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"Who is a Scientist?": Effects of an Intervention to Change Students' Ideas about Science and Scientists

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"WHO IS A SCIENTIST?"

EFFECTS OF AN INTERVENTION TO CHANGE STUDENTS' IDEAS ABOUT SCIENCE AND SCIENTISTS

A Thesis Presented
by
LAUREN A. FOLEY

Submitted to the Office of Graduate Studies and Research of the University of Massachusetts of Boston in partial fulfillment of the requirements for the degree of

MASTER OF ARTS
May 1992

Critical and Creative Thinking Program
"WHO IS A SCIENTIST?"

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This thesis is dedicated to the scientists, teachers, and especially students, who participated in Science-By-Mail™ and made it a success.
ABSTRACT

"WHO IS A SCIENTIST?"

EFFECTS OF AN INTERVENTION TO CHANGE STUDENTS' IDEAS ABOUT SCIENCE AND SCIENTISTS

MAY 1992

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Advocates for improving science literacy have focused much attention on the negative impressions about science and scientists held by many Americans. The image of scientists as "nerdy" bespectacled men in laboratories has been related by some researchers to people's lack of interest in pursuing science. This thesis analyzes one component of a program aimed at changing that stereotype.

The Science-By-Mail program at the Museum of Science in Boston was designed to give students a more inclusive image of scientists. Central to the program was the creation of pen-pal relationships between students in grades 4-9 with scientists who did not fit the stereotype. The correspondence was driven by a set of hands-on science challenges, which included a variety of experiments. The activities introduced students to science as an engaging process of critical thought and exploration.
To determine whether participants' images of scientists changed, an empirical study was performed. Pretest and posttest questionnaires, consisting of five questions related to student images of science and scientists, were distributed to all participants. Responses from all students who returned both components of the evaluation were matched to form a test population of 217 pairs, and analyzed using a series of statistical tests.

Only one of the five questions, "What does a scientist look like?" was analyzed. This question was seen as the most likely to elicit responses about the appearance of the scientist. Responses were evaluated to determine the number of exclusive indicators, such as "all scientists wear lab coats," as well as inclusive indicators, such as "a scientist looks like anyone."

The stereotype's existence before the intervention was confirmed. The average number of exclusive indicators decreased significantly from pretest to posttest, regardless of age or gender of subject, gender of pen-pal scientist, or number of correspondences exchanged. No single feature of the program could be isolated as necessary for producing change, but overall the data showed a positive shift in students' images of scientists. The results prompted questions for further investigations into the causes and effects of the stereotype of scientists.
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In recent years concern has been raised in the educational community as well as the mass media regarding the problem of science illiteracy. Educators and scientists have approached the issue with a variety of questions. Among them are: How can science be taught so that our students will have the information they need to function in an increasingly technological society? How can we decide which information they should learn? How should we test our students to evaluate whether they are retaining what we teach them? How can we encourage students to enter scientific careers? While the challenges raised by these questions certainly are important, a deeper current runs beneath them, namely, our students' conception of science and scientists. Indeed, the student's image of a scientist in society may be one factor that has a direct effect on the number of students who choose or reject science as a career or academic pursuit.

Research conducted over the past forty years indicates that a consistent stereotypic image of scientists and science pervades public opinion. There are indications from the research that this stereotype carries negative implications that may dissuade children from pursuing further study in the field. Researchers have advanced recommendations for changing science teaching as a means of bringing about a
change in the perception of science and scientists. The purpose of this thesis is to analyze the effectiveness of the Science-By-Mail program conducted by the Museum of Science in Boston in bringing about change in children's perceptions of what scientists look like.

A great deal of the discussion regarding science illiteracy in the United States has focused on the low numbers of American students enrolled in science courses and entering careers in science. In an April 1990 cover story in Newsweek magazine, Begley et al. discussed the issue at great length. At the 1989 annual meeting of the American Association for the Advancement of Science, Mary Beth Ruskai, a mathematical physicist on the faculty of the University of Lowell, cited a recent study indicating that only 26% of all male high school students and 14% of female students take a physics course (Ruskai, 1989, p. 1).

One of the most significant factors contributing to the lack of scientific aptitude in this country, according to Ruskai (1989) and the authors of the Newsweek article (Begley et al. 1990), is the "nerd factor," or the stereotyping of scientists as social misfits. These researchers found, in a variety of studies, that the commonly held stereotype of the scientist is one that carries a set of exclusive characteristics, effectively eliminating scientific careers as potential choices for many students. The roots of
this negative stereotyping have been traced to many sources, several of which will be discussed below. However, one of the contributing factors to the creation of misconceptions about science and scientists may in fact be the science curriculum and the media, say several researchers, including Basalla (1976), Mendoza (1984), Hodson (1985), Horwood (1988) and Carey et al. (1989).

The prescription offered by these researchers, the experts they interviewed, and others in the science and education communities is that students should have contact with "real" scientists doing "real" work as a means of exposing them to a less stylized image of who an actual scientist is. This prescription, combined with other proposals for improving the image of scientists, inspired the creation of the Science-By-Mail™ program at the Museum of Science in Boston. Science-By-Mail™ pairs elementary and middle school students with professional scientists as pen-pals who correspond throughout the school year as the students work to solve entertaining science challenges. The activities and challenges included in each Science-By-Mail™ kit provide hands-on opportunities for participants to engage in scientific role-playing and problem-solving. In addition to providing science content and knowledge building experiences, the activities are designed to emphasize the types of science that are present in children's daily lives.
It was hoped that through communication with scientists in the Science-By-Mail™ program and through activities they themselves engaged in, students would adopt a more inclusive view of a scientist: that a scientist can be anyone and can appear to be a regular person.

The focus of this thesis, then, is to determine whether or not a particular intervention (the Science-By-Mail™ program) can bring about a change in students' stereotypes of scientists. The program is grounded in the theory of conceptual change. Conceptual change theory proposes that learners often approach a new situation with preconceptions about the possible results or outcome. However, when faced with a situation that directly contradicts their preconceptions, learners are forced to re-adjust their conceptions of the situation. In a larger sense, the theory of conceptual change challenges teachers to provide learning experiences in which students must scrutinize their own ideas. In endeavoring to alter children's sense of who a scientist is, it is critical to have a full understanding of the image of a scientist that exists in the present culture and that students might bring to their science classes.

The holding of stereotypes is related to making generalizations and reaching conclusions without sufficient evidence. As an empirical discipline, science often depends on the construction of new knowledge from the gathering of
data or the interpretation of experiences, rather than on conjecture alone or reliance on preconceived notions. The type of thinking required for the construction of knowledge in such a fashion is not isolated to science, however. Thinkers of all disciplines can benefit from gathering evidence to support their ideas. Science-By-Mail™ is designed to help students develop good critical thinking skills, not only for the completion of the program's activities, but for the construction of a broader image of scientists.

Chapter II provides a review of the significant relevant research and literature related to children's stereotyped image of the scientist in post-World War II western society. The review also discusses the methods used by various researchers to investigate the stereotype and provides a rationale for the method used in the current study.

Chapter III examines the recommendations that people have made about how to address the negative image of the scientist. It then discusses how the Science-By-Mail™ program fits with these recommendations.

Chapter IV details the design of the present study, with a description of the evaluative tools used, the scoring system, and the population involved in the study. It also lays out the key hypotheses tested, namely, that at the
outset of the program, students would be found to hold some stereotypic notions about scientists, and that after participation in the program, these images would be more broad and less stereotyped. It was also proposed that some aspects of the program might stand out as significantly related to a change in students' image of scientists. Factors considered as possible influencing variables were the age and gender of the students, the gender of the scientist and the number of correspondences between the student and the scientist.

Chapter V presents the data and corresponding analyses, approaching each of the research questions in detail. The results showed that the students did in fact hold some stereotyped images of scientists before their participation in Science-By-Mail™, and that following participation those images were less stereotyped. This shift was found to exist for students of both genders and of all ages, and did not seem particularly related to the gender of the pen-pal scientist or the number of letters the student exchanged with the scientist.

Finally, Chapter VI provides a discussion of the overall study, including questions raised by the results. Conclusions and suggestions for further investigation are also discussed in this chapter.
CHAPTER II
EVIDENCE FOR A NEGATIVE STEREOTYPE

This chapter presents a review of research into the roots and characteristics of a negative stereotype of scientists, beginning with the Mead and Metraux (1956) study, which provided the basis for the development of a composite image from student essays. Following the discussion of Mead and Metraux, several tests of attitudes using Likert scales and other objective measures are presented, including the studies of Beardslee and O'Dowd (1961) and Fraser (1978). Applications of the Draw-A-Scientist Test are also discussed (Chambers, 1983 and Fort and Varney, 1989).

Chapter II also presents the results of research into the roots of the stereotype, including findings related to children's ideas about science, the influences of the media on the image of science, the role of women in science, and the role of formal science education in reinforcing negative images about science and scientists. This chapter ends with comments regarding the implications of the research and makes some recommendations for the development of future research tools.
Images of Scientists as Reported by Previous Research

Since the seminal work of Mead and Metraux in 1956, a number of studies have been performed, all of which suggested that a stereotype of scientists exists. This stereotype includes both positive and negative factors. Among the positive factors found were that scientists contribute significant discoveries and advances to society and that the scientist is a highly intelligent, committed individual. However, the negative characteristics of the stereotype far outweighed the positive in all of the studies. The research showed that the scientist is seen as someone who is socially withdrawn and involved in strange tasks using dangerous equipment, and who sacrifices a "normal" life in order to pursue science. Of particular concern in this thesis is that false beliefs arising from the stereotype may lead people to have widely restrictive beliefs about the type of person who can be a scientist.

Several different methods have been used in the investigation of the stereotype, depending on the specific objectives of each research team. Each method has some biases which may lead to an overestimation of the amount of stereotyping found. This chapter critically reviews those studies to provide a context for the present work. In the present work, I have chosen to question children in a
somewhat different way. My approach is based in part on the methods of earlier researchers, but may be less biased.

The Mead and Metraux Study: Development of a Composite Image from Student Essays.

As a footnote to an article presenting the results of their investigation of high school students' image of scientists, Margaret Mead and Rhoda Metraux (1956) stated:

There is a great disparity between the large amount of effort and money being devoted to interesting young people in careers as scientists or engineers and the small amount of information we have on the attitudes those young people hold toward science and scientists. The Board of Directors of the AAAS has on several occasions discussed this disparity and the desirability of learning more about what high-school students actually think of science and scientists. This paper is one result of those discussions. (p. 384)

The Mead and Metraux study was one of the first attempts to determine popular images and opinions about scientists. Subsequent to the publication of the results of that study, the findings were corroborated by several other researchers, confirming the presumption that a consistent stereotypic image of science and scientists does, indeed, exist.

More than 35,000 high school students nationwide participated in this study. Each student was given one of three forms and asked to write a brief essay in response.
Form I asked students to complete the following statement:

"When I think about a scientist, I think of__"

Form II asked students to complete one of the following:

"If I were going to be a scientist, I should like to be the kind of scientist who__"

For girls, this option was provided:

"If I were going to marry a scientist, I should like to marry the kind of scientist who__"

Form III asked students to complete one of the following statements:

"If I were going to be a scientist, I would not like to be the kind of scientist who__"

Once again, a different option was provided for girls:

"If I were going to marry a scientist, I would not like to marry the kind of scientist who__"

It is interesting to note the apparent gender bias on the part of the designers of this questionnaire. The choice on the part of Mead and Metraux to include an option for girls to describe their potential husbands implies that the researchers felt girls were more likely to marry scientists than to become scientists. This bias is particularly alarming since both of the researchers were women.
Mead and Metraux (1956) chose to focus their analysis on qualitative, rather than quantitative, data. They made this decision because they felt that subjects would be better able to express their feelings or reasons for their feelings in a qualitative format rather than a quantitative format. To analyze the responses, sets of answers were collected and divided among independent consultants. The consultants then met and pooled their results. Essays from schools and classes were kept together for context. In addition, one thousand essays were pulled for a detailed pattern analysis; graduate students were hired to evaluate smaller samples, an additional consultant was hired who had had no previous experience with the materials, and a final meeting of the senior consultants was held to determine the final form of the findings. In this manner, the members of the research team felt that they were able to form a composite image based on the results of essays produced by students from all over the country, resulting in an image that would represent the common views of high school students.

This study resulted in a composite image of a scientist that not only included descriptions of the physical appearance of the scientist, but also provided insight into high school students' attitudes toward some of the personality characteristics they believed common to the scientist. The open-endedness of the questions ensured that nothing in the instrument would lead students to give a
response that was cued in any way, unlike some of the other instruments described below. It was a very comprehensive study of many components of a popular image, and has served as the foundation for many later studies. However, this research was reported in a highly subjective manner; data from individual subjects were not presented, only a composite image. The implicit assumption underlying this method was that one composite view existed. Further, there was no way to test how widespread the image was, or to determine if different students had different images. This study prejudged the existence of a stereotype.

The composite image that emerged from the Mead and Metraux (1956) study is that a scientist is:

...a man who wears a white coat and works in a laboratory. He is elderly or middle aged and wears glasses. He is small...or tall and thin. He may be bald. He may wear a beard, may be unshaven and unkempt. He may be stooped and old. He is surrounded by equipment: test tubes, bunsen burners, flasks and bottles, a jungle gym of blown glass tubes and weird sounds: the bubbling of liquids in test tubes and flasks, the squeaks and squeals of laboratory animals, the muttering voice of the scientist. He spends his days doing experiments. He pours chemicals from one test tube into another. He peers rapidly through microscopes. He scans the heavens through a telescope (or a microscope!) He experiments with plants and animals, cutting them apart, injecting serum into animals. He writes neatly in black notebooks. (pp. 386-387)

This description, while vivid and highly detailed, presented an exaggeration of a very specific type of
scientist -- the laboratory scientist, and in particular, the biologist or chemist. The profile did not include references to theoretical sciences, outdoor sciences, or even physical sciences. There was a heavy focus on the technology and tools of laboratory science.

In addition to the physical description of the scientist (appearance and work environment) were the implications that this profile carried about his personality and character. The stereotyped image failed to include many important aspects of the scientific arena and may have led people to make conclusions or inferences about specific scientists based on a broad generalization.

Mead and Metraux (1956) discussed many of these implications as part of their analysis of high school students' images of scientists and identified positive and negative characteristics. The positive descriptions focused mostly on the scientist's intelligence and commitment to his work and the importance of his work in medicine and new technologies. The negative descriptions focused on the scientist's position as being isolated from society, and his involvement in dangerous work:

He is a brain; he is so involved in his work that he doesn't know what is going on in the world. He has no other interests and neglects his body for his mind...He neglects his family...He is never home...he brings home work and also bugs and creepy things. He is always running off to his
laboratory. He may force his children to become scientists also. A scientist should not marry. No one wants to be such a scientist or to marry him. (p. 387)

After presenting both of these images, the authors concluded that, "This image in all its aspects... is one which is likely to invoke a negative attitude as far as personal career or marriage choice is concerned" (p. 387).

Tests of Attitudes Using Likert-Type Scales and Other Objective Measures.

Beardslee and O'Dowd. A few years after the publication of the Mead and Metraux study, Beardslee and O'Dowd (1961) investigated the attitudes of college students toward scientists and toward the desirability of science as a career. The authors embarked on their study as a means of determining whether the stereotype that was described by high school students was maintained when students reach college. They further wanted to find out whether there were any predictors in life experience or the students' major field of study that were associated with beliefs about occupations.

The researchers were less interested in the students' physical descriptions of the scientist than they were in students' perceptions of the scientist as an element of society. Their survey was conducted on a quantitative basis, using a Likert-type scale that asked students to rank fourteen occupations, including scientists, on a scale for
extreme aspects of various characteristics. Questions were included in the survey on the basis of responses that the researchers had collected in earlier formative questionnaires and interviews. Examples from their questionnaire are:

1. wealthy; not well-to-do
2. optimistic; pessimistic
3. excitable; calm

(Byardslee and O'Dowd, 1961, p. 997)

The questionnaire was given to approximately twelve hundred college students. From their results, the researchers were able to form a composite image and to compare students' perceptions about a scientist with their perceptions of several other professions, determining correlations among the various choices.

The study indicated that many subjects ranked scientists, professors, and engineers similarly on some indicators, most notably high intelligence, self-sufficiency and perseverance. However, although subjects ranked scientists at the high end of these particular scales, the positive responses were outweighed by negative scores on other personality traits. In other words, although the scientist may share several admirable qualities with professors and engineers, the researchers concluded that he was thought to be "more of an egghead than the engineer and to lack the artistic interest, good taste, and sensitivity of the college professor. The scientist is intellectual, but
not a cultured intellectual" (Beardslee and O'Dowd, 1961, p. 998).

The focus of the Beardslee and O'Dowd (1961) study was on how college students' views of scientists would affect their likelihood of pursuing a career in science. Their findings led them to conclude that "There is clearly a well-defined stereotype of the scientist among college students as well as among high school students" (p. 997), and that this stereotype was consistent with the Mead and Metraux image that had been published five years earlier.

After establishing that the general subject population confirmed the stereotype, Beardslee and O'Dowd then isolated sub-groups for comparisons. Their comparisons included male vs. female subjects, students from private vs. public colleges, freshmen vs. seniors, students from varying socioeconomic backgrounds, and students who came from professional vs. business families. The researchers could find no significant differences among their subjects' views of the scientist. The similarity of responses led them to state that, "This is clearly a stable image that is shared widely among college students with varied histories and experience" (p. 999).

However, they did find, in a smaller study conducted with a subgroup of the subject pool, that a set of entering
freshmen who had stated an intention to pursue science careers did exhibit some differences:

Those who intended to be scientists had a more favorable image of both the scientist and the engineer than the remainder of the newly arrived freshmen. The would-be scientists, as compared to the other freshmen, viewed the scientist as more colorful and interesting, of higher social status, more successful, more sensitive to art, and of a more sociable temperament. (Beardslee and O'Dowd, 1961, p. 999)

This finding suggests that individuals who have a more positive view of scientists are more likely to pursue science than those who hold a negative view. However, we cannot tell from such a correlational study which factor is cause and which effect. As the authors noted in their concluding remarks:

It is interesting that students intending to pursue careers in science should have a more favorable image of the scientist than their colleagues who are planning other careers. It is not known whether commitment to a field changes the image or whether those with a more favorable image are drawn to the field. (Beardslee and O'Dowd, 1961, p. 1000)

Many of the negative factors that Mead and Metraux (1956) found in their research were present in the Beardslee and O'Dowd (1961) interviews. In a manner similar to that used by Mead and Metraux, Beardslee and O'Dowd were able to form a composite image of the scientist from their research, which in fact was more negative than the image exacted from the Mead and Metraux study:
Students see him most prominently as a highly intelligent person...At the same time, the scientist is seen as socially withdrawn; he is indifferent to people, retiring, and somewhat depressed, and he rates low in social popularity. In overall sociability the scientist rates lowest among individuals in the 15 high-level occupations. It is therefore not surprising that he is believed to have a relatively unhappy home life and a wife who is not pretty. There is an air of strangeness about him; he is hard to like and comprehend...The scientist is believed to be highly intelligent but not interested in art...In summary, there emerges a picture of the scientist as a highly intelligent individual devoted to his studies and research at the expense of interest in art, friends, and even family. (pp. 997-998)

An interesting finding that Beardslee and O'Dowd discussed is that when students were asked their views of scientists in specialized fields (biology, chemistry, engineering), they gave more positive responses, rating the biologist as the most "normal" (p. 999). Overall, however, the researchers concluded that the stereotype image that they found had "the effect of recruiting a certain type of person and discouraging others" (p. 1000).

This study did not provide for spontaneous answers. Instead, it used comparative rank-ordering to make inferences about students' attitudes toward various careers. Conclusions drawn from this study therefore cannot be absolutes; rather, they must be presented in comparative terms. Since the authors were primarily interested in students' views of science compared to other career choices,
this is acceptable. However, it becomes difficult to extract general inferences about the results without referring to these comparisons.

Fraser. Fraser (1978) developed the Test of Science-Related Attitudes (TOSRA) as a means of investigating attitudes toward science and scientists. It was used as a quantitative instrument, and asked subjects to provide an "agree" or "disagree" response to each of several statements. Each statement was classified by the developer to refer to a particular aspect of science-related attitudes. Some sample statements included in the questionnaire were:

"Scientific discoveries are doing more harm than good."

"Scientists usually like to go to their laboratories when they have a day off."

"I dislike reading newspaper articles about science."

"I would prefer to find out why something happens by doing an experiment rather than by being told."

(p. 510)

Fraser (1978) investigated seven aspects of attitude toward science: social implications of science, normality of scientists, attitude to inquiry, adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science, and career interest in science. Each of these scales contained 10 items scored from 1 (complete disagreement) to 5 (complete agreement). The possible scores
on each scale ranged from 10 to 50. A score of 30 indicated a neutral tone statement, below 30 a negative tone, and above 30 a positive statement.

The scale with the highest student score (mean = 38.4, Standard Deviation = 6.1) was student attitude to inquiry. The mean results on other scales were as follows: social implications of science: mean = 35.5, SD = 5.5; normality of scientists: mean = 35.5, SD = 5.0; adoption of scientific attitudes: mean = 37.8, SD = 4.8; enjoyment of science lessons: mean = 31.8, SD = 9.2; leisure interest in science: mean = 25.0, SD = 8.3; career interest in science: mean = 27.3, SD = 8.0.

Fraser's intent in developing the TOSRA was to improve on other attitude scales. His commentary therefore reflected only his impressions of the usefulness of the instrument and its test-retest reliability. However, the results of his study would seem to indicate that the subjects he pooled were, at best, neutral in their attitudes about their own participation in science, whether at an academic, professional, or leisure level. As shown above, scores for all of these tests hovered around the neutral range of the scale. Although the students showed low interest in pursuing science for themselves, they were slightly more positive about the value of science to society and about the importance of scientific attitudes of inquiry. These results
are consistent with those of some of the earlier researchers, who found that subjects respected the value of science, but did not feel that they themselves should be scientists.

This instrument, by including references to particular aspects of science, might have led subjects to provide responses that they otherwise would not make. It is possible that, if asked simply to discuss their feelings about science or scientists, subjects might never have thought of some of the areas mentioned in the questionnaire. Rather than serving as a test of subjects' attitudes about science and scientists as a general category, this instrument served as a test of attitudes toward very specific issues related to science and scientific professions.

Further attitude studies. Erb (1981, 1983) and Krajkovich and Smith (1982) used the Image of Science and Scientists Scale (ISSS) with a similar purpose to Fraser's (1978). This instrument is similar in format to the Beardslee and O'Dowd (1961) test, in that it uses some Likert-type scales to quantify subject responses. The subject matter in each of the fifty test statements was taken from the Mead and Metraux (1956) study. The instrument included an equal number of positive and negative statements. Two types of items were incorporated into the form. Some involved completion, such as
"When I think of a scientist, I think of a person who sits in a laboratory all day; is courageous; is intelligent; works in a dreary laboratory."

(Krajkovich and Smith 1982, p. 40).

Other items called for some level of agreement or disagreement:

"A scientist's work is dangerous." strongly agree; agree; mildly agree/mildly disagree; disagree; strongly disagree"

(Krajkovich and Smith 1982, p. 40)

Implicit in many of the studies included in this review was the discouragement of women from pursuing scientific careers. As has been alluded to throughout this discussion, the stereotype of a scientist is clearly that of a male. While many opportunities have become available for women in science since the Mead and Metraux (1956) and the Beardslee and O'Dowd (1961) surveys, there has been little change in the perception that the typical scientist is male. As we will see below, this perception may play a significant role in the social implications of who can become a scientist.

The ISSS scale was designed specifically to investigate changes in scientific attitudes from the beginning to the end of an intervention or curriculum unit. The authors (Krajkovich and Smith, 1982) noted, however, that an interesting use of the test was to "examine item by item results and then use those results in a lesson" (p. 43).
This was seen as an effective method for exposing and countering stereotypes.

The ISSS was used by Erb (1981) in an investigation of adolescents' (age 10-16) attitudes toward science careers. The study was grounded in the premise that career education must be targeted at a certain critical juncture in school curriculum. The research was aimed at finding the point when it would be most appropriate to introduce students to careers in science, and to dissuade them from developing negative attitudes toward science. Erb's investigation focused particularly on gender differences in attitudes toward science and scientists.

Erb (1981) found that in the youngest students surveyed (age 10), contrary to his hypothesis, girls scored higher on tests of attitude toward science careers than boys. However, the girls' scores declined steadily after age 10, while the boys' scores increased. These results brought him to the conclusion that interventions aimed at encouraging girls to pursue science should start in the early middle grades, before their interest began to decline.

In his investigation of attitudes toward science, careers in science, and women in science, Erb (1981) used a slight modification of the ISSS. The ISSS, by including several options for completion and several levels of
agreement, is more open-ended than the TOSRA model developed by Fraser (1978). However, it still leads subjects to make responses that they might not have made if the particular selections were not included, or, to make fewer responses than they might have in other circumstances. For instance, the question "When I think of a scientist, I think of a person who____." includes several options for response. Subjects were asked to select only one. However, the composite drawn by Mead and Metraux (1955) included most of the responses provided as selections to this question. The researchers may have forced the elimination of some useful data by designing their instrument in the manner they did.

Instruments such as those used by Beardslee and O'Dowd (1961), Fraser (1978), and Krajkovich and Smith (1982) are useful in determining subjects' attitudes toward specific aspects of science or scientists, an objective that is difficult to accomplish in the more general Draw-A-Scientist Test (DAST) described below. A drawback to the more quantitative question design, however, is that it may engineer responses that a subject might not otherwise consider, except when prompted to do so by the wording of a question. In this respect, the DAST-type of test is a less biased or leading measure. At the same time, it allows researchers to uncover general stereotype characteristics, and to evaluate responses reliably for quantifiable elements that have been pre-determined by the researchers.

In recent years, another instrument for determining stereotypic characteristics of scientists, the Draw-A-Scientist Test, (DAST) was developed and has been used in at least four studies (Chambers, 1983; Schibeci and Sorensen, 1983; Fort and Varney, 1983; Mason, Kahle, and Gardner, 1989).

The Draw-A-Scientist test was introduced by Chambers (1983) as a means of investigating stereotypic indicators in children's perceptions of scientists. Chambers isolated seven indicators of the typical stereotype image of a scientist based partly on the literature. He selected indicators that he felt incorporated inferences about not only the physical appearance of the scientist, but also his or her personality or social presence. The seven indicators he selected were:

1. Lab coat (usually but not necessarily white)
2. Eyeglasses
3. Facial growth of hair (including beards, mustaches, or abnormally long sideburns)
4. Symbols of research: scientific instruments and laboratory equipment of any kind
5. Symbols of knowledge: principally books and filing cabinets
6. Technology: the 'products' of science
The implementation of the DAST involved simply asking children to draw a picture of a scientist. The subjects' drawings were then evaluated to determine how many of the seven indicators were present. Chambers studied subjects in the age range from kindergarten to grade 5. These results were tabulated for children at each grade level to provide an average number of indicators for each age. Although Chambers did not isolate gender as a stereotyped attribute in his study, he did investigate the frequency of drawings that included male and female scientists, and found that only girls drew female scientists. The subject pool in this study consisted of 4,807 students of whom 2,355, or 49%, were girls. A total of twenty-eight, or slightly more than 1% of the girls in the study, drew female scientists. With regard to the indicators he had pre-determined, Chambers found that the mean number of indicators increased as children got older. The mean number of indicators for each grade appear in Table 2.1.
### Table 2.1:
Indicators Identified by Chambers in the Draw-A-Scientist Test

<table>
<thead>
<tr>
<th>Grade</th>
<th>Mean Number of Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kindergarten</td>
<td>0.31</td>
</tr>
<tr>
<td>First grade</td>
<td>0.71</td>
</tr>
<tr>
<td>Second grade</td>
<td>1.81</td>
</tr>
<tr>
<td>Third grade</td>
<td>2.43</td>
</tr>
<tr>
<td>Fourth grade</td>
<td>3.05</td>
</tr>
<tr>
<td>Fifth grade</td>
<td>3.26</td>
</tr>
</tbody>
</table>

(Chambers, 1983, p. 259)

Schibeci and Sorensen (1983) performed a study using DAST to determine whether it would be a "quick, reliable method of assessing elementary school children's images of scientists" (p. 16). They found that it could "be scored reliably if the total number of indicators in a drawing is used as the criterion" (p. 16); and they recommended its use as a means of gathering children's overall and "global images" (p. 18).

In their study for *Science and Children*, Fort and Varney (1989) used a method similar to the DAST. They asked children to write 50 to 100 words and draw a picture of what a "typical" scientist would look like. The researchers were primarily interested in gender differences, racial
differences, and fictional vs. real scientist images. For each of these aspects, the researchers found that the stereotype of a scientist as a white male was borne out. Of 1,654 respondents, fewer than 20 drew non-white scientists, and no Asian scientists were drawn. With regard to gender, the authors note that:

Nearly 60% of the respondents were girls. Nonetheless, a vast majority of students of both sexes described male scientists. Eighty-six percent of girls pictured male scientists, and of the 705 essays by boys, 699...were about males. (Fort and Varney, 1989, pp. 8-9).

Mason, Kahle, and Gardner (1989) implemented the DAST as a means of determining children's views of males and females in science. Their objective was to determine whether a classroom intervention could have an effect on student views regarding the gender of scientists. The goal of their intervention was to improve student attitudes toward science and to broaden students' images of scientists, particularly with regard to gender of the scientist. To accomplish these goals, a teacher-training program was implemented, which gave teachers information and instruction for "incorporating career information, role models, equitable materials, and innovative practices" into the classroom (Mason, Kahle, and Gardner, 1989, p. 4).

After the participating teachers had been through the preliminary training program, they went back to their classes
and implemented the intervention. As part of the evaluation, the researchers observed some of the classroom interactions between the teachers and the students. Following the intervention, they administered the Draw-A-Scientist test and analyzed it by counting the frequency of drawings of female scientists. In the experimental group, 26% of the girls drew female scientists following the intervention, while only 16% of the girls in the control group drew females. For boys, six percent of the experimental group drew females, while none of the control group boys did so. The article describing this study does not mention the administration of a pretest, but only comments on these post-intervention data. Based on these results, the researchers concluded that their intervention was successful in increasing the tendency to draw women, and that the DAST was an appropriate means of evaluating children's attitudes about science.

The tendency to envision scientists as laboratory-oriented is a development of the twentieth century, according to Chambers (1983). In a presentation of the findings of his research of elementary students' stereotypic images of the scientists, he described the popular views of scientists during previous centuries:

During the eighteenth and nineteenth centuries visual and verbal images of the scientist were many and varied. Caricaturists, cartoonists, artists, and writers produced a diverse range of stereotypic figures: diabolical madmen, distinguished professors, harmless eccentrics, learned buffoons,
and fashionable dilettantes. Naturalists in the field among flora and fauna were often pictured, as were physical scientists in their laboratories surrounded by vials and beakers...With a few exceptions, these images are now seldom seen. As science has transformed its organizational structure, improved its general social status, and firmly established its social authority, a new professional image has emerged in the popular media. This image, apparently more in keeping with the institutional goals and procedures of modern science, differs in significant ways from earlier stereotypes. The naturalist has been almost completely replaced by the laboratory scientist. (Chambers, 1983, p. 255)

As has been stated above, the Mead and Metraux (1956) findings have been supported by several other studies. For instance, although Chambers' (1983) research was conducted nearly thirty years after the Mead and Metraux study, his subjects produced many of the same descriptive indicators in their responses as those given by the Mead and Metraux subjects. Other researchers have also found similar results. In fact, Basalla (1976) traced the image through the popular media, including movies and television, and found it virtually unchanged during the period from 1945 until he concluded his investigation in 1975.

In one of the most recent studies of the topic, Fort and Varney (1989) reported similar findings in a survey conducted for the National Science Teachers' Association magazine Science and Children. Although the presentation of their results was highly anecdotal, Fort and Varney described the responses to their survey as matching the stereotype in several key areas. They found indications that many children
pictured scientists as working indoors and conforming to many of the stereotypic characteristics.

The four most popular scientific professions—with 300 or more students envisioning a typical scientist at work in each field—are inventing, biology, chemistry, and medicine (1654 subjects)... Regardless of the scientist's occupation, a majority of our respondents described male scientists with stereotypical characteristics. (Fort and Varney, 1989, p. 12)

The similarities in the characteristics of "a scientist" as reported by several researchers indicate that the Mead and Metraux image is pervasive and that it is not affected by age once it has been adopted (Basalla, 1976; Beardslee and O'Dowd, 1961; Schibeci and Sorensen, 1983; Brush, 1979). Chambers found that between kindergarten and fifth grade, the number of key features reported per child increased with age, but was relatively constant from fifth grade through adulthood. It seems, from the results of Chambers' work and from the work of Schibeci and Sorensen (1983), that children begin to develop an image of the scientist in elementary school.

Data collection using Chambers' method is considerably more quantitative and less subjective than that using the Mead and Metraux tool. However, there remains an element of subjectivity built into the reasoning and assumptions made in the design of the research instrument. Chambers isolated seven physical descriptors from the Mead and Metraux image,
each of which, he argued, carried an implication about the personality or social acceptability of the scientist. He briefly described some of these implications as they might relate to the practice of science in its stereotyped form:

Eyeglasses, for example are associated with eye strain (and thus intense observation). Lab coats are associated with dirty work (and thus experimentation and empirical knowledge), but also with purity...Beards may be seen as meaning “unshaven” (working long and unusual hours). (Chambers, 1983, p. 257)

In addition to the physical characteristics of the image of the scientist that emerge from these findings, it is also useful to consider the influences that may have led the subjects to their responses. Of interest in the Fort and Varney (1989) study were the subjects' responses when asked to describe the basis for their images of scientists. Of 1654 respondents, only 404 (24%) were able to rely on personal experience with a scientist; 830, or 50%, cited the source of their image as a book, magazine, movie, or television. Another 25% of the subjects answered that their image came from their imagination. Many of the scientists (910 of 1654) described in Fort’s and Varney’s article were fictional; and only 435 of the students referred to real scientists (historical figures or personal acquaintances) in their descriptions.
The Stereotype and Negative Attitudes Toward Science: Sources and Consequences

Influences of the Media on the Image of the Scientist.

The media has been accused of providing its audience, and particularly its youth audience, with a negative caricature image of scientists. Mead and Metraux (1956) stated: "Straight across the country there is a reflection of the mass media image of the scientist, which shares with the school materials the responsibility of the present image" (p. 388). Schibeci and Sorensen (1983) argued that "If there is a negative and/or distorted view of scientists in the community, popular culture and the media are probably responsible" (p. 15). Maugh (1979) cited an editorial in TV Guide in which Carl Sagan (1976) accused Saturday morning children's programs of presenting scientists as "moral cripples driven by a lust for power or gifted with a spectacular insensitivity for the feelings of others," (Maugh, 1979, p. 37) and he further stated that the result is that children receive a message that science is dangerous. Specific examples of such cartoon-type scientists abound.

A television "scientist" who was remarkable in his complete personification of the Mead and Metraux composite was "Dr. Bunsen Honeydew," a character created for the
children's program *The Muppet Show*. Dr. Honeydew, a middle-aged, bald, white man who wears glasses, was a regular on the program. With few exceptions, the set for his appearances was his laboratory, which was filled with flasks, bubbling solutions, colored liquids, and test tubes. He frequently performed experiments that resulted in physical trauma of every sort to his assistant, Beaker, a perpetually frightened-looking sidekick who, like his employer, was attired in a white lab coat.

Another recent media character who appeared as a living caricature of a scientist was "Doc Brown," who invented the time-travel machine in the film *Back to the Future* and its sequels. Doc fits the description given by a seventh grader in the Fort and Varney (1989) study: "I've always thought of scientists as being smart, crazy, and scary looking." Although the results of the *Science and Children* survey produced many descriptions of "mad scientists" (p. 11), the authors noted that the children who provided those descriptions were aware that the scientists they were discussing were fictional characters, and that the fictional characters had come from the media:

Our analysis of the students' sources of information showed that the children's stereotypical image of the "mad" scientist came from books and magazines, television, or the movies. While their individual imaginings were, of course, affected in significant ways by these print and electronic media, all of the "mad" scientist
essays directly cited one or all of these three sources. (Fort and Varney, 1989, p. 10)

In a recent evaluation of the implications of stereotypes of scientists on children's gender perceptions, Mason, Kahle, and Gardner (1989) interviewed children who had drawn pictures of scientists. When asked to describe and explain their pictures, a majority of the students stated that the pictures were based on impressions of science and scientists derived through movies and cartoons, which often depict scientists as mad, antisocial men.

Regardless of whether the students think of the scientists as fictional or real, if their perception of a scientist is that he is quite unlike themselves, they may be less likely to consider his professional identity to be one that is appropriate for them. In her discussion of the "Avoidance of science and stereotypes of scientists," Brush (1979) provided evidence indicating that "students who enroll in science courses see themselves as more like their image of a scientist than do others." (p. 237) Brush's study focused in part on the notion of self held by the subjects, and evaluated the amount of difference that subjects reported between their image of themselves and their image of the stereotype. She found statistically significant results (p < .001) to show that students who were majoring in math and science were more likely to relate to the characteristics of the stereotype of scientists. With respect to these
findings, Brush commented that "students who feel closer in personal characteristics to their image of scientists do enroll more frequently in science" (Brush, 1979, p. 240). She found that the self-image measure was a better predictor of enrollment in science courses than measures of attitudes toward science. Since the research in Brush's study was correlational, not experimental, we cannot be sure whether there was a causal relationship between student attitudes toward science and their pursuit of science careers, but her results were consistent with those found by Beardslee and O'Dowd (1961).

The Science Curriculum.

Another possible (and more subtle) source of negative attitudes toward science may come from the science curriculum itself. Several researchers have raised concerns that the implicit message in much of traditional science teaching serves to perpetuate ideas that science must be done in a certain manner, by a certain type of people, and must follow a textbook or recipe-style format.

The research that has been conducted into the role of science education in the formation of children's ideas and attitudes in science focuses generally in two areas: a discussion of the objectives of science education and a
description of the philosophy of science as it should be understood and presented by teachers. Although various researchers have chosen to highlight different aspects of the discussion, the central argument seems to be that science is often presented as a cold, alien set of facts and figures that is hard to understand, and that students should instead be introduced to science as a purposeful endeavor of humans actively pursuing understanding.

Carey et al. (1989) noted that while students are being introduced to the process of science and the critical thinking skills involved in that process, the “standard curriculum fails to address the motivation or justification for using these skills in constructing scientific knowledge” (p. 1). This practice, according to Carey and her associates, has the effect of separating the basis of science, defined as inquiry about phenomena, from its process, thus leaving children in a position of not being aware of the reason for performing a skill or doing an experiment.

Carey et al. (1989) cited several studies which found children performing experiments with a goal of producing a desired effect rather than with a goal of determining the outcome of a series of events that they had observed purposefully and inquisitively. Children in these studies saw evidence as instances illustrating the theory rather than
being independent of the theory. "Experimentation consists of simply trying things out. Their view of the goal is to reproduce the bubbling phenomena rather than identifying what ingredients are necessary" (p. 8).

A goal of science education is that "students should understand that observation and experimentation are purposeful, theory-driven activities." (Carey et al., 1989, p. 3). The intervention that she and her colleagues designed and implemented was intended to bring about this understanding. Through their intervention, a unit on the nature of science, the intention was to increase students' level of understanding of the relationship between theories and ideas in science.

It is here that the class begins to learn that systematic experimentation has a purpose; it is in the service of constructing a deeper explanation of the phenomenon. (Carey et al., 1989, p. 9)

The idea of a constructivist nature of science as held by Carey and her associates relies on the students' ability to take prior learning experiences and use them as a basis for developing new knowledge. In her intervention, the students moved through a series of experiences with yeast. By proceeding through a purposeful experimental procedure (about the behavior of yeast under certain conditions), the students
come to accept the mechanism they did not originally favor....Their very notion of a living organism is challenged; it must be expanded to include what looks like an inert brown powder, which can survive being frozen, remaining dormant until conditions support activity and growth.

(p. 10)

Another researcher who discussed the separation of science from its related process skills was Hodson (1988). He argued strongly that if teachers were trained in the philosophy of science, students would be in a better position to understand the nature of scientific knowledge. By isolating the process skills, and foregoing an emphasis on "the teaching of science as a body of established knowledge" (p. 19), children are being denied the opportunity to acquire new knowledge. In a manner more forceful than Carey's, Hodson criticized the curricular advances of the last decades as moving away from the constructivist nature of science. With respect to the numerous science curricula that were introduced in the late 1960's and 1970's, he said:

Perhaps even more damaging was the mistaken assumption that scientific knowledge is best learned through experiences based on the procedures of science....Curriculum developers confused the teaching of science as inquiry (i.e., a curriculum emphasis on the processes of science) and the teaching of science by inquiry (using the processes of science to learn science). (Hodson, 1988, p. 22)

As has already been discussed above, popular culture has a role to play along with formal education in the formation
of children's images of science, a sentiment that Hodson echoed:

What children understand about the nature of science and the activities of scientists and their attitudes toward science are compounded by their curricular experiences and the existing public image of science as portrayed by informal learning channels... (Hodson, 1988, p. 22)

Schebeci and Sorenson (1981) claimed that many teachers only put explicit value on cognitive objectives and leave attitudes and concern with the appreciation of the nature of science to chance. If this view is correct, then it is the implicit, unplanned philosophy of science underpinning the curriculum that carries the important message about what science is and is ultimately responsible for forming children's attitudes and beliefs.

In another study, Hodson (1985) discussed the ramifications of what he referred to as the "hidden curriculum" (p. 40). He said that the design of many discovery-based classes is actually a "stage-managed pseudo-discovery of the inevitable," in which the teacher directs the experience to such a degree that the "thrill of discovery" (p. 42) is spoiled.

Children are frustrated because they frequently make observations and discoveries which the teacher, because of prior theoretical knowledge, dismisses as irrelevant or wrong. Faced with such experiences, they quickly lose confidence and incentive to pursue such activities....
Unfortunately, the view of scientific method propagated by such courses is too simplistic in implying that theories are simple propositions which should stand or fall on the evidence of single experiments. (Hodson, 1985, pp. 40,42.)

This implication that many curricula are targeted toward a specific right answer is something that Carey et al. (1989) addressed in their study, commenting that in a particular activity, students "cannot determine which of their hypotheses is 'right.' Instead, they must decide which hypothesis offers the best account of the evidence." (p. 7).

In a similar vein, Horwood (1988) remarked on the role of teachers in explaining and describing concepts in science teaching. He defined the principal goal of science education as contributing to a student's ability to make sense of the world. With this goal in mind, he asked:

...how a person goes about learning how to explain things when there is no teacher to do it? Is it possible that science teachers have a role to play in helping pupils develop explanatory ability--this latter as distinct from being able to recite the explanations of others? (Horwood, 1988, p. 41)

Horwood's query reflects a philosophy in line with the arguments advanced by Hodson (1985) and Carey et al. (1989); These researchers placed some of the responsibility for the negative image of science in the hands of science educators and proposed that children be given the opportunity to experience science as a process of exploration, where the
answers are not engineered and where inquiry is a necessary part of the process, rather than an end in itself. The gaining of scientific knowledge, according to Carey and Hodson, depends on the learner being able to build upon prior experience and knowledge. This cannot be accomplished if the building process and the knowledge are separated.

The Stereotype and Women's Role in Science.

There is a great deal of evidence that fewer women than men pursue education and careers in science. The National Science Foundation announced that of 1982 high school graduates, 8.2 percent of males and 5.7 percent of females had taken calculus, and 22.1 percent of males and 11.6 percent of females had taken physics. Also, while more than 50% of male college-bound seniors in 1984 planned to major in science or engineering, fewer than 30 percent of females had the same intentions (Gardner, Mason, and Matyas, 1989). Other data present slightly different statistics, but the findings essentially are the same. Briscoe (1984) cited a study indicating that 18% of young men in college were majoring in science or engineering, compared to 7% of young women. Mendoza (1984) describes a research project conducted by Children's Television Workshop while that company was preparing its children's science program 3-2-1 Contact. The CTW researchers found that 25% of boys and only 3% of girls
at the end of elementary school said they would consider careers in science and engineering.

In her lecture, Ruskai (1989) discussed female students' decisions not to pursue science with respect to stereotypes, and, with reference to the information sources that girls rely on in making these decisions:

What I find particularly striking about these figures is that the overwhelming majority of girls have made the decision not to study physics before they have ever encountered a physics course or a physicist. Thus, their decision not to study physics must be based upon whatever perceptions about the physical sciences, whether true or false, exist in our society. (Ruskai, 1989, p. 9)

In other recent studies, research findings have indicated that most students still envision the typical scientist as a male. As shown previously in this chapter, Chambers (1983), Mason, Kahle, and Gardner (1989), and Fort and Varney (1989) found only rare instances in which subjects described scientists as female.

Implications of the Research

Significant research has been performed to determine whether there exists a stereotype of scientists. Researchers have used several methods to uncover this stereotype and the attitudes that accompany it. As seen
earlier in this chapter, the first significant research in this area was performed by Mead and Metraux (1956). Their results were used as the basis for several other instruments that were developed over the subsequent thirty years.

The research that has been conducted regarding the public's, and specifically children's, images of science and scientists, indicates that there is a stereotype of scientists that is deep-rooted and pervasive. The composite image is that of a white man who works in a laboratory. The stereotype carries with it negative implications that are, it seems, partly responsible for preventing young people from seeking careers in science. Many researchers cited results indicating that subjects would be unwilling to pursue careers in science, and that they held scientific careers in lower esteem than other careers.

A particularly disquieting aspect of the stereotype of the scientist is the implication that only men can be scientists. While the research does not indicate a purposeful exclusion of women, it does show that when asked to describe a scientist, the first image that comes to the mind of most people is that of a man. There is ample evidence in the research to indicate that science is not considered an appropriate field for women, or even for most people.
Specifically, Fort and Varney (1989) noted that only 1% of boys drew female scientists in their study, compared to 14% of girls. Also Chambers (1983) found that only girls drew female scientists. When Mason, Kahle, and Gardner conducted a similar test (1989), they found that in the control group, 16% of girls and none of the boys drew female scientists. Even following their intervention, there was a sizable difference between 26% of girls and 6% of boys drawing female scientists.

In addition to finding that the stereotype of scientists may prevent people from pursuing scientific careers, researchers also found that the scientist is often thought of as socially unacceptable. Although he is considered to be quite intelligent, the scientist appears slightly unkempt and is socially isolated. The scientist is thought to be someone who is too involved in his research to maintain interests in other areas of life, and is therefore unable to have normal relationships with people. The scientist is not considered to be a desirable marriage mate or family person.

Overall, there is clear evidence to support the existence of the stereotype of scientists. The stereotype is common among subjects of varying age groups. The personality traits associated with the stereotype are generally negative.
It seems that the stereotypic image is so pervasive and so consistent that regardless of the method used, researchers found results that corroborated the characteristics first put forward in the Mead and Metraux (1956) investigation. A particularly striking feature of these findings, as detailed above, is the generally negative perception that subjects exhibit regarding the desirability of science as a career choice.

Faced with these data and the implications involved, it seems clear that attempts should be made by the scientific community to bring about change in the public's perception of scientists. With young people presently avoiding advanced level science classes and refraining from the pursuit of scientific careers, it will be increasingly important to present science as a worthwhile and challenging career path.

Advocates for changing the image of science and scientists have been presenting their case for at least 35 years, since Margaret Mead and Rhoda Metraux presented their arguments in Science magazine in 1956. Since then, as the above discussion indicates, neither the image nor the recommendations have changed significantly, despite the technological advances that have occurred and the social and demographic changes that have brought more women and minorities into the work force. The image of the scientist as male, laboratory-focused, not socially oriented, and
"nerdy," is inaccurate. If American students are to be successful in a society that is in many ways characterized by technology, they must be encouraged to see themselves and their peers as potential scientists.

Recommendations for the Development of Future Research Tools

The investigative instruments detailed above used a wide variety of strategies to obtain information related to attitudes about science. Each has strengths and weaknesses when evaluated either as a general test of attitudes toward scientists and science-related careers or in the context of the objectives set out by the research team. In the process of framing new questions, it is instructive to consider the features of the previous research tools.

The research cited above can be divided into two general categories. First, there are instruments that use open-ended questions to elicit general responses related to the issue. Those responses are then evaluated, and composite images are created. Second, there are instruments that use closed-ended questions intended to collect information about specific aspects of the topic. These studies produce quantifiable data that can be analyzed in an objective manner. The major drawback of the open-ended questions, particularly in the Mead and Metraux (1956) study, is that the interpretation of data is extremely subjective.
Although the Mead and Metraux data interpretation was performed in a subjective manner in that there was no coding strategy or quantifiable material for particular individuals, it did provide later researchers with a starting point for developing more quantitative instruments. It is significant to note that nearly every researcher cited here made reference to that study. Since the findings of that earlier study were corroborated with such a variety of means and with such a variety of subjects, future researchers can rely on the data provided there with relatively high confidence.

The use of questions targeted at specific attitudes or specific statements has the weaknesses of possibly leading subjects to responses that they might otherwise not make, and also of not allowing for elaboration. Elaboration is a major difference between the two categories, since in the open-ended style, subjects are given a means of expanding, qualifying, or streamlining their responses, an opportunity which is not available in the closed-ended instruments. However, closed-ended instruments provide a concrete, measurable set of data which can be reliably tabulated.

It would seem, then, that the ideal investigative tool would be one in which subjects could answer freely, while the researcher would be prepared to find quantifiable items in the response. To a great extent, the Draw-A-Scientist Test
is such a tool. In developing the test, the researchers defined a set of indicators that they thought would be likely responses. They were then able to analyze the responses to an open-ended question in a quantitative manner. Since the indicators selected for this instrument were derived completely from Mead and Metraux (1956), it is clear that the earlier study provided a means to an improved research tool.

To strengthen the test even more, the use of interviews or other qualitative research could also be included, if only for a subset of the subject pool. Such a measure would allow subjects to elaborate on their answers, and would allow researchers to probe more deeply into the responses given by subjects, perhaps eliciting more details about deeply held notions. Qualitative measures such as interviews would also be useful in the formative stages of developing the research tool, as investigators could use the results of these preliminary data collection tools to formulate a list of indicators that seems typical of the respondents.

The first step in inventing a new tool is to focus the investigation on a certain set of indicators or statements and to devise a coding strategy to count those indicators. The second step is to devise an open-ended question that will allow subjects the freedom to answer in whatever format seems appropriate to them, elaborating as they see fit. The
question must be framed in such a way that the researcher is able to identify the indicators easily and quickly.

While the Draw-A-Scientist Test meets many of these requirements, there are risks in asking subjects to produce a drawing as a response to a question. For example, when asked to draw a scientist, a subject is likely only to draw one scientist, even if that subject might think of a scientist as having a variety of looks. This could lead evaluators to false conclusions about the subject's image of the gender of a scientist. Secondly, researchers analyzing drawings would need some training in analyzing depictions of generic people in order to isolate distinctions between drawings of an "average person" and those of a scientist.

It appears that an appropriate tool for conducting further study into the stereotype of the scientist would be to alter the structure of the Draw-A-Scientist test from a drawing test to a written or oral model. A further development beyond asking subjects solely to prepare a written or oral answer to a question would be to design an interview that could be delivered to a subset of the population. This interview would be conducted to elicit elaborative responses from subjects, adding to the researcher's base of information about how committed the subjects are to the indicators they mention in their initial response to the questions.
CHAPTER III
RECOMMENDED STRATEGIES FOR BRINGING ABOUT CHANGES IN CHILDREN'S VIEWS OF SCIENCE AND SCIENTISTS

Recommendations from Previous Research

In each of the studies cited in Chapter II, the authors made recommendations for strategies to be used by educators, the media, and the scientific community for changing the public perception of scientists. Mead and Metraux (1956) followed their discussion of high school students' views of scientists with a list of recommendations, many of which were echoed by later researchers:

1. Encourage more participation and less passive watching in the classroom...
2. Begin in the kindergarten and elementary grades to open children's eyes to the wonder and delight in the natural world...
3. Teach mathematical principles much earlier...
4. Emphasize group projects; let the students have an opportunity to see science as team work...
5. Emphasize the need for the teacher who enjoys and is proficient in science subjects, irrespective of that teacher's sex; this would mean that good women teachers could be enlisted instead of depending on men...
6. Change the teaching and counseling emphasis in schools which now discourages girls who are interested in science...
7. De-emphasize individual representatives of science...
8. Avoid talking about the scientist, science, and the scientific method [as general terms].
All of these strategies are aimed at creating a more human image of the scientist, an image that would allow for diversity and individuality. Brush (1979) concurred that a contributor to the negative stereotype of the scientist may be that he appears cool and purely rational, and she recommended "actions on the part of the professor which demonstrate his warmth, sensitivity, and sense of humor" (p. 240). Mead and Metraux (1956) argued that by giving children a more realistic science experience in their classrooms, they will be more likely to consider science a field in which they have an aptitude, an interest, and an opportunity. Horwood (1988) echoed this sentiment in his call for teachers to move away from explaining concepts to their students: "A teacher working within this emphasis would pay a lot of attention to the students' intellectual activity as explainers" (p. 47).

To increase the perception of science as a field that is as equally accessible to women as to men, Erb (1981) noted from his research that the thirteenth year is pivotal, and he supported "arguments for career education interventions during seventh and eighth grades in middle level schools" (p. 116). He also stated that interventions at an earlier age might improve images about females in science.
Gardner, Mason, and Matyas (1989) provided an update to the recommendations given by Mead and Metraux (1956), making many similar suggestions specifically directed at teachers. They called on teachers to maintain a balanced attitude, expecting and encouraging the same performance from male and female students. They suggested frequent use of hands-on activities for both boys and girls, including, for example, asking female students to set up electronics and audio-visual equipment. They discussed the benefits of small group work and the use of gender-neutral language. They also emphasized the importance of making curriculum material relate to life experiences and to career information in both a formal and informal manner. Finally, they called for female or minority guest speakers to be used whenever possible to help students see that many scientists do not fit the stereotype.

Begley et al. (1990) quoted Nobel prize winning physicist Leon Lederman, who accused schools of taking "naturally curious, natural scientists and [beating] that curiosity right out of them," and Harvard professor Gerald Holton, who said, "There's no mystery about how to teach science." The authors of the article went on to say that "There are only two problems in science education: what is taught and how. Educators get into trouble when they forget that the best way for students to learn science is to have them do science" (p. 55).
Mason, Kahle, and Gardner (1989) also discussed the effects of teacher behavior on student attitudes and achievement levels. In their interviews with students, the authors found that students were more likely to enjoy science when they participated in hands-on activities that had an open-ended format. This format lends itself naturally to group work, which is a method that has been found to be an extremely useful learning style for both boys and girls.

Carey et al. (1989) emphasized that "it is vital that the entire curriculum provide opportunities for students to reflect on the process of constructing scientific knowledge.... Students should be asked to reflect on a problem and to examine the motivation for each step of the process of inquiry" (p. 23). Hodson (1988) also looked to the formal science curriculum for changes, calling for teacher training in the philosophy of science and for a focus on science as "a body of established knowledge" (p. 21), not to be separated and isolated from process skills.

However realistic the recommendations seem, implementation is a large undertaking. Beardslee and O'Dowd (1961) speculated that the stereotype discussed here is one which is "imbedded in a system of other stereotypes with which people, even highly educated people, structure their social world" (p. 1000).
With respect to the media and entertainment industry, Maugh (1978) recommended that agencies such as the American Association for the Advancement of Science should "protest to movie studios and networks when inaccuracies appear and when scientists are portrayed in a denigrating fashion" (p. 37). This strategy is one, he noted, that has been successfully used by other minority groups. His sentiment was expressed earlier by Mead and Metraux (1956), who called for an emphasis in the mass media "on the real, human results of science--on the way in which scientists today work in groups, share common problems, and are neither 'cogs in a machine' nor 'lonely and isolated'" (Mead and Metraux, 1956, p. 389).

**Conceptual Change Theory as a Philosophical Basis**

Each of the researchers making recommendations for changing the popular image of scientists called for a strategy that employs, to some extent, the principles of conceptual change theory as described by Kenneth Strike and George Posner (1985). Their theory argues that people come to many experiences with preconceptions about the characteristics of the experience. Unless their preconceptions are challenged or are shown to be inconsistent with personal experience, people will continue to operate on the basis of their preconceptions. The deep roots of the stereotype of a scientist can be understood easily in this context. If students are regularly presented with examples
of science and scientists that are not inconsistent with the stereotype they bring to the experience, they will have no reason to change their image. Strike and Posner outlined four conditions that are necessary for conceptual change to occur. Each of them is strongly connected to recommendations made in the present discussion.

1. There must be dissatisfaction with existing conceptions. Scientists and students are unlikely to make major conceptual changes until they believe that less radical changes will not work.

2. A new conception must be minimally understood. The individual must be able to grasp how experience can be structured by a new conception sufficiently to explore the possibilities inherent in it.

3. A new conception must appear initially plausible. Any new conception adopted must at least appear to have the capacity to solve the problems generated by its predecessors, and to fit with other knowledge, experience, and help. Otherwise it will not appear a plausible choice.

4. A new conception should suggest the possibility of a fruitful research program. It should have the potential to be extended, to open up new areas of inquiry and to have technological and/or explanatory power. (Strike and Posner, 1985, p. 216)

When Mead and Metraux (1956) made their recommendations for changes in classrooms and the media, they called for changes that would give children opportunities to see real science, both by participation in real scientific research, and through contact with science teachers and professionals who are proficient and enthusiastic about science. They
argued against emphasizing individual representatives of science because the uniqueness of these few outstanding people "convinces most students that they can never be scientists..." (Mead and Metraux, 1956, p. 389). If teachers can provide students with an environment that challenges their conception that scientists are only those few brilliant geniuses who make startling discoveries, they will be more likely to alter the stereotype, or to find the idea of women, minorities, and "normal" people to be plausible.

Gardner, Mason, and Matyas (1989) and Mason, Kahle, and Gardner (1989) made similar recommendations for providing challenges to the conception that scientists can only be men. By purposefully using gender-neutral language and incorporating real experiences and career-related information into science lessons, they argued, teachers can provide evidence to make non-stereotyped images of scientists more plausible. The specific suggestion by Gardner, Mason, and Matyas to bring female or minority guest speakers into science classes would provide students with specific individual examples of people who do not fit the general preconceptions of who can be a scientist.

Beardslee and O'Dowd (1951) and Maugh (1978) commented on the level to which the stereotype of scientists has permeated society. When Maugh suggested that scientific organizations form lobbies to counter misconceptions
presented by the media, he was calling for a challenge to society's conceptions and for the introduction of a new theory that can be understood by people as more consistent with reality.

Science-By-Mail™ as it Fits with the Recommendations

In the context of the above recommendations, the Science-By-Mail™ program can be seen as an intervention that might address some of the challenges facing the science education community. In its overall design and philosophy, the program seeks to present an image of science that directly challenges the stereotype as it has been presented above.

In a general sense, the program seeks to create a more human view of science and scientists, as recommended throughout the Mead and Metraux (1956) work. This objective is accomplished in a variety of ways, including the encouragement of hands-on problem solving, group work, contact with a real scientist who, in most cases, does not match the stereotype, and the use of activities that are related to real-life situations to which children can relate. Also, drawings and illustrations included in the Science-By-Mail™ materials counter the stereotype. These challenges to the stereotype are intended to be pervasive, supporting the ideas of conceptual change theory.
**Hands-on Approach.**

Science-By-Mail™ is in essence a hands-on program. Participants in the program receive materials that enable them to engage in a series of hands-on activities. For instance, an activity kit focusing on the science of being a detective includes fingerprint powder and a hand lens. Another kit, which teaches students how to make ice cream, includes a thermometer and insulating materials. Student learning therefore comes as a direct result of experience, rather than through reading or listening. The hands-on approach also allows students to direct their own learning and set their own pace. Also, in that they are labelled as actually "doing" science, students in the program are led to see science as approachable. Since these are enrichment activities, they do not necessarily reflect some of the important aspects of science, such as sustained exploration or deepening levels of explanation of scientific principles and content. However, the activities in Science-By-Mail™ kits do make strong connections between everyday life and some interesting aspects of science that engage students.

**Group Work.**

Science-By-Mail™ is designed so that students participate in small groups of up to four members. This group size has been shown to maximize the benefit that all members gain from the experience:
Have learners work in groups of three or four when they first attempt a new kind of task. By working in a group, learners can pool their resources and diffuse frustration, thus maintaining a sense of competence. (Perkins, 1988, p. 119).

As a group, the members are given a challenge to solve. They can work together on each activity or divide the activities among themselves. Each member brings to the challenge her or his own perceptions, ideas, and interpretations. The collective set of ideas can help each member to build an individual knowledge base, and to use the ideas of other students in the construction of ideas about science that may be different than the student's initial concepts.

Association with a Real Scientist.

Each group of Science-By-Mail™ members is assigned to correspond with a practicing scientist, who also receives the challenge packets. One of the scientist's responsibilities as a participant in the program is to send the students an introductory letter with a self-description and a profile of her or his work. This letter is seen as one of the first components of the program to challenge student stereotypes of scientists. The scientists receive suggestions from the Science-By-Mail™ staff for how to address some of the aspects of the stereotype through this letter. Introductory letters are usually informal, chatty, and autobiographical. Often, the scientists will describe anecdotes from their daily lives, their pets, their hobbies, or their families.
Sometimes they describe their education or preparation for their jobs, and frequently they ask the children to write back with similar information. Some scientists even send photographs of themselves, and ask children to do the same. The vast majority of scientists who volunteer to correspond with children through this program do not match the stereotype as described above, and this inconsistency with the stereotype comes through in the introductory letters. The informal pen-pal relationship is intended to put students at ease. As students get to know "their" scientist, the scientist becomes less of an icon and more of a real person with individualized characteristics, most of which do not match the image that the students have in their own minds about what a scientist "should be." Although the stereotype pegs scientists as old, male, and working in a laboratory setting, slightly more than half of the scientists in the program (56%) during 1988-1989 were women. Many of the scientist pen-pals are graduate students or people in the age range of 25 to 35. Many scientists have families, spouses, or young children. One Scientist-By-Mail even gave birth during the 1988-1989 Science-By-Mail® program, and wrote a letter to her pen-pals from the hospital announcing the new arrival.

Real-life Activities.

Each of the challenge packets used in Science-By-Mail® is organized around a fictional story that deals with a topic
or issue appropriate for and interesting to children. Topics have included the science of ice cream, the science of being a detective, cinematic special effects, magic, time machines, and more. By creating activities around topics that are appealing to children, Science-By-Mail® seeks to emphasize that science is something that anyone can do, and to create a sense that science is a part of daily life, not something that only happens in a laboratory.

Use of Illustrations.

Consistent with the overriding philosophy of the program, the illustrations that accompany the story include depictions of characters from a variety of ages, both genders, and many types of physical appearance. Often, the main characters in the activity books are female. Physically handicapped people, the aged, and members of several races have also been included. The illustrations that accompany activities usually show the use of basic equipment that can be readily found at home or in the classroom, further supporting the idea that science is approachable and can be done by anyone.

Critical Thinking Skills.

Infused into the text of the various Science-By-Mail® activity books are lessons that develop the use of critical
thinking skills. In particular, causal reasoning, accuracy of observation, problem-solving, and decision-making are incorporated into the hands-on activities. Although these skills are introduced as related to discrete activities, the text includes commentary that encourages students to use these thinking skills in a more general way. For instance, an activity that focuses on observing the stars instructs students to think about the consistency of their measurements not only for this activity, but at other times when they are making any kind of observations.

As is clear from the recommendations listed above, the underlying issue for researchers who investigated the stereotype of the scientist was that the scientist should appear real and human, and that science should be something that children can experience in a full sense. Through its design and structure, Science-By-Mail seeks to accomplish those goals. This thesis represents an effort toward the evaluation of the program's ability to change children's beliefs about what scientists look like.
CHAPTER IV
DESIGN OF STUDY

Subject Profile

The study described here involves a pretest and posttest questionnaire sent to the students involved in the Science-By-Mail program during the 1989-1990 school year. The focus of the study is to determine whether participation in the program affects students' image of what a scientist looks like. During the 1989-1990 school year, there were 1,534 memberships in the Science-By-Mail program, of which 379 were individual children. The remaining 1,255 memberships were group memberships, with an average of 2.5 members in each group. Total estimated participation in the program, then, was 3,517 students.

All program participants received questionnaires prior to the delivery of the first activity packet. The questionnaire asked students to answer five questions related to their image of a scientist, and to return the completed form (See Appendix). Following delivery of the third activity packet, a posttest with identical questions was mailed to the same group. Subjects were again asked to complete and return the form.
Several options for analyzing the data were considered. One option called for analyzing all pretests and posttests, and determining general trends across the entire population of respondents. While this method would have allowed for a larger subject pool in the analyses, it was felt that such a strategy would not point out individual shifts in conceptions. For this reason, it was decided that statistical analyses would be performed on a set of matched pairs. All of the posttests that had been received were matched with the pretests from the same students to isolate a set of subjects who had returned both the pretests and posttests.

A total of 217 matched pairs was assembled; and this set became the subject pool for the present study. These pairs represent 6% of the participant pool and are representative in terms of age and gender of the program population. However, they were not a random sample and may represent students who were more involved with the program. The generality of the findings of the present study could be tested by analysis of the data returned by all respondents, including tests to determine whether there is an overall change in the number of indicators described between the pretest and the posttest.
Evaluation and Scoring

Subjects' responses were evaluated to determine whether their image of a scientist changed as a result of participation in the Science-By-Mail™ program. More specifically, the results were evaluated to determine the degree to which subjects believed in the stereotypical image of the scientist both before and after participating in the program. Evidence for a stereotypic image was defined as a statement that included any of eight pre-determined exclusive indicators, or a description that defined a scientist in terms of other exclusive conditions. The eight pre-determined indicators were:

- Lab coat or specific laboratory clothing, including "white clothes"
- Eyeglasses
- Protective gloves
- Unusual hair (white hair, bushy hair)
- Male (stated specifically, or listed as having facial hair)
- Old (or described as having gray hair)
- Facial hair
- Brain or nerd-type

This list was constructed on the basis of previous research into the stereotypical image as described above.

In addition to evaluating subjects' responses for exclusive descriptors, pretests and posttests were analyzed to determine the number of respondents who described
scientists using inclusive descriptions, exemplified by a statement such as "A scientist can look like anybody." These responses were counted as being significantly different from the stereotyped responses, and were, in fact, considered to be direct contradictions to the stereotyped responses.

Finally, responses were evaluated to determine what factors may have led to the change in perception. Two factors in particular, the gender of the scientist and the number of letters exchanged between the student and the scientist, were thought to be strongly correlated with this change.

Of the five questions included in the pre and posttests, this study focuses only on question #3, "What does a scientist look like?" This question was chosen as central to the study because it was the most likely to elicit responses that would be related to the stereotypic image described above. The other items in the questionnaire were more closely related to subjects' epistemologies regarding the field of science. Questions such as "What kinds of things does a scientist do?" "What kinds of things does a scientist know?" and "How does a person become a scientist?" were related to student images of how scientific knowledge is constructed, used, and developed. The present study will be strengthened by a future analysis of subject responses to the other questions that were included on the pretest and
posttest. Student concepts of epistemology are certainly of value, but earlier research gave little direction in methods for analyzing such responses, which tended to be more ambiguous and less conducive to scoring. In the present thesis, analysis was limited to reading students' written responses. Student ideas about scientific knowledge and its acquisition may be better probed with an investigative tool that allows subjects to provide more elaborative answers, and for researchers to seek clarification and follow up on subject responses.

**Coding Strategy**

For the evaluation, subjects were identified by numbers. Each subject was described by age, gender, gender of pen-pal scientist, and number of letters received. These descriptors formed the set of independent variables. Coding of student responses was a straightforward exercise, consisting of determining whether the subject's response confirmed any of eight pre-determined stereotypical indicators on question 3. Reliability of the coding was performed informally, by two other individuals who reviewed subsets of the questionnaires and coded the responses. Their findings were shown to match those of this researcher, and the coding strategy was felt to be reliable.
A description that included any of the eight indicators led to a score of "1" in the appropriate column on the data sheet. If a subject did not describe the indicator, a score of "0" was recorded in that column for that subject. A ninth column was included for any other exclusive indicators that the subject described. Scores in this column were recorded as the number of other exclusive indicators given, and ranged from 0 to 2. Subjects were then scored on the basis of whether or not they provided an inclusive response in their description of a scientist. An example of an inclusive response, as stated above, would be "A scientist can look like anybody." This column was scored on a "0" or "1" basis, with "1" given to respondents who gave an inclusive description.

After the data had been entered, three calculations were performed, the results of which were added as new columns. These columns included a total count of pretest exclusive indicators for each subject; a total count of posttest exclusive indicators for each subject; and a final column which showed the difference between the two exclusive totals. Descriptions of inclusive indicators, as in "a scientist can look like anyone," were listed as either "1" or "0," indicating whether or not the subject had made any inclusive responses.
Specific Hypotheses

Data from all of these columns were used in performing a series of statistical analyses to evaluate a series of hypotheses about subjects' stereotypical image of scientists. These hypotheses were:

1. That the negative stereotype of scientists presented in the literature review still exists and would be found at the time of the pretest in this sample of students.

2. That after participation in the Science-By-Mail™ program, students of both genders and all ages would describe scientists with more inclusive attributes and fewer exclusive indicators.

3. That the effect of the intervention might be greater for those who corresponded more frequently with their scientists. This hypothesis was based on the premise that the more contact students had with an individual who did not match the stereotype, the more likely they would be to construct an inclusive image of scientists in general.

4. That girls would be less likely than boys to describe scientists as male, both at the pretest and posttest, and students who corresponded with female scientists would be less likely to describe scientists as male than students who corresponded with a male pen-pal.
Question 1: Does a Negative Stereotype of Scientists Exist?

Before analyzing the possible changes to, or factors affecting, the subjects' attitudes toward scientists, it was critical to establish a measure of the subjects' preliminary images of scientists. One reason for asking this question was to determine the "starting point" images of the subjects of this study. A second reason for this question was to place the attitudes and responses of these subjects in a context with the findings of previous research into children's attitudes toward scientists. My first hypothesis was that a negative stereotype of scientists still exists.

An analysis of the pretest responses showed that there was some confirmation that a negative stereotype of scientists existed among the participants of the Science-By-Mail™ program. The pretest data showed that 53% of the subjects, or 116 of 217 subjects, responded to the question "What does a scientist look like?" with a description that included at least one of the exclusive indicators described above. Of the 53% of subjects who described at least one indicator, the mean number of indicators listed was 2.2 indicators. The results of the Science-By-Mail™ test were somewhat consistent with Chambers'(1983) findings on the
Draw-A-Scientist Test, especially in the kind of indicators that were included in subjects' description. The Draw-A-Scientist Test did, however, result in a higher mean number of indicators per subject than the Science-By-Mail test. In the Chambers study, third graders described an average of 2.4 indicators; fourth graders reported an average of 3.1; and fifth graders described an average of 3.3 exclusive indicators in describing scientists. In contrast, in my study of 7 to 14 year olds, the mean number of exclusive indicators on the pretest was 1.2 per subject.

The difference in the results of these two tests may be related to the difference in the testing instruments, since drawings (as in the Chambers study) may exhibit more elaboration, and hence more indicators. The most common indicator described (97 of 217, or 44.7%) was that a scientist wears a lab coat. In addition to the 8 indicators coded, there were also some other exclusive descriptions provided by students, including:

- Looks like a doctor
- Looks like Albert Einstein
- Wears a name tag/identification badge
- Wears a gas mask
- Works in a lab
- Wears a specific types of shoes (usually black)
- Uses scientific instruments (microscope, beakers, etc.)
- Is of a specific height or size (short, very tall)
- Reference or drawing of a light bulb caption
- Has a book in his hand
- Looks regal
- Specific facial features (long nose, small eyes)
- Looks crazy
- Wears a tie
- Has a pad in his pocket
- Works with explosions

The frequencies for the coded exclusive indicators are listed in Table 5.1, below.

Table 5.1
Frequencies of Exclusive Indicators on the Pretest

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Number of Subjects Listing Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Coat</td>
<td>97</td>
</tr>
<tr>
<td>Glasses</td>
<td>42</td>
</tr>
<tr>
<td>Male</td>
<td>26</td>
</tr>
<tr>
<td>Unusual Hair</td>
<td>16</td>
</tr>
<tr>
<td>Gloves</td>
<td>12</td>
</tr>
<tr>
<td>Old</td>
<td>10</td>
</tr>
<tr>
<td>Brain/Nerd</td>
<td>10</td>
</tr>
<tr>
<td>Facial Hair</td>
<td>5</td>
</tr>
<tr>
<td>Other Exclusive Indicator</td>
<td>32</td>
</tr>
</tbody>
</table>

Gender Differences in Pretest Results.

Following the analysis of the general population, the responses were divided into subgroups and re-analyzed to determine whether there was any difference in the number of indicators described by students of different genders. For boys, the mean number of pretest indicators was 1.28. For girls, the mean number of pretest indicators was 1.02.
To test whether there was a gender difference in the number of pretest exclusive indicators given, I used a Mann-Whitney nonparametric analysis. For this and other analyses I used nonparametric tests rather than parametric tests because I could only confidently assume ordinal measurement had been achieved for the variable being tested. Given the large sample size, however, this test is fairly powerful and a good alternative to the t-test. The Mann-Whitney nonparametric analysis comparing girls' and boys' overall pretest responses resulted in a z value (corrected for ties) of .992. A z score of 1.96 or greater would be needed to be significant at the .05 level. The results that were found here did not support the hypothesis that there would be a gender difference.

Another analysis related to gender was performed to test whether there was a difference in describing scientists as male. This tested one aspect of my fourth hypothesis that boys would list maleness as an exclusive indicator more often than girls. In the pretest, 16 of 109 boys (15%) listed maleness as an exclusive indicator, while 10 of 108 girls (9%) described scientists as male. A Mann-Whitney test of these data resulted in a z-value of 1.226, which was not sufficient to show significance. Thus, this feature of my fourth hypothesis was not confirmed.
With regard to inclusive responses, the pretest results indicated that 126 subjects (58%) responded with an inclusive description of a scientist. Of these subjects, 66 of 108 girls (61%) used an inclusive description and 60 of 109 boys (55%) described a scientist using inclusive language. To determine whether the differences in these responses indicated a significance related to gender, a Mann-Whitney test was performed, which produced a z value of 1.178. This was not found to be statistically significant.

Most subjects fell into one of two categories, either listing exclusive indicators only or inclusive indicators only. However, there were 27 students who described scientists with both exclusive and inclusive descriptors. Several of the subjects in this group gave responses such as "He can look like anyone." or "A scientist looks like anyone in a white coat." (Emphasis added to show the exclusive portion of the sample statements). The number of students giving such mixed responses decreased to nine on the posttest. Of those nine students, four reported that "A scientist can be anyone who wears a white coat." Two continued to describe scientists as male, two described the scientist as wearing glasses, and one described a scientist as looking like a doctor.
Age Differences in Pretest Results.

To determine whether the age of the subject was related to the response, the population was analyzed according to three age categories:

1: age 7-9
2: age 10 and 11
3: age 12-14

For the youngest group, the mean number of indicators was .95 for the middle group, 1.28, and for the oldest group, 1.15. A Kruskal-Wallis 3-group test was performed to determine whether the difference among these results was significant. In applying this test to the three age groups, a resulting value of 5.99 or greater would be needed to indicate significance at .05. Here, this test resulted in a value of 2.718, clearly showing no significant difference in pretest results for students of different ages.

Question 2: Is There a Pretest to Posttest Change in Students' Image of the Scientist?

Two comparisons were made to determine whether subjects exhibited a change in their description of the scientist. The first test compared the difference in the number of exclusive indicators listed on the pretests with the number
of exclusive indicators on the posttests. The second test compared the number of inclusive responses on the pretests with the number of inclusive responses on the posttests. These analyses test my second hypothesis that the Science-By-Mail™ intervention would lead to a change in students' images of scientists.

Overall, there was evidence of a change in pre- to posttest responses. For the total population, the mean number of pretest exclusive indicators was 1.151, compared to a mean posttest result of .29. Overall, the percent of children giving any exclusive indicators decreased from 53% to 18%. The Wilcoxon signed-rank test was performed on each set of variables. For a large sample such as this, a z-value of greater than 2.58 was required for significance at the 1% level and a level of greater than 1.96 is required for significance at the 5% level in a normal distribution (Spence et al. 1976). A comparison of the overall population's pretest to posttest exclusive responses resulted in a z-value (adjusted for ties) of 7.851 on the Wilcoxon test, which is highly significant. Specific results for changes in each exclusive indicator from pretest to posttest are shown in Table 5.2.
Table 5.2
Frequencies of Exclusive Indicators on Pretest and Posttest

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Pretest Number of Subjects Listing Indicator</th>
<th>Posttest Number of Subjects Listing Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Coat</td>
<td>97</td>
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</tr>
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<td>Facial Hair</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Other Exclusive Indicator</td>
<td>32</td>
<td>9</td>
</tr>
</tbody>
</table>

In addition to the significant change in the number of exclusive indicators, a positive shift was also found in the number of inclusive indicators reported on the pretests and posttests. The number of such responses changed from 126 on the pretest to 184 on the posttest, representing a move from 58% to 84%. A Wilcoxon analysis of these data showed a z-value of 6.835, which again is highly significant.
Question 3: If There is a Change, What Factors Seem Related to This Change?

After determining that there was, indeed, a significant change in the number of exclusive and inclusive indicators given on pretests and posttests, comparisons and analyses were made to determine whether any variable was a likely predictor of such a change. A series of non-parametric tests was used to analyze the results. Four factors were investigated, two of which I predicted would be related to a change in student's images. The two factors that were predicted to have the greatest potential of influencing student images were the number of correspondences and the gender of the pen-pal scientist. Both of these factors were related to the student's contact with a scientist who did not match the stereotypic image.

Number of Correspondences.

One set of comparisons related to the number of letters that were exchanged between the subjects and their pen-pal scientists. Since the recommended number of letters was three, the group was sorted into students who had received considerably fewer than three letters (0-1 letters), students who had received approximately 3 letters (2-4), and those who received considerably more than 3 letters (5 or more).
Comparisons were made on the basis of change in number of indicators between pretest and posttest. This evaluation tested my third hypothesis, that the amount of contact with a scientist would be related to a greater likelihood of changing the stereotype.

For those who received one or no letters from their scientists (n = 46), the number of exclusive indicators decreased from a pretest total of 53 (mean = 1.15) to a posttest total of 6 (mean = .13). Students who received 2-4 letters (n = 141) indicated a decrease in exclusive indicators from a pretest total of 163 (mean = 1.16) to a posttest total of 46 (mean = .33). Finally, students who received five or more letters (n = 31) showed a decrease in exclusive indicators from a pretest total of 35 (mean = 1.13) to a posttest total of 11 (mean = .355). A Kruskal-Wallis test was performed to determine whether there was any likelihood that the number of correspondences was related to pre-to-post change. In applying this test to 3 groups, a resulting value of 5.99 or greater would be needed to achieve a significant difference at the .05 level. The resulting value in this analysis was .242, which is not sufficient to isolate the number of correspondences as a significant predictor of change.

Further analysis of the responses showed that there were 26 subjects who reported that they received no letters from
their scientist. This subset of students was isolated and their pretest to posttest change was compared with the larger population. For these 26 subjects, the mean number of pretest exclusive indicators reported was 1.19. The posttest mean for exclusive indicators was .19. A Mann-Whitney test comparing these values with the larger population produced a z-value of .27, which is not sufficient to show significance (a z-value of 1.96 or greater would be needed). Thus, there was no support for my third hypothesis.

Gender of Scientist.

Another factor I predicted to be important was the gender of the scientist. Specifically, I expected to find that subjects who corresponded with female scientists would be less likely than those who corresponded with males to describe scientists as male following the intervention. Out of 217 subjects, 16 did not specify the gender of their pen­pal scientist, so this test was performed using a population of 201. For subjects who corresponded with male scientists (n = 101), the number of pretest exclusive indicators decreased from 111 (mean = 1.1) to a posttest level of 27 (mean = .27). For subjects who corresponded with female scientists (n = 100), the number of pretest exclusive indicators decreased from 114 (mean = 1.14) to a posttest level of 31 (mean = .31). Again, a Mann-Whitney test was performed to determine whether there was any significance in
the changes from pretest to posttest for students who corresponded with male or female scientists.

The levels of significance required in this analysis are the same as those required in the previous test. A z-value of at least 1.96 is required for significance at the 5% level, and 2.58 for significance at the 1% level. The z-value of .411 which resulted here is not sufficient to indicate a significant difference in results between students who corresponded with male and female scientists. This analysis does not support the hypothesis that correspondence with a female scientist is linked to a greater likelihood to change the image of a scientist.

Gender of Subject.

For various sub-samples of the population, equally significant changes were found. Boys (n = 111) exhibited a decrease from 142 total pretest indicators (mean = 1.28) to 30 total posttest indicators (mean = .27). Girls (n = 107) decreased from 109 pretest indicators (mean = 1.02) to 33 total posttest indicators (mean = .31). A Mann-Whitney non-parametric analysis was performed with these data, comparing the changes in scores by gender. Table 5.3 shows the frequency of different exclusive indicators by gender of subject.
In a Mann-Whitney test with the population in each sample greater than 8, the z-value must be greater than 1.96 for significance at the 5% level, and greater than 2.58 for significance at the 1% level. In this case, the z-value of 1.5 is less than 1.96, which is not sufficient to show significance at the .05 level. This analysis does not provide evidence that gender of the subject is a significant predictor of change between pretest and posttest, thus supporting my hypothesis that a change in stereotype would occur regardless of the gender of the subject.

Table 5.3
Frequencies of Exclusive Responses by Gender

<table>
<thead>
<tr>
<th>Indicator</th>
<th>BOYS</th>
<th></th>
<th>GIRLS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>Lab Coat</td>
<td>58</td>
<td>15</td>
<td>46</td>
<td>17</td>
</tr>
<tr>
<td>Glasses</td>
<td>25</td>
<td>3</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Male</td>
<td>16</td>
<td>6</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Unusual Hair</td>
<td>11</td>
<td>1</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Glasses</td>
<td>6</td>
<td>0</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Old</td>
<td>8</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
<td>4</td>
<td>18</td>
<td>5</td>
</tr>
</tbody>
</table>

83
Another set of comparisons was made to determine whether the age of the subject was related to the pretest to posttest change. Among the youngest subjects, ages 7-9 (n = 56), the mean number of pretest exclusive indicators decreased from 53 (mean = .95) to a posttest level of 20 (mean = .36). For subjects ages 10 and 11 (n = 127), the number of pretest exclusive indicators decreased from 163 (mean = 1.28) to a posttest total of 32 (mean = .252). For subjects ages 12 and older (n = 34), the total number of exclusive indicators decreased from 35 (mean = 1.029) to a posttest total of 11 (mean = .324). The greatest change in the number of exclusive indicators was found to be in the 10 to 11 year old range. To investigate these differences, a Kruskal-Wallis test was performed for the three age groups.

To achieve significance at the .05 level, the resulting value in this analysis needed to be greater than 5.99. This test resulted in a value of only 2.17, indicating that there was no evidence of a significant effect in the change from pretest to posttest based on the age of the subject. These results are consistent with my hypothesis that the change in student image of the scientist would occur across all age groups.
An original intent in this research project was to investigate the relationship between student images of scientists and the occupations of those students' parents. The purpose of such an investigation was to determine whether children whose parents were employed in scientific fields would be less likely to use a stereotyped image to describe scientists than students whose parents were not involved in scientific fields. Data for this analysis were to be collected from student responses to the questions "What kind of job does your mother do?" and "What kind of job does your father do?" However, many of the student responses to these questions were not interpretable. For instance, several subjects answered "My mother/father works at XYZ Corporation." It was impossible to determine from such a response whether the parent was a janitor, a chief executive, or a sales associate, much less whether the parent's occupation focused on science. In a future study, this question would need to be re-designed to elicit a more specific response, whether by asking directly "Is your mother or father a scientist?" or by asking students to have their parents complete part of the questionnaire.

Summary

Of the four hypotheses advanced in this thesis, two were supported by the analyses discussed in Chapter V. The first hypothesis was that the negative stereotype of scientists as
presented by the literature would be found among the participants in the Science-By-Mail program at the time of the pretest. This hypothesis was borne out by the data, although not at such high levels as were reported by other researchers in previous studies.

The second hypothesis was that following participation in the Science-By-Mail program, a shift in student images of scientists would occur in the form of students' describing scientists with fewer exclusive indicators. From the data presented here, it is evident that this shift did occur. Furthermore, as the hypothesis proposed, the shift was found to have occurred among students of both genders and all age groups.

The third hypothesis was that there might be a greater effect shown for students who had corresponded with their scientists on a frequent basis. This hypothesis was not supported by the data, and in fact, it was shown that students who received no correspondence from their scientist at all were equally likely to experience a shift in their perception of scientists as those students who corresponded with their scientist several times. This finding raises the question of whether any correspondence is necessary to alter student perceptions of scientists, or whether the messages about scientists presented through the activity packets were sufficient to bring about a shift.
The fourth hypothesis was that there would be a gender difference in the likelihood of describing scientists as male on both the pretest and the posttest. Specifically, it was advanced that girls would be more likely than boys to describe scientists as female, and that students who corresponded with a female scientist would be less likely to describe scientists as male on the posttest. The results showed that there was no significant difference between boys and girls in their descriptions of scientists as male or female on the pretest. Further, it was found that the gender of the pen-pal scientist was not significantly linked to a difference in the gender description of scientists on the posttest.
The data show that there was a pretest to posttest shift away from the stereotyped image of the scientist. Based on the analysis of responses to Questionnaire item 3, there seems to be strong support for the conclusion that participation in the Science-By-Mail™ program was related to a positive change in students' perceptions of what scientists look like.

Comments on the Pretest Results with Respect to Earlier Research

In large part, the data presented here support earlier findings from previous research. There are many similarities between the findings of the pretest component of this study and those of earlier research. In particular, the specific indicators listed by subjects in their descriptions of scientists are quite similar to those found by other researchers. A feature that is worth noting from the present study, however, is the relatively low average number of pretest indicators listed by Science-By-Mail™ participants. Of the total population included in this study, slightly more than half (53%) used some type of exclusive determination in their description of a scientist. Chambers (1983) found that
students of similar age (4th and 5th grades) included more than 3 exclusive indicators in their drawings, while the subjects in the Science-By-Mail™ study listed an average of only 1.28 such indicators. There are several possible explanations for this difference, some related to the investigative tool and some related to the population.

First, with regard to the testing instrument, there is a wide allowance for inclusive responses, and for students to elaborate on their descriptions. Where a drawing limits the subject to describing only one example of a scientist, a written format such as that used here allows students to describe a scientist as having many possible traits. While it might have been possible to give such an open description in response to the other instruments, the results presented by those researchers do not indicate such a trend.

An additional note is that it is unclear what percentage of respondents in the previous studies gave responses that were not consistent with the stereotyped image. The researchers discussed their data only to the extent that they confirmed the stereotype.

Further, this test did not include any multiple choice items. Such formats, as has been proposed above, might have the tendency of leading subjects to make more stereotyped responses than they might have if they had been given the
opportunity to provide only their own thoughts without prompts.

The characteristics of the population involved in this study may be slightly different from the subjects in some of the previous studies. Although Science-By-Mail™ was designed to be engaging as an extracurricular activity, it is marketed as an enrichment program in science, and may be seen as a more academic choice than, for instance, intramural sports. The type of student who chooses to participate in an activity like Science-By-Mail™ may already have some ideas about science that are more sophisticated than students who do not have an interest in pursuing academically oriented extracurricular activities. It is difficult to determine whether this conjecture is accurate, since the subjects in other studies cited here were also self-selected, specifically, the Fort and Varney (1989) and Erb (1981) investigations. In addition, many of the participants in the Science-By-Mail™ program were enrolled by teachers who chose, without the input of their students, to incorporate the program into their regular science curricula.

Another note related to this particular subset of the Science-By-Mail™ population is that this study was conducted using responses from 6% of the overall population in the program during the year of the test. Since it was determined that matched-pair tests would be used for the statistical
analyses, the subject pool for this study was composed of those students who returned both a completed pretest and a completed posttest instrument. Although these students are representative of the larger population in terms of age, gender, and geographic distribution, they may have some different traits from the larger population, specifically their propensity to return the questionnaires. This could raise the suggestion that perhaps these students were more invested in the program than the students who did not choose to respond to the posttest. Perhaps, then, the non-responding students were also less likely to experience change in their view of scientists.

It is also possible that there is a trend in society away from the stereotype image of scientists, and that the trend is a recent development which has been evolving since some of the studies cited here. Regardless of the reason, it is encouraging to find that the students in this study did not present an extremely restrictive notion of who a scientist is.

Of particular interest is the large number of students who described the scientist using inclusive terms, with regard to gender and physical appearance. More than half of the population of this study used inclusive terms in their pretest responses, before they had been exposed to the program.
While other researchers found that very few subjects in their studies described scientists as female, (Fort and Varney, 1989; Mason Kahle, and Gardner, 1989; and Chambers, 1983), it is notable that in the study described here, only 26 of 217 subjects described a scientist as male.

Implications of the Pretest to Posttest Analyses

As is indicated by the statistics listed in Chapter 5, the goal of the Science-By-Mail™ program of changing students' images of scientists was accomplished, at least in terms of students' image of the appearance of a scientist. The overall shift between pretest and posttest totals in the number of exclusive indicators described by students was highly significant across a range of variables. It is more difficult to determine what factors produced that change. From this study, it is difficult to isolate any variables as predictors of a change in the image of the scientist as described by the subjects. Another study of the Science-By-Mail™ program, focusing on specific variables or another subset of the population, might result in different findings or isolate other variables that influence change in student images of scientists.

It does not seem that the amount of correspondence with a scientist was related to the amount of change. Students who received only 0-1 letters changed as much as those who
received 5 or more. It is possible that the introductory letter from the pen-pal scientist, in which many scientists described themselves as different from the stereotype, may have been a sufficient means of changing students' images, although even this is in doubt, because some students reported that they received no letters and still changed their stereotypes. It is hard to determine from the data whether these students' responses meant that they got no replies from the scientist about their activities, or no introductory letter at all.

Following this introductory letter, the illustrations and language of the Science-By-Mail™ kits may have reinforced students' construction of a more diverse and inclusive view of scientists. Each Science-By-Mail™ kit involved a role-playing component, in which participants were asked to play the part of some type of scientist. To solve the problem presented in each kit, students completed a series of hands-on activities. This structure provided an opportunity for students to identify themselves as scientists working in a variety of areas. Through this experience, many participants may have felt some identification with the practice of science, and subsequently, reframed their image of scientists.

It is clear, however, that in the interval between the pretest and the posttest (from October, 1988 to June, 1989),
there was a measurable change in the description of "a scientist" by the participants in the Science-By-Mail™ program. The similarity of results in all of the statistical analyses can be interpreted as an indication that this program was successful in achieving its goals regardless of the gender or age of the participant, and regardless of the gender or level of participation on the part of the student's pen-pal scientist.

These results indicate that a conceptual change occurred in student images of scientists. The permanence of this change and the effects that it might have on students' future participation in science are not known, however, and remain open to further study. This analysis investigated only one aspect of subjects' images of science and scientists. While the results show clearly that there was a change in students' description of the physical appearance of practitioners of science, it is unclear how their views of the practice of science may have changed.

Directions for Further Investigation

This analysis is based on a review of responses from a subset of the overall population. As explained in Chapter IV, the decision was made to analyze results of matched pair tests. An analysis of the complete pool of pretest and
posttest responses might produce different results or provide confirmation of the results presented here.

The results presented here could be enhanced by further analysis of the features of the Science-By-Mail™ program which were most important in bringing about change in students' ideas about scientists. Such an analysis could be accomplished through different statistical tests or through the design and administration of a different instrument.

An analysis of the registration and participation records of the program could identify students who had been influenced by only one aspect of the program. One aspect of participation that would be worth analyzing is the type and amount of correspondence that occurred. Although 26 students in this study reported that they had received no letters from their scientist, it is difficult to discern whether their responses meant that they had received only an introductory letter, but no replies to their solutions to the Science-By-Mail™ challenges, or whether they had, in fact, received nothing at all from their scientists. A search through the program's administrative records could identify students who had never corresponded with their scientist and had never received an introductory letter. Also, it might be possible to isolate students who had enrolled in the program and never engaged in any activities, but who had received a letter from a scientist. The responses given by these groups of students
could be compared with those of students who had participated in a more standard way in the program, with some correspondence and some participation in the activities. This analysis would help to determine whether correspondence or participation in activities were influential in the development of student images of scientists.

A different analysis, focusing on the subjects' responses to other questions on the questionnaire, such as "What does a scientist do?" and "How does a person become a scientist?" might lend further information about the depth of change that subjects experienced in their participation in this program.

This investigation does not provide information about the breadth, generality, or permanence of the change reported. A longitudinal study following some of these subjects over several years could provide such evidence. Since there is the possibility that the same student could participate in the Science-By-Mail™ program over several years, the same instrument could be administered to students on an annual basis, and the progress of some students could be tracked over a period of years as a means of charting the permanence of change.

An encouraging implication of this study is the confirmation of the effectiveness of recommendations made by
researchers and cited in Chapters II and III of this document with regard to appropriate changes in the teaching and presentation of science. From this investigation it seems that the implementation of these plans can contribute to the development of a more open and inclusive image of science and its practitioners.

At the end of the first year of the Science-By-Mail™ program, a female participant said that she had always thought that scientists were old men with beards. She went on to say that she was surprised and excited to find out that scientists could be all sorts of people, because her pen-pal scientist was pregnant. Anecdotes like this raised hypotheses about the Science-By-Mail™ program's ability to change student ideas about scientists. This thesis provides evidence to validate such hypotheses.


Carey, S. et al. (1969) "An experiment is when you try it and see if it works": A study of seventh grade students' understanding of the construction of scientific knowledge." (unpublished manuscript)


APPENDIX

Pretest and Posttest Questionnaire Instruments
Who is a scientist? What does a scientist do?

Before we send your first Science-By-Mail™ packet in a few weeks, we would like to know your ideas about who scientists are and what scientists do. Please use the front and back of this form to tell us what you think it means to be a scientist.

Please answer these questions:

1. What kind of person is a scientist?
2. How does a person become a scientist?
3. What does a scientist look like?
4. What kinds of things does a scientist do?
5. What kinds of things does a scientist know?

If you will be doing Science-By-Mail™ with other people, have everyone in your group use a separate sheet of paper to write their answers. Send all your answers back to the Science-By-Mail™ office so that we can read your ideas.

Thank you.

Your Name
Are you a boy or a girl?
How old are you?
What kind of job does your father do?
What kind of job does your mother do?
Who is a scientist? What does a scientist do?

Science-By-Mail™ is ending for this year. At the beginning of the year we asked you some questions about what a scientist is. We would like you to answer these questions again so that we can know more about your ideas about science and scientists. Please use the front and back of this form to tell us what you think it means to be a scientist.

Please answer the following questions:

1. What kind of person is a scientist?
2. How does a person become a scientist?
3. What does a scientist look like?
4. What kinds of things does a scientist do?
5. What kinds of things does a scientist know?

If you have been doing Science-By-Mail™ with other people, have everyone in your group use a separate sheet of paper to write their answers. Send all of your answers back to the Science-By-Mail™ office so that we can read your ideas.

Thank You.

Your name
Are you a boy or a girl?
How old are you?
Who was your pen-pal scientist in Science-By-Mail™?
How many letters did you get from your scientist this year?