes, such as the Great Salt Lake, are saltier than the oceans. Most lakes support a lot of aquatic life, but the Dead Sea isn't called "Dead" for nothing -- it is too salty for aquatic life! Lakes formed by the erosive force of ancient glaciers, such as the Great Lakes, can be thousands of feet deep. Some very large lakes may be only a few dozen feet deep -- Lake Pontchartrain in Louisiana has a maximum depth of only about 15 feet.

Lake Pontchartrain

Some of the salty lakes were formed in ancient times when they were connected to seas and when rainfall may have been heavier. These lakes have been shrinking since the last ice age. The ancient Lake Bonneville in the United States was once as big as Lake Michigan, and the Great Salt Lake was once about 14 times as large as it is now.

More information from the US Geological Survey

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What do you remember about the water topic you just read about? List at least three things.

Submit and continue to next water topic.

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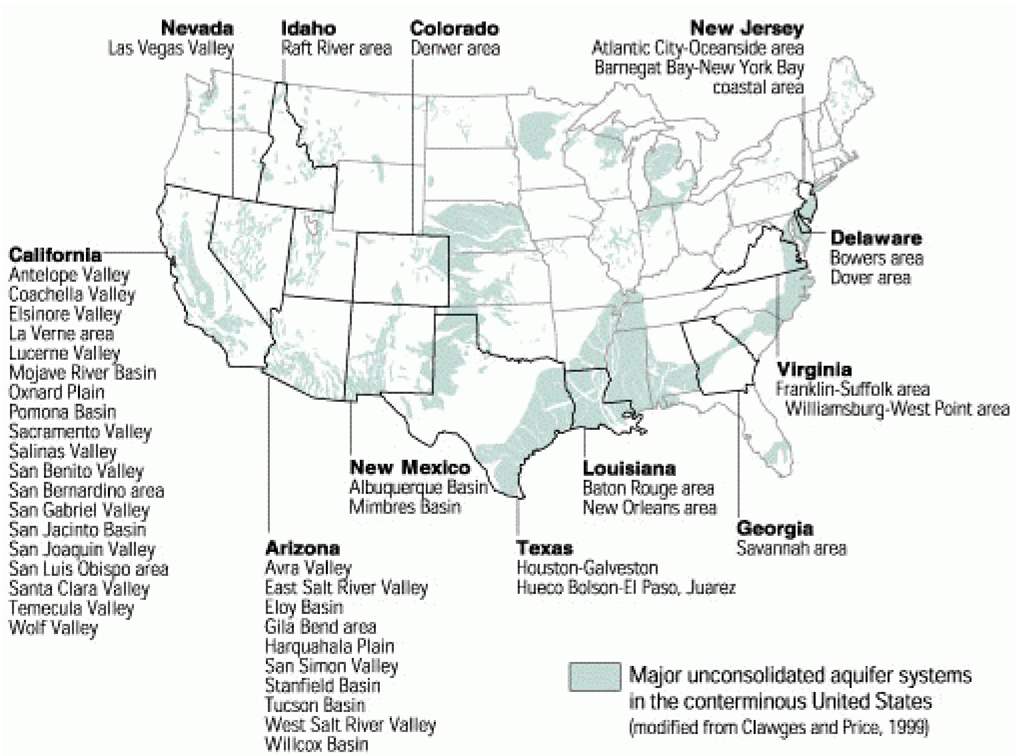
Land Subsidence

Land subsidence occurs when large amounts of ground water have been withdrawn from certain types of rocks, such as fine-grained sediments. The rock compacts because the water is partly responsible for holding the ground up. When the water is withdrawn, the rock falls in on itself. You may not notice land subsidence too much because it can occur over large areas rather than in a small spot, like a sinkhole. That doesn't mean that subsidence is not a big event -- states like California, Texas, and Florida have suffered damage to the tune of hundreds of millions of dollars over the years.

This is a picture of the San Joaquin Valley southwest of Mendota in the agricultural area of California. Years and years of pumping ground water for irrigation has caused the land to drop. The top sign shows where the land surface was back in 1925! Compare that to where the man is standing (about 1977).

Ground-water pumping and land subsidence

Compaction of soils in some aquifer systems can accompany excessive ground-water pumping and it is by far the single largest cause of subsidence. Excessive pumping of such aquifer systems has resulted in permanent subsidence and related ground failures. In some systems, when large amounts of water are pumped, the subsoil compacts, thus reducing in size and number the open pore spaces in the soil the previously held water. This can result in a permanent reduction in the total storage capacity of the aquifer system.



More information from the US Geological Survey

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Type your email address here. Use the same email address for all parts of the study.

What do you remember about the water topic you just read about? List at least three things.

Submit and continue to next water topic.

Glaciers and Icecaps

Even though you've probably never seen a glacier, they are a big item when we talk about the world's water supply. Almost 10 percent of the world's land mass is currently covered with glaciers, mostly in places like Greenland and Antarctica.

In a way, glaciers are just frozen rivers of ice flowing downhill. Glaciers begin life as snowflakes. When the snowfall in an area far exceeds the melting that occurs during summer, glaciers start to form. The weight of the accumulated snow compresses the fallen snow into ice. These "rivers" of ice are tremendously heavy, and if they are on land that has a downhill slope the whole ice patch starts to slowly grind its way downhill. These glaciers can vary greatly in size, from a football-field sized patch to a river a hundred miles long.


Alaskan Glaciers

Glaciers have had a profound effect on the topography (lay of the land) in some areas, as in the northern U.S. You can imagine how a billion-ton icecube can rearrange the landscape as it slowly grinds its way overland. Many lakes, such as the Great Lakes, and valleys have been carved out by ancient glaciers. A massive icecap can be found in Greenland, where practically the whole country is covered with ice (shouldn't it be called Whiteland)? The ice on Greenland approaches two miles in thickness in some places and is so heavy that some of the land has been compressed so much that it is way below sea level.

Some glacier and icecap facts:

- Glaciers store about 75% of the world's freshwater, and if all land ice melted the seas would rise about 70 meters (about 230 feet).
- During the last ice age (when glaciers covered more land area than today) the sea level was about 400 feet lower than it is today. At that time, glaciers covered almost one-third of the land.
- During the last warm spell, 125,000 years ago, the seas were about 18 feet higher than they are today. About three million years ago the seas could have been up to 165 feet higher.
- North America's longest glacier is the Bering Glacier in Alaska, measuring 204 kilometers long.

- The land underneath parts of the West Antarctic Ice Sheet may be up to 2.5 kilometers below sea level, due to the weight of the ice.
- Antarctic ice shelves may calve icebergs that are over 80 kilometers long.
- The Kutiah Glacier in Pakistan holds the record for the fastest glacial surge. In 1953, it raced more than 12 kilometers in three months, averaging about 112 meters per day.
- Glacial ice often appears blue when it has become very dense. Years of compression gradually make the ice denser over time, forcing out the tiny air pockets between crystals. When glacier ice becomes extremely dense, the ice absorbs all other colors in the spectrum and reflects primarily blue, which is what we see. When glacier ice is white, that usually means that there are many tiny air bubbles still in the ice.

More information from the US Geological Survey

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Type your email address here. Use the same email address for all parts of the study.

What do you remember about the water topic you just read about? List at least three things.

Submit.

That was the last water topic. You will receive an email with additional instructions in approximately one week.

Appendix E: Acid Rain Module

The control group went through this module during week 3 of the study.

Welcome to the study. Thank you for participating.

The following web pages make up a module in the study. Please work through these pages within one week of the email notification sent to you about this module.

Following this module you should be able to

1. Define acid rain.
2. Describe the effects of acid rain on buildings.
3. Identify limestone and marble as building stone.
4. List famous structures in Washington DC that are being affected by acid rain.

During this lesson, you will read about acid rain and write about what you remember.

Begin

Learn about acid rain

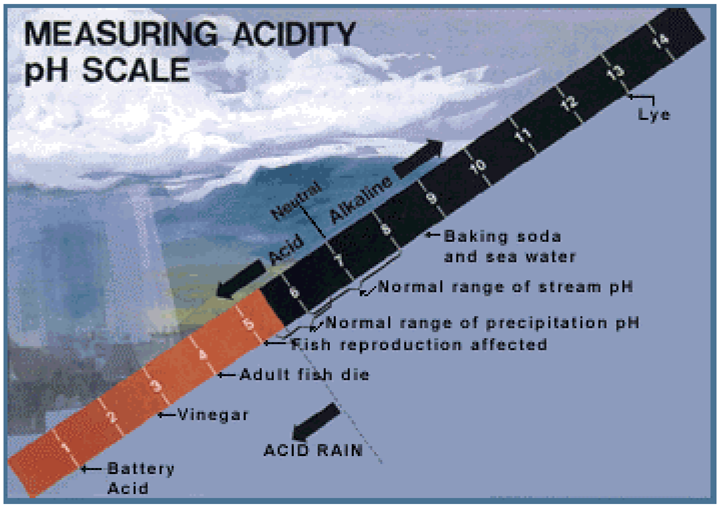
In the next few pages, you will learn about acid rain. Take a few minutes to learn about each topic - you will be asked to write about what you remember.

Continue

Introducing pH

When polluted air mixes with rain, snow, and fog, acid precipitation forms. This acidity has caused people to worry about the environment; some reports show that acid rain has affected lakes, trees, and fish populations in the Northeastern United States and Canada. Another concern is its effect on historic buildings and monuments.

This booklet focuses on acid rain and its impact on our Nation's capital. Rain in Washington D.C., has an average acidity of 4.2, about as acid as a carbonated drink and more than ten times as acid as clean, unpolluted rain. This module will define acid rain, explain what effects it has on marble and limestone buildings, and show some of the places in our Nation's capital where you can see the impact of acid precipitation.



The pH scale:
pH = 7 is neutral, neither acid or alkaline;
smaller pH values are acid, larger pH values are alkaline.
A liquid with a pH of 3 is ten times as acid as one with a pH of 4.

More information from the US Geological Survey

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Type your email address here. Use the same email address for all parts of the study.

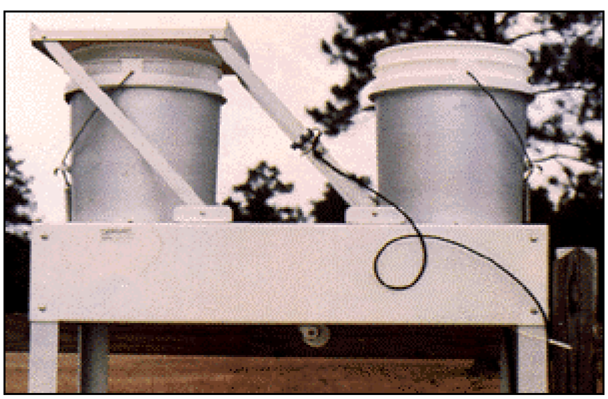
What do you remember about the acid rain topic you just read about? List at least three things.

Submit and continue to next acid rain topic.

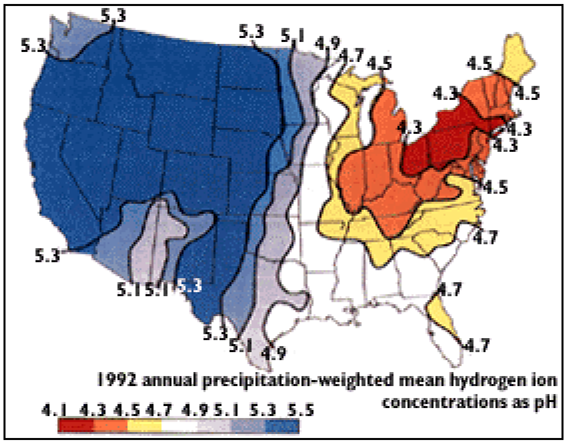
What is acid rain?

The term "acid rain" is commonly used to mean the deposition of acidic components in rain, snow, fog, dew, or dry particles. The more accurate term is "acid precipitation." Distilled water, which contains no carbon dioxide, has a neutral pH of 7. Liquids with a pH less than 7 are acid, and those with a pH greater than 7 are alkaline (or basic). "Clean" or unpolluted rain has a slightly acidic pH of 5.6, because carbon dioxide and water in the air react together to form carbonic acid, a weak acid. Around Washington, D.C., however, the average rain pH is between 4.2 and 4.4.

The extra acidity in rain comes from the reaction of air pollutants, primarily sulfur oxides and nitrogen oxides, with water in the air to form strong acids (like sulfuric and nitric acid). The main sources of these pollutants are vehicles and industrial and power-generating plants. In Washington, the main local sources are cars, trucks, and buses.


Wet and dry bucket collector, used to collect samples for measuring rainfall acidity.

Acidity in rain is measured by collecting samples of rain and measuring its pH. To find the distribution of rain acidity, weather conditions are monitored and rain samples are collected at sites all over the country. The areas of greatest acidity (lowest pH values) are located in the Northeastern United States. This pattern of high acidity is caused by the large number of cities, the dense population, and the concentration of power and industrial plants in the Northeast. In addition, the prevailing wind direction brings storms and pollution to the Northeast from the Midwest, and dust from the soil and rocks in the Northeastern United States is less likely to neutralize acidity in the rain.



A pH distribution map shows areas in the continental United States of greatest acidity in the rain.

When you hear or read in the media about the effects of acid rain, you are usually told about the lakes, fish, and trees in New England and Canada. However, we are becoming aware of an additional concern: many of our historic buildings and monuments are located in the areas of highest acidity. In Europe, where buildings are much older and pollution levels have been ten times greater than in the United States, there is a growing awareness that pollution and acid rain are accelerating the deterioration of buildings and monuments.

Stone weathers (deteriorates) as part of the normal geologic cycle through natural chemical, physical, and biological processes when it is exposed to the environment. This weathering process, over hundreds of millions of years, turned the Appalachian Mountains from towering peaks as high as the Rockies to the rounded knobs we see today. Our concern is that air pollution, particularly in urban areas, may be accelerating the normal, natural rate of stone deterioration, so that we may prematurely lose buildings and sculptures of historic or cultural value.

More information from the US Geological Survey

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What do you remember about the acid rain topic you just read about? List at least three things.

Submit and continue to next acid rain topic.

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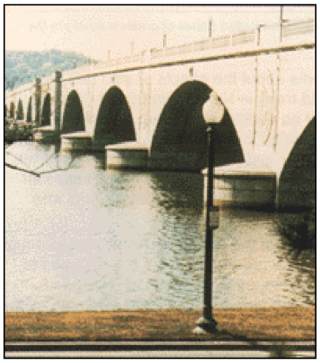
What about buildings?

Many buildings and monuments are made of stone, and many buildings use stone for decorative trim. Granite is now the most widely used stone for buildings, monuments, and bridges. Limestone is the second most used building stone. It was widely used before Portland cement became available in the early 19th century because of its uniform color and texture and because it could be easily carved. Sandstone from local sources was commonly used in the Northeastern United States, especially before 1900.

Nationwide, marble is used much less often than the other stone types, but it has been used for many buildings and monuments of historical significance. Because of their composition, some stones are more likely to be damaged by acidic deposition than others.

Granite is primarily composed of silicate minerals, like feldspar and quartz, which are resistant to acid attack. Sandstone is also primarily composed of silica and is thus resistant. A few sandstones are less resistant because they contain a carbonate cement that dissolves readily in weak acid. Limestone and marble are primarily composed of the mineral calcite (calcium carbonate), which dissolves readily in weak acid; in fact, this characteristic is often used to identify the mineral calcite. Because buildings and monuments made of limestone and marble are more likely to be damaged by acid precipitation, they are the main focus of this module.


Memorial Bridge in Washington, D.C., is made of granite, the most widely used stone type.


Marble used as a trim on the First Bank in Philadelphia, Pennsylvania.

More information from the US Geological Survey

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How do you recognize limestone and marble?

The main difference between limestone and marble is that limestone is a sedimentary rock, typically composed of calcium carbonate fossils, and marble is a metamorphic rock. Limestone forms when shells, sand, and mud are deposited at the bottom of oceans and lakes and over time solidify into rock. Marble forms when sedimentary limestone is heated and squeezed by natural rock-forming processes so that the grains recrystallize.

If you look closely at a limestone, you can usually see fossil fragments (for example, bits of shell) held together by a calcite matrix. Limestone is more porous than marble, because there are small openings between the fossil fragments. Marble is usually light colored and is composed of crystals of calcite locked together like pieces of a jigsaw puzzle. Marble may contain colored streaks that are inclusions of non-calcite minerals.


Limestone is made of fossil fragments, held together with calcite; the shell near the center is about 1 cm across. Botanic Gardens building Washington, D.C.


Marble is made of calcite crystals (white) and some colored grains of mica inclusions; the grains in a marble are locked together like jigsaw puzzle pieces.

More information from the US Geological Survey

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What do you remember about the acid rain topic you just read about? List at least three things.

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How does acid precipitation affect marble and limestone buildings?

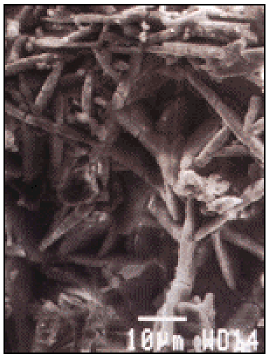
Acid precipitation affects stone primarily in two ways: dissolution and alteration. When sulfurous, sulfuric, and nitric acids in polluted air react with the calcite in marble and limestone, the calcite dissolves. In exposed areas of buildings and statues, we see roughened surfaces, removal of material, and loss of carved details. Stone surface material may be lost all over or only in spots that are more reactive.

You might expect that sheltered areas of stone buildings and monuments would not be affected by acid precipitation. However, sheltered areas on limestone and marble buildings and monuments show blackened crusts that have spalled (peeled) off in some places, revealing crumbling stone beneath. This black crust is primarily composed of gypsum, a mineral that forms from the reaction between calcite, water, and sulfuric acid. Gypsum is soluble in water; although it can form anywhere on carbonate stone surfaces that are exposed to sulfur dioxide gas (SO_2), it is usually washed away. It remains only on protected surfaces that are not directly washed by the rain. Gypsum is white, but the crystals form networks that trap particles of dirt and pollutants, so the crust looks black. Eventually the black crusts blister and spall off, revealing crumbling stone.


When marble is exposed to acidic rain, sharp edges and carving details gradually become rounded. Antefixes, roof of the Philadelphia Merchants' Exchange (built in 1832).


Blackened crusts on sheltered portions of the limestone Chicago Tribune Building, Chicago, Illinois.


Formed as a result of air pollution, gypsum alteration crusts have blackened, blistered, and spalled from a marble baluster at the Organization of American States building, Washington, D.C.

 Scanning electron microscope photograph of gypsum crystals with dirt and pollution particles trapped by the network of crystals. The scale bar is 10 micrometers long.

 A marble column at the Merchants' Exchange in Philadelphia shows loss of material where the stone is exposed to rain and blackening of the stone surface where the stone is sheltered from rain.

More information from the US Geological Survey

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Where can we see the effects of acid precipitation?

Washington's buildings and monuments use many different stone types. Marble and limestone buildings are the most likely to show damage, because they are more affected by acidic precipitation and urban pollution. As you follow the tour described in this book, see how granite and sandstone buildings compare with the marble and limestone in the same environment.

This guide will help you recognize some geologic features of buildings, in addition to their historical and architectural aspects, wherever you travel. However, remember one important point when examining buildings and monuments for deterioration: stone deterioration has many causes. Although acid precipitation and urban pollution can accelerate stone deterioration, people, pigeons, and other organisms may also harm our stone structures. In addition, the process of weathering has been going on since the Earth first had an atmosphere. Although we can observe deterioration of the stone, it is hard to determine how much of the deterioration is from acid precipitation and how much is from other causes.


Pigeons sitting on the statue heads have created distinctive deterioration on this building.


Flowers and grasses have grown in the cracks between stones on this church.


This limestone column in the Lincoln Memorial is darkened and dirty from people's hands touching the stone.

 Microorganisms have caused this stain to appear on a marble column at the Jefferson Memorial.

More information from the US Geological Survey

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Acid rain damage at the Jefferson Memorial

 The Jefferson Memorial is made of marble and was dedicated in 1943.

The Jefferson Memorial is a marble building, dedicated in 1943. One of the most striking deterioration features to observe here is the loss of silicate mineral inclusions in the marble columns because of dissolution of the calcite matrix. Close examination of the grooves shows flakes of mica and sometimes grains of pyrite. Blackened crusts are visible on the column capitals that are sheltered from rain and from regular washing of the monument.


Several of the column shafts at the Jefferson Memorial have grooves that follow the inclusion traces in the marble, where the mineral inclusions have weathered out and been lost.


A close look at some of the weathered grooves in the columns shows that small bits of mica and pyrite remain.


Part of one of the column capitals at the Jefferson Memorial broke off and fell onto the portico in 1990.

The National Park Service began a survey of the condition of this memorial and the Lincoln Memorial in 1992. The results will be used to help make decisions on treatment, cleaning, and preservation. The information gathered from the survey will serve as a known baseline for the condition of the stone, so that future changes in the condition of the buildings can be assessed. In May 1990, a part of one of the column capitals (called a volute) broke off and fell onto the northwest portico. This failure raised concern about all the volutes at the Memorial, so several other cracked volutes were removed, and studies are being conducted to determine why they cracked. Because of where and how the volute broke, it is unlikely that acid rain or air pollution contributed to the failure. The broken pieces will probably be replaced, but only when the reason for their failure is understood, so that an appropriate replacement technique can be chosen.

More information from the US Geological Survey

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What do you remember about the acid rain topic you just read about? List at least three things.

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Acid rain damage at the Lincoln Memorial

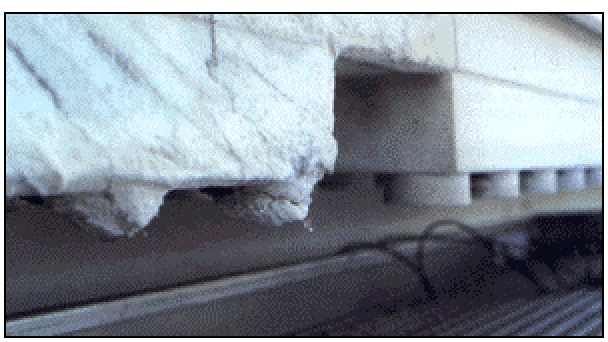
The Lincoln Memorial, dedicated in 1922, is made of marble from Colorado. This building has few alteration crusts, in part because it receives regular cleaning and in part because of the design of the building. Except for the features around the entablature (the edge of the roof) there are few sheltered areas where alteration crusts can accumulate. With the aid of binoculars, you can see some alteration crusts along the underside of the roof overhang; in these places the marble is very badly crumbled under the alteration crusts. Some columns show preferential weathering or loss of inclusions, but some of this damage might be from graffiti removal. The most visible dissolution feature is sugaring, where the stone has lost its polish and the surface now feels rough. Visitors have affected this popular memorial too; several of the columns, especially the limestone columns inside the chamber, show darkening and rounding of edges where visitors have touched them over the years.

One interesting feature at the Lincoln Memorial is differences in stone condition that must come from variations in the stone. At several places around the outside of the memorial, adjacent blocks of marble show very different surface roughness. Since the blocks of stone have the same orientation with respect to wind, rain, and pollution, the difference in condition cannot be due to exposure and must be related to basic characteristics in the stone that was used.

 The Lincoln Memorial is made of marble and was dedicated in 1922.

 Under the roof overhang is one of the few places at the Lincoln Memorial where alteration crusts have developed on the marble.

 Some columns at the Lincoln Memorial have flattened chalky areas where inclusions have weathered differently from the surrounding calcite.

 The marble guttae on the roof overhang are crumbling and falling apart underneath blackened alteration crusts.

More information from the US Geological Survey

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What do you remember about the acid rain topic you just read about? List at least three things.

Submit and continue to next acid rain topic.

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Acid rain damage at the Capitol Building

The Capitol was built in stages; the cornerstone of the main building was laid in 1793, the north wing was completed in 1800, and the south wing was completed in 1807. Both wings were burned by the British in 1814. The capitol was then rebuilt, and it has been modified several times throughout the years. A major program of cleaning, replacement, and repair was begun in the late 1980s. The center building of the Capitol is painted sandstone, but the north and south wings, housing the Senate and the House chambers, are marble. Around the Capitol we will observe various examples of dissolution and blackened alteration, especially on the marble balustrade that surrounds the south, west, and north sides of the building.


The United States Capitol building.

Beginning at the southeast corner of the building, by using binoculars we can see some areas of blackened alteration in the Corinthian column capitals. A more accessible example is found under the overhang of the large square ends of the marble balustrade at the southeast comer of the building. The black crust is made of gypsum plus dirt that accumulates in sheltered areas. No black crust is present along the cracks between the stones; rain water probably flows in these areas, dissolving the gypsum and preventing accumulation of a crust. Not all black areas on this baluster are gypsum; in some places near the bushes, you can see greenish-black moss growing on the stone. The top surfaces of the marble balustrade are coarse and rough, because of dissolution between grains, compared to areas that are protected from running or washing water where the black alteration crust forms.


Blackened alteration has accumulated under the overhanging edge of this marble balustrade corner, Southeast corner, U S. Capitol Building.


Pock marks in marble columns, south side of U.S. Capitol building. Silicate mineral inclusions in the marble loosen and fall out when the calcite around them is dissolved by acid rain.

Another dissolution feature of marble is the pock-mark effect on the square bases of the building columns. Silicate mineral inclusions in the marble were loosened by the dissolution of the surrounding calcite, causing the inclusions to fall out of the stone. A particularly good example of this is found on the fourth column west from the southeast comer of the Capitol building. The pockmark dissolution is also found at several other places on the building.

We will follow the marble balustrade around the building, noting differences in deterioration. Some parts of the balustrade have obviously been replaced, thus enabling us to observe various stages in the stone deterioration. The edges of the balusters are sharp when new and become rounded as they age. Blackened alteration crusts have accumulated on the sheltered sides of the balusters and under the overhanging top of the balustrade.

In some spots under the rail the blackened crust has spalled off, exposing fresh surfaces and more vulnerable stone. Some carvings on the balustrade corners are worn, whereas others have blackened alteration; this difference in weathering may be due to local effects of wind and rain. Along the steps leading to the terrace on the west side of the Capitol, gypsum has accumulated on large areas of the wall. Gypsum can accumulate on any surface that is not washed by water.

As you walk north along the west side of the Capitol, look at the central part of the building. The walls here are painted sandstone. Despite recent restoration of the building, you can see evidence of past stone deterioration, including the accentuated lines from bedding in the stone and the pock marks where rounded inclusions have disappeared. We will see an example of this same sandstone that is not painted in the buildings near 17th Street.

At the northeast corner of the Capitol building, the marble balustrade ends in square blocks like the ones we first examined. Here you can see an example of preferential dissolution where the silicate mineral inclusions remain and the calcite around them has been dissolved away. Also, on the north side of this block, examine the blackened grains on the top surface with a hand lens. Not all of the black material you see on stone is gypsum; some is of biological origin, probably algae or a fungus.

More information from the US Geological Survey

Next

Type your email address here. Use the same email address for all parts of the study.

What do you remember about the acid rain topic you just read about? List at least three things.

Submit

That was the last acid rain topic. You will receive an email with additional instructions in approximately one week.

Appendix F: Email Messages Sent to Participants

To: Potential study participants
From: Phyllis Leary Newbill
Date: Week 1
Subject: Please participate in a study

The purpose of this email is to request your participation in a study that examines what people learn from a set of learning materials. During the study, you will respond to surveys and record your thoughts in an on-line journal. The study will run for four weeks. It should take you about 15 minutes the first week, about one hour the second and third weeks, and 10 minutes the final week. The study won't take much of your time and will give you an opportunity to experience a research study using on-line instructional materials.

If you are willing to participate, please point your browser to

https://survey.vt.edu/survey/entry.jsp?id=1079632978316

to begin the study for Week 1. Please complete this part of the study by 5:00 p.m. Friday, October 29.

To: Study participants
From: Phyllis Leary Newbill
Date: Week 2
Subject: Next part of online learning study

It's time to complete the next part of the online learning study. This section should take you about one hour to complete. To begin, please point your browser to

https://filebox.vt.edu/~pnewbill/Intervention/Minerals/MIi1.htm - Group 1 (exp)
https://filebox.vt.edu/~pnewbill/Intervention/Scientists/SCi1.htm - Group 2 (exp)
http://filebox.vt.edu/users/pnewbill/Intervention/Water/WAi1.htm - Group 3 (control)

Be sure to enter your email address every time you are asked.

Please complete this section by 5:00 p.m. on Friday, November 5, 2004.

To: Study participants

From: Phyllis Leary Newbill
Date: Week 3
Subject: Next part of online learning study

It's time to complete the next part of the online learning study. This section should take you about one hour to complete. To begin, please point your browser to

https://filebox.vt.edu/~pnewbill/Intervention/Scientists/SCi1.htm - Group 1 (exp)
https://filebox.vt.edu/~pnewbill/Intervention/Minerals/MIi1.htm - Group 2 (exp)
http://filebox.vt.edu/users/pnewbill/Intervention/AcidRain/ARi1.htm - Group 3 (control)

Be sure to enter your email address every time you are asked.

Please complete this section by 5:00 p.m. on Friday, November 5, 2004.

To: Potential study participants
From: Phyllis Leary Newbill
Date: Week 4
Subject: Final step in study

Thank you for your work so far in the science study. This email confirms that I have received your work from the first three weeks of the study. It's time to complete the final part of the online learning study. This section should take you about 15 minutes to complete. To begin, please point your browser to

https://survey.vt.edu/survey/entry.jsp?id=1069432261470

to complete the study.

Please email me if you have any questions. Many thanks for your participation.

Phyllis Leary Newbill

Appendix G: Qualitative Coding Scheme

The object of this task is to code meaning units from participant journals into the categories listed below.

- ✓ Begin with a spreadsheet of the participants' responses. The questions the participants were asked are on the horizontal axis; the participant identification codes are on the vertical axis.
- ✓ The second spreadsheet is called the analysis spreadsheet. This spreadsheet has the coding scheme shown below on the vertical axis and the participant identification codes on the horizontal axis. The coder should become familiar with all the codes in the coding scheme.
- ✓ For each meaning unit (phrase, sentence, or set of sentences), determine to which code it belongs. Cut the meaning unit from the data spreadsheet and paste it into the cell on the analysis spreadsheet that corresponds to the meaning code and the participant. Because the coding scheme is intended to be exhaustive and mutually exclusive, all the meaning units should fit into the coding scheme, and each should go in only once.
- ✓ Responses from the pre-module journals should be coded to parts 1, 2, or 3 of the coding scheme, which basically correspond to the three journal prompts. Where participants' responses did not match the question (for example, if a participant wrote what she knew about scientists as a response to the feelings question), code the meaning units wherever they make sense. Responses to the first prompt don't have to be coded in part 1 of the coding scheme.

- ✓ Responses from the post-module journals should be coded to part 4.
- ✓ When one participant includes more than one meaning unit for a code, separate the two meaning units with a divider symbol (such as ellipses[…]).

1. Feelings before
   - 1.1. Positive past experience (module, classes, teachers)
   - 1.2. Negative past experience (personal or vicarious)
   - 1.3. Intrigued, open, curious, willing to learn, interested, receptive,
   - 1.4. Worried /anxious about doing well
   - 1.5. I like to learn / I hope to learn / I value knowledge
   - 1.6. Scientists are valuable to society
   - 1.7. Rather do something else / anything else
   - 1.8. Not interested / not excited / not thrilled / bored / disappointed / unhappy
   - 1.9. Not for me, OK for someone else
   - 1.10. Indifferent / ambivalent / I don't mind / doesn't mean much/ no feelings / flip-flopping
   - 1.11. Don't know what to expect
2. What I know before
   - 2.1. Don't know much / expect to learn
   - 2.2. Negative scientist stereotypes (male, lab coat, old, goggles, pocket protector, crazy, strange, no social life, antisocial / work all the time)
   - 2.3. Aware of my stereotype
   - 2.4. Non-negative characteristics of scientists (educated, normal, value their work, hard work, diligent)
   - 2.5. What scientists do (research, teach, field work, find cures)
   - 2.6. Specific science jobs and areas of study
3. How I'll do it
   - 3.1. Distractions yes

3.2. Distractions no

3.3. Fast / fast as possible / quickly

3.4. Slow / moderate

3.5. Careful / thorough / paying attention / the pace I need to understand

3.6. I'll do what I have to

3.7. I'll do my best

3.8. How I will do it depends [on whatever]

3.9. Doing it for the credit / points

4. After codes

4.1. I know something new about scientists / science includes more variety of jobs than I thought

4.2. Scientists are not "others," abnormal, or different / stereotypes are wrong

4.3. Scientists are good / good for society

4.4. Love jobs / hobbies relate to jobs

4.5. I would like to meet them (why)

4.6. Not for me / not interested

4.7. I already knew / was not surprised [about whatever]

4.8. Expected something different in module