A COMPARISON OF STUDENTS' AND SCIENTISTS' UNDERSTANDING OF THE CHARACTERISTICS OF SCIENTISTS

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A COMPARISON OF STUDENTS' AND SCIENTISTS' UNDERSTANDING OF THE CHARACTERISTICS OF SCIENTISTS

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ABSTRACT

This study investigated high school students' and scientists' understanding of the characteristics of scientists. Students' and scientists' responses on a similar instrument were compared. An instrument (Characteristics of Scientists Survey) was developed consisting of 14 Likert-type subscales. This instrument assessed a wide range of characteristics such as the scientific attitudes of scientists, their motivation, their philosophical and religious beliefs, their role in society and their non-professional life style. A second instrument (Semantic Differential--Scientist) was used to further assess student impressions as to the personal characteristics of scientists.

The following three hypotheses were tested in the study:

I. There are no significant differences in the perceived characteristics of scientists, as revealed on an appropriate instrument, among various groups of professional scientists.

II. There are no significant differences in the perceived characteristics of scientists, as revealed on an appropriate instrument, among various groups of eleventh grade students.

III. There are no significant differences in the perceived characteristics of scientists, as revealed on an appropriate instrument, between professional scientists and eleventh grade high school students.

Students' and scientists' responses were analyzed using multivariate analysis of variance. The 14 subscales or category scores were the dependent variables. Factors such as type of scientist, years of experience, highest degree received, student's sex, science class of student, student's hometown size, and his socio-economic status were the

independent variables. The means of student responses on the Semantic Differential were graphed for comparison purposes.

The results indicated no differences among groups of scientist scores, but significant differences were found among student groups for some of the 14 subscales. These differences were due mainly to science class and socio-economic status. Generally, students in chemistry, physics and biology had a more positive image of scientists as to their scientific attitudes at work, and their true motivation, than did students in earth science and physical science. Students of low socio-economic status felt more strongly than did medium or high socio-economic status students that scientists were motivated less by external factors such as financial rewards and prestige, and that scientists were much like they appeared in science fiction movies and stories.

Students' and scientists' mean scores differed for nine of the 14 categories or subscales. Students had a more positive impression than scientists as to the scientific attitudes (integrity, operational adjustments, and critical abilities) used by scientists at work. Generally, students felt more strongly than scientists that scientists were motivated to do science by a desire to improve human welfare. Students felt that scientists were more religious, and also that scientists were less confident as to their beliefs in a comprehensible and knowable universe, than did scientists. Students also felt more strongly than scientists that most scientists needed to play a stronger role in making decisions about the uses of science.

There was no common agreement or disagreement among students and scientists as to whether scientists were strongly motivated by external motivation, or whether scientists should keep the public informed about their work, or whether most scientists were highly interested in non-professional activities and home life. However, students and scientists strongly agreed that most scientists were highly motivated by intrinsic factors such as curiosity and the desire to know, and that most scientists recognized the importance of contributions made by science and technology to social progress and melioration.

Student responses on the Semantic Differential--Scientist suggest in general a very positive image of the scientist. Although some negative attitudes were expressed, indicating that some students felt the scientist was a little strange, slightly radical and somewhat untidy in appearance.

This study illustrated the need for more detailed investigations into student attitudes pertaining to scientists and their work, and the need for more research on scientists' own attitudes about aspects of their work. Also the study indicated the need for more attention to be paid to student attitudes in future science curriculum development.

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CHAPTER 1

INTRODUCTION

Background of the Study

The new science curricula of the past decade have placed major emphasis on an understanding of the nature and processes of science and on the acquisition of scientific knowledge, but very little emphasis on the understanding of the characteristics of scientists. The few scientists who are examined are usually the "great" men and women such as Einstein, Newton, Darwin and Madam Curie, whose atypical image only serves to increase the public's misunderstandings of scientists in general (Reis, 1972). Consequently, students may obtain a narrow and somewhat erroneous understanding of the scientific enterprise.

There is general agreement that science and scientists have had a major effect on our way of thinking and on our standard of living. Science has provided us with an empirical method of investigation that has had unparalled success in areas to which it has been applied. Science has released nuclear energy, explored the moon, performed near miracles with new medical and surgical techniques, and has laid the basis for the development of high speed computers and a whole host of new practical products. At the same time the spectre of over-population, excessive pollution, and genetic engineering of future off-spring has brought home to the public the double-edged nature of science. At the center of the current controversy concerning the value of science is the character and responsibility of the scientist himself. Yet in spite of the growing news about science and scientists, studies repeatedly have shown that the average high school student has lacked a clear understanding of both science and scientists (Mead, 1957; Allen, 1959; Barlow, 1961). With few exceptions he tends to place all scientists in an extreme positive or negative stereotype.

If the public is to have any say in the direction science takes, or if it is to develop realistic expectations of what science can and cannot do in the future, then it is necessary that it have an accurate and complete understanding of the work, personalities, abilities, influence, concerns, responsibilities and to some extent, the personal lives of practising scientists.

Some recognition has been given in science teaching to certain professional characteristics of scientists. The new curricula have emphasized "learning like a scientist" using the laboratory "to convey the method and spirit of scientific inquiry" (Hurd, 1969). However, in practice a knowledge of the attitudes, concerns, and influences of scientists remains at the level of a broad objective, and the growth of student learning along these lines is virtually ignored.

There is definite need to provide innovative curriculum materials which will aid students in developing a valid understanding of the characteristics of scientists. However, before this can be done, it is necessary to know as precisely as possible what current understanding students have of the characteristics of scientists and ways in which their knowledge of scientists may be inaccurate and incomplete.

The Problem

This study attempted to determine what students' understanding of scientists is and in what ways their understanding may be inaccurate and incomplete. A major task of the study was to develop an appropriate instrument to determine as accurately and completely as possible, student understanding of the characteristics of practising scientists. The instrument was based on categories assessing a wide range of the characteristics of scientists pertaining to the work they do and the life they lead. Both grade eleven high school students and practising scientists in various fields were given a similar instrument, and comparisons between scientists' and students' responses were made. The responses of scientists about their own roles and the role of their colleagues was a type of "yardstick" to which comparisons of students in high school biology, chemistry, physics, earth science and physical science courses were made.

Briefly the problem was to:

I. determine the characteristics of scientists as perceived by various scientists in such fields as biology, chemistry, physics and geology;

II. determine the characteristics of scientists as perceived by eleventh grade high school students;

III. compare the understanding of the characteristics of scientists possessed by students with that of practising scientists, as obtained from similar instruments presented to both groups;

IV. investigate the effects of different variables, such as town size, grade ten average, sex and teacher experience on students' responses, and field of study and years of experience on scientists' responses.

Definitions

The cognitive or intellectual component of attitude is measured in this study. This refers to the respondents' understanding of the characteristics of scientists, ie. what respondents think scientists are like, what they think scientists do, etc., as opposed to the affective or emotional component of attitude, ie. what they think scientists should be like or what they think scientists should do.

"Intellectual attitudes are said to be based upon some knowledge about the psychological object of the attitude" (Moore and Sutman, 1970). In this study the respondents' knowledge of various areas pertaining to the life of scientists (such as motivation, scientific integrity, etc.) is assessed; that is, "the characteristics of scientists" is the universe of content on which the intellectual attitudes of respondents are measured. The strength of the respondent's attitude is measured using a response mode which ranges from strongly agree to strongly disagree

The word scientist as used in this study refers to people who have completed at least a B.Sc. in a science field and who have done or are still doing some research in one of these fields.

Hypotheses

The determination of specific characteristics of scientists as viewed by students and professional scientists did not involve hypothesis testing. Specific hypothesis testing became necessary when comparisons were made of the understanding of scientists among various groups of students and professional scientists.

The hypotheses tested in this study were:

1. There are no significant differences in the perceived characteristics of scientists, as revealed on an appropriate instrument, among various groups of professional scientists.

2. There are no significant differences in the perceived characteristics of scientists, as revealed on an appropriate instrument among various groups of eleventh grade students.

3. There are no significant differences in the perceived characteristics of scientists, as revealed on an appropriate instrument, between professional scientists and eleventh grade high school students.

The effects of factors such as field of study (eg. biology, chemistry, etc.) highest degree received, and years experience, on scientists responses were examined. Possible interactions such as that which might exist between type of scientist and years experience were also investigated.

The effects of factors such as town size, science class (eg. biology, chemistry, etc.), sex, grade ten average, number of different high school science courses completed by the student, and teacher experience, on student performance on the instrument were investigated. Various interactions among factors such as town size, sex and science class were tested to determine if these had any significant effect on student responses.

Delimitations and Limitations

The delimitations of the study are:

1. The study was limited to samples of grade eleven students enrolled in all types of science courses in the high schools of Newfoundland. No attempt was made to measure the understanding of the characteristics of scientists held by tenth grade, junior high or elementary school students, or students outside of the province. The reason for choosing eleventh graders was the desire to survey students' understanding of scientists at the end of their formal schooling.

2. The study was designed to investigate the understanding that scientists and students have of the characteristics of scientists, ie. the cognitive or intellectual component of their attitudes. No attempt was made to measure the emotional component of attitude, ie. what they think scientists should do or what they think scientists should be like, or whether they would like to be scientists.

The limitations of the study are:

1. The study was limited mainly to university scientists in various departments at Memorial University and to some biologists and geologists working in Newfoundland. However, there was a lack of industrial chemists and physicists in this area, and no attempt was made to survey scientists outside the province.

2. The study was limited in that of the 193 questionnaires, Characteristics of Scientists Survey, sent to scientists only 107 (56%) were returned. Interpretation of scientists' responses had to be made in the light of this return. The results may have been different if a higher percentage of questionnaires were received.

Significance of the Study

Past research (Mead, 1957; Allen, 1959; Beardslee and O'Dowd, 1961) has indicated that school children have many misunderstandings as to the characteristics and roles of scientists. Most of these studies were concerned with formulating hypotheses about children's understanding of scientists, whereas this study is concerned with testing hypotheses concerning students' and scientists' understanding of the characteristics of scientists. Most studies have been narrow in scope, while this study attempted to investigate students' and scientists' understanding of a wide range of the characteristics of scientists. This study attempted to compare scientists and students with respect to their understanding of the characteristics of scientists on similar instruments, and this hasn't been attempted in any previous research study.

A major aspect of this present study involved measuring students' understanding of scientists by asking them the extent they agreed or disagreed with statements about scientists. To this end, an instrument was developed to assess scientists' and students' understanding of the characteristics of scientists, their role in the scientific community and in society. No previous instruments were available for these purposes.

The overall agreement or disagreement among scientists pertaining to each of these statements served as a basis for a "valid" understanding of scientists. The students' responses were then compared to those of the scientists, and areas of misunderstanding or discrepancies in the knowledge of students were analyzed.

The above information gained from the comparisons can serve as a basis for developing curriculum materials (special reading materials, classroom visits by scientists, simulation games, etc.,) which could help correct any misunderstandings of the characteristics of scientists among students. The results of this study also have implications for scientists by providing further knowledge of how each profession is viewed by colleagues in various fields and from various backgrounds.

CHAPTER II

REVIEW OF THE LITERATURE

A review of the literature reveals very few studies that attempt to measure students' understanding of the characteristics of scientists. Most of the published reports deal with measurements of attitudes towards science, not scientists. Also, very few of these are directly concerned with high school students, and none of them attempt to compare students' and scientists' responses on a similar instrument. Some of the studies deal specifically with the development of instruments to measure attitudes in science. These studies were very helpful in providing the groundwork for the development of the instrument used in this study.

The studies reviewed here can be considered under one of two general categories. The first category contains studies that deal directly with the attitudes and characteristics of scientists. The second category involves studies concerned with the measurement of student attitudes and understanding of scientists, some of which deal specifically with the development of instruments.

Studies of the Actual Characteristics of Scientists

Studies of the characteristics of scientists have been done by Roe (1953), Hinricks (1964), Lenher (1964), Brown and Brown (1972).

The most searching study of the actual characteristics of scientists themselves was conducted by Roe in the early 1950's. She interviewed numerous research scientists from all parts of the United States. Notwithstanding the many outward differences between men and women of science, Roe found many scientists shared common personality traits. A few of these were high intelligence, need for independence, emotional stability and sensitivity, strong egos, and an interest in community affairs. Some of these characteristics are clearly at odds with those expressed by students in the Mead and Metraux (1957) and Beardslee and O'Dowd (1961) studies, which are discussed later in this chapter.

Lenher (1964) in a study of 2,400 researchers at the DuPont Company found that 88 percent of the scientists were married, that the injury rate for scientists was lower than the over-all company rate, that 75 percent mentioned participation in church activities, that they did not find research work dull, and that they were active in at least 64 different civic projects. These studies indicate that scientists are similar in behavior to everyday people or they are near the norm for all people. However, the data from these studies was contrary to the students' images of the scientists as found by Mead and Metraux (1957).

Hinricks (1964) surveyed the attitudes of one third of the U.S. PhD. graduates in chemistry for the year 1960-61. Component analysis of questionnaire data isolated 3 basic attitude patterns: (a) attitudes valuing freedom and "pure science", (b) materialistic attitudes accepting business values possibly at the expense of science values, and (c) attitudes which reflect little conflict between industry and science values. New PhD.'s with high pure science attitudes tended to enter academic employment, others tended to enter industry. For an independent sample of 286 industrial chemists, both the orientation to "applied science" and the materialistic orientation were stronger for chemists with high number of years experience than for recent hires. No attempts were made to compare the attitudes of research chemists with those of other research scientists.

Brown and Brown (1972) used a series of Semantic Differentials each consisting of 12 bipolar scales for ten scientific values (eg. cause and effect, curiosity, integrity, creativity, etc.) to compare professors of science with professors of the humanties. The twelve scales for each value were composed of 3 items for each of four dimensions: evaluative dimensions, potency dimensions, activity-oriented dimensions and stability dimensions. The ratings of 30 professors of science and 30 professors of the humanities at Calfornia State Polytechnical College were compared. The ten "scientific values" were considered important to scientists in general. Results of this study show them to be not significant on the whole as characteristics differentiating professors of science from the humanities professors. Also, in this study no attempts were made to compare scientists in the different fields, or draw a composite image of the scientist.

The studies quoted under this section are very small in number and consist of scattered piecemeal attempts to survey the characteristics of scientists. Most were done more than ten years ago, and no recent studies have been conducted which consider in any detail, the characteristics of practising scientists, nor have any comparisons been made among groups of practising scientists from different fields.

Studies Concerned with the Measurement of Students' Attitudes Toward and Understanding of, Scientists

Studies concerned with student images of, and attitudes towards, scientists include those by Mead and Metraux (1957), Allen (1959), Beardslee and O'Dowd (1961), Tartara (1964), Tuominen (1964), Wickline (1964), Crossman (1968), Raskin (1968), Selmes (1969), Issertedt and Schmidt (1971), Mitias (1970), and McNarrey and O'Farrell (1972).

Mead and Metraux (1957) studied the image of scientists among high school students. This study involved open-ended questions given to a large (35,000) sample of students. They made the following observations from paragraphs about scientists written by students:

> <u>The negative</u>: The scientist neglects his family, pays no attention to his wife, never plays with his children, he has no social life, no other intellectual interest, no hobbies or relaxations. He bores his wife, his children and their friends-- for he has no friends of his own or knows only other scientists-- with incessant talk that no one can understand; or else, he pays no attention or has secrets he cannot share. He is never home. A scientist should not marry. No one wants to be such a scientist or marry him.
>
> <u>The positive</u>: The scientist is a very intelligent man-a genius or almost a genius. He has long years of experience training in high school, college, or technical school, or perhaps even beyond, during which he studied very hard. He is interested in his work and takes it seriously. He is careful, patient, devoted, courageous, and open-minded.
>
> He is a dedicated person, who works not for money or fame, or self-glory, but like Madame Curie, Einstein, Oppenheimer, Salk --for the benefit of mankind and for the welfare of his country.

Mead and Metraux reported that with few exceptions, students' views of scientists fit closely to the typical stereotype found in science fiction movies and stories. The late 1950's was a time of serious concern about the lack of qualified students choosing science as a career and the recommendations from this study centered almost exclusively on ways of improving the negative aspects of the students' image of scientists.

Allen (1959) made a study of 3000 high school seniors for the Science Manpower Project in the United States. He developed a 95-item Likert-Type scale to measure their attitudes toward science and scientific careers. The instrument was developed with the intentions of investigating aspects of the negative and positive images of scientists held by students. It seems, according to the results of the study, that students had constructive attitudes toward the scientific enterprise, but many of them exhibited misunderstanding and confusion with respect to the public image of scientists. Allen had this to say:

> "It should be noted, however, that an item analysis makes clear that on many important matters related to a public image of science and scientists there was misunderstanding, confusion and possibly ignorance exhibited by substantial numbers of seniors responding to the statements on the attitude inventory."

A similar type of study, carried out at Purdue University by Remmers (1956) also revealed attitudes similar to those above.

Beardslee and O'Dowd (1961) gave a Semantic Differential questionnaire to 1200 undergraduate men and women in four colleges in the North-eastern United States. Students were asked to indicate the appropriateness of a series of terms to each of 15 occupations, including that of the scientist. The results of the study are in close agreement with those of Mead and Metraux (1957). Beardslee and O'Dowd conclude that "scientists are seen as intelligent and hard-working but also as uncultured and not interested in people." A comparison of the profile of the scientist with profiles of individuals in other occupations revealed a high correlation (.77) between college professors and scientists and a lower correlation (.51) between scientists and engineers. Both scientists and college professors have personality characteristics represented by high scores on self-sufficient and perservering, middle values on strong, active, confident, and self-assertive and low scores on stable and adaptable in habits. Members of the two professions differ in that the scientist is thought to lack the artistic interest, good taste and sensitivity of the college professor. In public matters the scientist is influential, but, he was seen as somewhat naive. However, the scientist is seen as having a more markedly active, perservering and rational approach to life and work than the professor. The engineer is seen as less intelligent, less nonconfusing, less sensitive esthetically, and less valuable to society than the scientist, but as more "normal". The Semantic Differential used by Beardslee and O'Dowd (1961) was modified and used as part of an instrument in this study to measure students' beliefs about scientists among high school students.

Controlled experiments were carried out by Wickline (1964), Tartara (1964), and Raskin (1968) in attempts to measure the effects of presenting a more positive image of scientists on students' attitudes and ideas about scientists. Tartara studied the effects of novels and Wickline studied the effects of films. Allen's (1957) 95-item Likert-Type scale was used to measure attitudes before and after the experiments.

In Wickline's study the experimental group consisted of 113 students in twelfth grade physics, eleventh grade chemistry and American History and tenth grade biology. The experimental group viewed a different film from the Horizons of Science Films every week for ten weeks. It was found that scores on Allen's (1957) "Attitude Toward Science" improved for both groups, but not differently for the two groups. In this study changes in attitude toward science and scientists were not related to grade level, course content, mental age, total SCAT score, sex or elective science courses.

Tartara (1964) was concerned with the effect of reading selected novels presenting a positive image of scientists. Two experimental and two control groups of 30 students were used. The results show that reading, in general, makes students' attitudes toward science and scientists more positive, but this was not true for all students or all aspects of science attitudes. It is noteworthy that girls' attitudes changed more than boys', perhaps because the former was less positive to start with. The effects on attitudes were not related to IQ, reading ability, or grades in science. In addition, the reading did not have a significant effect on students' understanding of science, nor did it encourage more students to become scientists.

Raskin (1968) asked college-bound girls to express their interests in becoming scientists and their opinions of scientists, before and after the presentation of two lectures. One lecture was concerned with career opportunities for young women in the sciences and the other lecture dealt with some social aspects of the lives of women in science. The second lecture had more effect than the first on the girls' expressed opinions of women scientists, but it did not affect their expressed intentions of becoming scientists. However, this was an expected result of the lectures and helping girls decide to become scientists was not a major objective of the study.

Tuominen (1964) described a field trip in which high-school students mixed and mingled with engineering scientists in a visit to a Western Electric plant. He maintained that the process of interacting directly with the scientist-engineers in the laboratory setting helped to overcome the stereotype of the scientists as unsociable, inhuman and generally ineffectual. However, this was not a controlled experiment, and there was no reporting on the use of any tests or questionnaires.

Crossman (1968) used 21 "self-selected" high school students, matched with 21 control subjects, to evaluate the effects on attitudes and scientific literary of a course in science and culture. He found significant positive effects of the experimental course on attitudes towards scientists, genral understanding of the scientific process, and critical thinking, but there was no significant changes in scores on science achievement tests.

Selmes (1969) analyzed about 12 hours of tape recordings of secondary school students in a variety of schools in England, in which they were asked to freely express their attitudes concerning science and scientists. The recordings were analyzed by noting the frequency of recurring phrases and expressions, in particular descriptive adjectival ones. The percentages below refer to the number of similar comments made in the discussions and not to the number of children who made the comments.

According to Selmes, a stereotype based on these recordings might read as follows:

> Scientists spend their time inventing things or messing about with chemicals (8%). They may invent good things like new drugs and...well, other things I can't name but

> also things which are not very good (18%) like H-bombs and other weapons, giving diseases to animals; and the thousands of scientists breeding germs. They are usually men...well, there's more scope for them and anyway ladies aren't wanted (8%). They have to be very brainy or clever (7%) but I think they're mad or eccentric because of it or because they don't care what they do (7%)... in fact they have to devote their whole life to it (7%) and do nothing else...it must be grim to be disconnected from the world. No, I don't read magazines about science... they're too complex and difficult to understand (8%). We aren't given enough information or programmes about scientists but I've enjoyed the TV programmes I've seen out of school (10%). I suppose we never see scientists doing normal kind of work but I think they do too much as they like (7%) and there ought to be more control over them by a non-scientific body, or they could be limited to specific problems, e.g. curing of cancer No, I'm not thinking of becoming a scientist (9%).

Selmes concluded that the two themes which seemed to underly most of these recordings were the kind of work which scientists carry out and the kind of people they are, and life they lead. Twenty-five percent of the comments recorded dealt with the kind of work they do and eighteen percent revealed a negative or critical attitude toward this work. Fifty percent of the comments were connected with the scientist as a person, most of which suggested the stereotype of the "mad" scientist of the horror films and comic papers, an inference drawn from the fact that twenty-one percent of the comments reflected the idea of a scientist living a narrow devoted life. However, the validity and reliability of the tape recording techniques used in this study jeopardize the interpretation of the results, since of fifty hours of tape recordings only about one-quarter of them were analyzed. One might ask, how representative of whole recording is the part that has been analyzed, or how representative of the attitude of secondary school children is the whole recording? Also, the size of the sample of students involved was not reported in the study.

Isserstedt and Schmidt (1971) studied a selected group of high ability high school students in an eight-week Science Training Program held at the University of Iowa during the summer of 1968. In general the 98 participants in the program were ranked in the upper 5% of their high school classes. A twenty-four item instrument was designed to collect information about the attitude of high school students toward science and scientists. The instrument was given at the beginning and at the end of the summer course. In nine of the twenty-four items, the response mode (strongly agree - strongly disagree) did not match that which the authors considered a response indicating an accurate, favorable, or accurate and favourable image of the scientist. The image did not change significantly as a result of the summer program. The authors concluded that there were two possible interpretations of their data: "(1) they were in error on expected outcomes on these items, or (2) the high school students had somehow developed an inaccurate and unfavourable image of the scientist."

Mitias (1970) conducted a study of the concepts of science and scientists held by 290 college students at Western Michigan University. Subjects included freshman to seniors and were all non-science majors enrolled in elective science courses. For three semesters, students were asked to complete statements relating to the concepts of science and scientists. Analysis of findings revealed negative concepts and attitudes towards science and scientists, and also a striking similarity between college students--in the study, and high school students' concepts in the Mead Study of 1957. It is interesting to note that this study was carried out in 1970 at a time of high scientific development (ie. space achievements, heart transplants, etc.) and when compared to Mead's study of 1957, college students still had certain negative concepts of science and scientists.

McNarrey and O'Farrell (1972) studied the attitude of high school students towards scientists, engineers and technologists. They used a Semantic Differential developed by Osgood with 20 scales. The test was given to a sample of 79 students in two high schools near Ottawa. They concluded that "the scientist fared better in that he is seen more helpful, wise and important than the technologist. However, the students still did not see him as a particularly attractive human being." McNarrey and O'Farrell also suggested "the need for more extensive examination of student attitudes as a concomitant to understanding the relationship of science and science teaching to the problems of society in the post-industrial era."

Instruments have been developed to measure students' understandings of science, scientists and the scientific enterprise. Among the most widely used instrument is the Test on Understanding Science (TOUS) developed by Klopfer and Cooley (1961). The test is a 60-item mutiple-choice test consisting of three subscales measuring students' understanding of science (18 items), scientists (18 items), and the scientific enterprise (24 items). The mutiple-choice items have one right answer and no provision is made to assess the strength of a persons attitude pertaining to a particular characteristic of scientists, nor is a very wide range of characteristics examined under the scope of the test. On this basis, it was decided that the test was not appropriate for use in this study.

Thurstone, Likert-type and mutiple-choice-type scales have been used to measure students understanding of science and scientists, and some use has been made of open-ended questions (essays), Semantic Differentials and projective-type techniques. Some studies already quoted, eg. Mead and Metraux (1957), used open-ended questions (paragraphs), and Selmes (1969) used tape recordings. Beardslee and O'Dowd (1961), and Brown and Brown (1972) used Semantic Differentials as described in an earlier part of the review of the literature. Other studies include those by Klopfer (1966), Lowery (1966), and Perrodin (1966). Klopfer applied the Semantic Differential technique to the assessment of students' images of science, scientists, and science instruction.

Lowery and Perrodin (1966) used projective instruments. Lowery designed an open-ended projective instrument to measure the attitudes of fifth-grade children toward science, the scientific process, and scientists. Lowery's instrument, which consisted of a word association test, an apperception test and a sentence completion test, had interrater and pretest-postest reliabilities in the .80's and .90's. Perrodin used a projective instrument twenty sentence fragments intended to stimulate the expression of feelings toward science-- in a study of fourth, sixth, and eight-grade pupils.

Some studies, such as Lowery's (1966) represented a many-sided approach to the measurement of attitudes. Belt (1959) compared the effectiveness of two types of attitude measures-- a set of multiple choice items concerned with factual material as a measure of accuracy of perception, and a set of Likert-type statements concerned with favourableness of attitudes toward science and scientists. The items on the two tests were matched on content, but the accuracy of perception items proved to be less ambiguous than the Likert items.

The studies reviewed under this section have been concerned with both college and high school students' images of scientists. Mitias (1970) showed that there was very little differences in the college student images of 1970 and the images that high school students held in the Mead study of 1957. Curriculum attempts at changing or modifying the image of scientists as held by students have been largely unsuccessful as evidenced from studies by Wickline (1964) Tartara (1964), and Isserstedt and Schmidt (1971).

The attitude scales and instruments surveyed under this section of the literature were not sufficient for the type of study on which comparisons were to be made between students and scientists. Most of the instruments were narrow in scope and none were concerned with assessing such a wide range of scientists' characteristics as considered in this study. Also, most instruments were designed to determine if student images of scientists were positive or negative, and did not focus on the accuracy of students' understanding of the characteristics of scientists. It should be noted that a positive image is not synonomous with an accurate image. Several instruments deal with the work of scientists (ie. science) and the characteristics of scientists is only given limited treatment.

Summary

Studies concerned with student images of scientists indicate a number of areas in the lives of scientists about which high school students, as well as college students have very little understanding. Most of these larger studies were carried out in the late 1950's or early 1960's. Some small scale studies conducted in the mid-60's indicate there has been little change in the stereotyped images that students hold.

However, the instruments used in these studies were limited in scope and did not assess such a wide range of attitudes as considered in this study. Most of the larger studies conducted more than a decade ago were concerned with promoting a positive image of the scientist, in attempting to recruit students into the sciences in the United States.

No extensive studies have been carried out recently to survey the actual activities and characteristics of scientists themselves. A few studies that were done in the early 1950's and early 1960's revealed that some of the activities and characteristics of scientists were clearly at odds with characteristics of student images of scientists. However, in the studies of scientists few attempts were made to compare scientists from different fields as is done in this study. Most of the studies concentrated on one type of scientist, ie. chemists or biologists.

Instruments used in these types of studies include multiple choice, open-ended questions, Likert-type and Thurstone scales. In a few studies a combination of the above instruments were used on a small scale to measure the attitudes and understandings of students. Most of the instruments are outdated and narrow in scope. The type of instrument which would measure a wide range of characteristics pertaining to the life and role of the scientist was not available. Thus, a major task of this study was to develop an instrument to assess a person's knowledge of the life and role of scientists. Such factors as motivation, scientific integrity, role in society, religious and philosophical beliefs and others which are described in the next chapter were examined. Studies which help to provide the content and information necessary for the actual construction of the instrument are referred to in Chapter Three.

While there have been a few more recent studies, usually conducted on a small scale, it is important to note that to date no researcher has attempted to correlate students' images of scientists with those held by scientists themselves, something which should enable one to determine more the extent to which students' images of scientists are accurate and complete. It is only by conducting this type of study, that specific recommendations can be made on ways of increasing students' understanding of scientists.

CHAPTER III

DEVELOPMENT OF THE INSTRUMENTS

The instrument consists of a questionnaire designed to investigate a person's understanding of various characteristics of scientists. It attempts to measure the extent to which both scientists and students agree or disagree with statements about scientists. The instrument was given to both students and scientists, and comparisons were made within and between both groups. The scientist "within groups" were the biologists, chemists, physicists and geologists at Memorial University of Newfoundland and some biologists and geologists working in the province during the summer of 1973. The student "within groups" were a random sample of those enrolled in grade eleven chemistry, biology, physics and earth science courses in schools in the province of Newfoundland. The "between groups" were the different types of scientists mentioned above and the grade eleven students taking the various high school science courses.

The instrument consists of two parts:

(1) Semantic Differential on the "Scientist".

(2) The Characteristics of Scientists Survey, consisting of fourteen Likert-Type Scales.

The Semantic Differential

The Semantic Differential used in this study was orignally developed by Beardslee and O'Dowd (1961), and modified in a study by Reis (1970).

The Semantic Differential measures a respondent's impression of scientists by having him judge that occupation against a series of descriptive bipolar scales.

Osgood's Semantic Differential is a measure of the affective meaning of words. In using the Semantic Differential the concept to be examined (in this case "scientists") is stated at the top of the page and the subject is asked to indicate his response in the appropriate space between the adjectival polar opposites for each of the scales below the concept. Two points must be emphasized: not all scale word pairs have equal weight and they do not all measure responses along the same axis in semantic space. For example, Osgood and his co-workers have identified three orthogonal axes: evaluation, potency and activity. Secondly, the use of redundant or apparently non-related scales and concept headings make it difficult for the subject to determine the purpose of the test and so adjust his responses accordingly.

The Semantic Differential used in the study (see appendix A) was modified slightly from the study by Beardslee and O'Dowd (1961) and Reis (1971). The scales:

has a pretty wife__:__:__:__:__:__:__ wife is not pretty

doesn't play poker__:__:__:__:__:__:__ plays poker

doesn't play bridge__:__:__:__:__:__:__ plays bridge

were replaced by the following scales, respectively:

athletic __.__.__.__.__.__.__ not athletic

attractive __:__:__:__:__:__:__ unattractive

tidy in appearance __:__:__:__:__:__:__ untidy in appearance

The changes were made in an attempt to incorporate scales relating to the physical attributes of scientists.

The reliability of the Semantic Differential was obtained by the test-retest method over a two-week period using a grade eleven biology class consisting of 35 students from Queen Elizabeth Regional High School, Foxtrap, Newfoundland. This class was not otherwise connected with the study. The responses of ten of the students, which were selected at random from the group, on the test and retest were correlated with themselves and an average correlation, as shown in Table I, was obtained using the Fisher-Additive tables.

The Semantic Differential is a useful technique for obtaining students views pertaining to descriptive adjectival bipolar scales. It was used in this study to assess students' images relating to the personal characteristics of scientists themselves. These characteristics are easily assessed and the instrument takes very little of the respondent's time to complete. The Semantic Differential is limited in that it only measures the affective meaning of words on a two-ended scale. Characteristics of scientists relating to the kind of work they do and the life they lead do not easily lend themselves to rating by descriptive bipolar scales. For these reasons it was necessary to develop a more comprehensive instrument which would measure a wider range of the characteristics of scientists pertaining to the kind of work scientists do, their views on religion and philosophy, and their professional and non-professional roles in society. This instrument is described in the following section.

TABLE I

TEST-RETEST CORRELATIONS ON SEMANTIC DIFFERENTIAL

Subject	Correlation r		Fisher-Additive Transformation z_r
1	0.789		1.071
2	0.666		0.802
3	0.764		1.008
4	0.496		0.534
5	0.860		1.293
6	0.451		0.485
7	0.642		0.758
8	0.666		0.802
9	0.594		0.685
10	0.554		0.626
		Total	8.073

Average z_r = 0.807
Average r = 0.670

The Characteristics of Scientists Likert-Type Scales

Research studies in the past, most of which involved open-ended questionnaires, have shown that students hold various stereotyped images of what scientists are like at work and away from work (Mead, 1957; Allen, 1959). The results of these studies suggested a number of areas in the life of scientists about which students have very little understanding. They provided information on the range of characteristics which students feel apply to scientists, and suggested possible categories which were used as the basis for the development of an instrument. Studies dealing with scientific attitudes (Diederich, 1967; Haney, 1964) and a model of "The Affective Attributes of Scientists" (Nay and Crocker, 1970) were used to help delineate some of the categories needed. Other areas concerning the life of the scientists were formulated from literature about the scientists' role in society, and their role in the scientific community.

There are a number of already existing attitude scales that focus on some aspects of attitudes in science; however, none are primarily concerned with attitudes toward scientists. The purpose of this questionnaire is to measure students' understanding of the life of scientists by ascertaining the extent to which they agree or disagree with statements concerning scientists. The emphasis of this instrument is on how students think scientists behave, feel and think, i.e. the cognitive component of their attitudes toward scientists.

Five major areas which characterize the scientist's life and work were identified, as summarized in Table II, and a number of categories were developed within each area. Of the specific items used, some were

TABLE II

SUMMARY OF CATEGORIES WHICH SERVED AS A BASIS FOR INSTRUMENT CONTRUCTION

Area	Category	Title of Category
I Scientific Attitudes	I-A	Scientific Integrity of Scientists
	I-B	Critical Requirements of Scientists
	I-C	Operational Adjustments of Scientists
II Motivation	II-A	Intrinsic Motivation of Scientists
	II-B	Altruistic Motivation of Scientists
	II-C	Extrinsic Motivation of Scientists
III Philosophy and Religion	III-A	Philosophical Beliefs of Scientists about a Real and Knowable Universe
	III-B	Religious Beliefs of Scientists
IV Scientist in Society	IV-A	Scientists' Role as Public Informer
	IV-B	Scientists' Role as Decision Maker
	IV-C	Scientists' Appreciation of Relationships between Science and Society
	IV-D	Scientists' Appreciation of the Contributions of Science and Technology to Social Progress and Melioration
V Non professional Characteristics	V	Characteristics of Scientists Outside of their Professional Life
	VI	Students Beliefs about Media's Image of Scientists (2 items)

modified from attitude scales previously developed, and others were constructed by the researcher. The response mode for all items was of the form, strongly disagree, disagree, agree, and strongly agree.

Areas and categories Which Served as the Basis for the Development of Attitude Statements

Area I - Scientific Attitudes

This area surveys the extent to which both students and scientists agree with statements about the "scientific attitudes" of scientists at work. These attitudes are intellectual behaviors which are fundamental to the scientists' contribution to or acceptance of new scientific knowledge (Nay and Crocker, 1970).

The components that follow serve as a partial definition for the "scientific attitude of scientists". They are considered under three categories.

I-A: This category investigates understanding about the scientific integrity of scientists. Such factors as objectivity, honesty, suspended judgment, rationality, open-mindedness, willingness to change opinions and idea sharing are considered.

A high score on Category I-A means the respondent feels that scientists value scientific integrity highly and that they make use of these attitudes in their work.

I-B: This category investigates feelings about the critical requirements of the scientific attitude such as critical mindedness, anti-authoritarianism, self-criticism, and a questioning attitude.

A high score on Category I-B indicates that the respondent feels that scientists are very critical of their work and the work of other scientists.

I-C: This category examines the operational adjustments scientists have to make if they are going to be competent and successful in science and perform at recognized standards (Nay and Crocker, 1970). These behaviors include dedication or commitment to the job (e.g. perserverence and patience), initiative and resourcefulness (e.g. confidence and self-direction) and their relations with peers such as cooperation, compromise, modesty or humility and tolerance .

A high score on Category I-C indicates the respondent feels that scientists have positive attitudes toward the operational requirements of a successful life in the scientific community.

Area II - Motivation

The items in this area investigates feeling about the extent to which certain factors motivate a person to become a scientist and continue to be one. This area consists of three categories:

II-A: The motivation to become a scientist may arise from a longing to know and understand natural phenomena--intrinsic motivation. It involves such factors as curiosity about nature, and fascination, excitement and enthusiasm about scientific study.

A high score on Category II-A indicates the respondent feels that the motivation to become a scientist is based mainly on intrinsic factors.

II-B: A second category is motivation which may arise out of a cultural concern to contribute to knowledge and human welfare. This would also include the degree of altruism among scientists and factors which affect the type of work which they take pride and satisfaction in doing.

A high score on Category II-B indicates the respondent feels that the motivation to become a scientist is strongly due to a concern about improving living conditions on this planet.

II-C: This category considers that the motivation to become a scientist may also come about as a result of external factors such as financial rewards and the desire to acquire positions of prestige, and others.

A high score on this category indicates the respondent feels that the motivation to become a scientist is strongly based on external or extrinsic factors.

The three categories described under area II of motivation are not mutually exclusive and a high score in all three is possible. However, it was necessary to consider the categories separately because a low score on one and a high score on another would cancel each other and cause problems in interpretation.

Area III - Philsophy and Religion

This area is concerned with an understanding about the values and beliefs that scientists possess in the realms of philsophy and religion. It is concerned with the impact of exposure to the scientific environment on these values and beliefs.

III-A: In the realm of philsophy it investigates the extent to which scientists feel that the universe is "real", that much of nature is comprehensible or knowable through observation and rational thought, while at the same time recognizing that there are certain limitations to science. It also examines their feelings about the causal, relativistic and probabilistic nature of phenomena.

A high score on Category III-A of philsophy indicates the subject feels that scientists believe in order and balance in nature and that the universe is real, and within limits, comprehensible and knowable. A low score would indicate a belief that nature is capricious and unpredictable and that little cause and effect relationship exists in nature.

III-B: In the realm of religion, the instrument investigates the extent of agreement among scientists about belief in the supernatural, the extent to which they appreciate the church and the extent of their belief in God.

A high score on Category III-B of religion indicates the respondent thinks that scientists are religious, in that they believe in God and appreciate the church. A low score would indicate the opposite.

Area IV - Scientist in Society

This area investigates how the respondent views the role of the scientist in society. The area has been divided into four categories:

IV-A: This category investigates how the respondent views the role of the scientist as a public informer and his obligations to society.

A high score on Category IV-A indicates the subject feels that scientists have strong obligations toward the public to keep them informed about their work.

IV-B: This category investigates the scientists role as decision maker and the extent to which scientists should be involved in politics.

A high score on Category IV-B indicates the respondent feels that scientists think they should have a strong role in decisions about how science is used.

IV-C: This category considers the extent to which scientists recognize the social basis for the development of science.

A high score on IV-C indicates that scientists recognize the need to develop a relationship between science and society as being important for the proper development of science.

IV-D: Category IV-D considers the extent to which scientists recognize the contributions made by science and technology to social progress and melioration.

A high score on Category IV-D indicates that scientists strongly recognize the importance of the contributions made by science to social progress and melioration.

Area V - Non Professional Characteristics

Area V consists of a single category which examines the characteristics of scientists outside of their professional life. These include such factors as: what the scientist is like at home with his family, how he spends his leisure time (reading, sports, etc.), extent to which the scientist spends most of his time conversing with other scientists and the extent to which he is active in non-professional groups.

A high score on category V means the respondent feels that scientists participate in a variety of activities outside of their line of work, and that they have an interest in home, family and social life. A low score indicates the respondent feels that scientists have narrow interests, little devotion to family, and participate in few activities outside of science.

Category VI: Upon the suggestion of one of the validators, a sixth category consisting of two items relating to whether the respondents believed the image of scientists presented by most science fiction movies and stories was added to the instrument.

A high score on items in Category VI indicates the respondent believes that scientists are much like they appear in science fiction movies and stories.

The Development of Specific Items

The above categories specify the particular characteristics of scientists that are to be assessed. The categories were described in an attempt to define as precisely as possible what is to be measured. Several items were then developed under each category in order to obtain a valid and reliable estimate of the extent to which students understood the characteristics of scientists pertaining to each of the categories. As in all types of attitude measurement, one can assume that a respondents' attitudes vary in strength; hence, each respondent was permitted to indicate the extent of his acceptance or rejection of each attitude statement.

Shaw and Wright (1967) note that:

> "It is possible to have a set of items that have content validity but represent only one part of the attitude continuum (eg. positive attitude), in which case the scale would not validly measure the attitude."

In an effort to ensure the content validity of the instrument, Characteristics of Scientists Survey, the universe of content, "understanding of scientists and their roles" is defined by two types of attitude statements: (1) positive intellectual, and (2) negative intellectual. The content validity of the inventory is insured by inclusion of samples of each type of attitude statement.

In writing items for use as attitude statements in the instrument, Edwards (1957) "Informal Criteria for Attitude Statements" were generally followed. Efforts were made to develop several items for each category in order to assess the respondent's understanding of scientists in each of the categories.

In the instrument, the respondent is asked to state the extent to which a statement applies to "most scientists". One of the purposes of the instrument was to determine whether students felt that most scientists could be categorized or stereotyped a certain way. Thus, students were given the instrument with attitude statements about "most scientists".

Scientists were given forms with attitude statements about colleagues in their respective fields, i.e.chemists were asked to respond to statements on how they viewed "most chemists", similarly for biologists, physicists and geologists. Scientists' views of their colleagues were then compared and also, a composite was made of all scientists' responses for comparisons with students' responses on each category of items.

Scientists were asked to rate colleagues in their respective fields because it was felt that they might respond differently to statements about their colleagues than to statements about scientists in general. For example, a chemist might view "most chemists" as being different in some respects from "most scientists". Scientists were not asked to respond to statements about their own personal life as individuals, but rather to statements about how they viewed the characteristics of most of their colleagues. This was felt necessary because of the small number of scientists involved in this study. Thus, it was felt that a more valid understanding of the characteristics of scientists could be obtained by asking the scientists contacted to respond to statements about most of their colleagues in each respective science discipline. However, if this study were to be done with a larger sample, the items could be worded so that each scientist would respond to the items on an individual basis.

Originally, when the instrument was being developed, it was proposed to ask the scientist to respond to each item pertaining to himself as an individual scientist, and also, how he felt about most of his colleagues. However, some of the validators felt this mode of response (i.e. requiring the scientist to respond twice to the same item) would be too confusing and too tedious for scientists to do. Thus, it was decided to ask scientists to respond only on the basis of how they felt items pertained to "most" of their colleagues in each of their respective fields.

The Validation of the Instrument

To select the best attitude statements, an initial pool of 146 items was presented to a group of five judges—three scientists and two science educators. The judges were asked to rate each item on a three point scale for clarity in meaning, and on a three point scale of appropriateness of an attitude statement for a designated category (see appendix C). The judges were also asked to examine the choice of categories, and to make any comments which they felt would contribute to the validity of the instrument.

An arbitrary criterion of agreement by four of the five judges that an item was clear and appropriate for a particular category was set as a standard of acceptance or rejection of items. Only 16 of the 146 items were eliminated when this criterion was applied. Some of the remaining 130 items were revised on the suggestions of the judges. Two initial forms of an instrument were developed, Form A which included all items in Categories I-A, I-B, I-C, II-A, II-B, II-C, and Form B which included all items in Categories III-A, III-B, IV-A, IV-B, IV-C, IV-D and V. In addition two items were added to Form A to measure the extent to which students believed the image of scientists as presented in science fiction movies and stories. The fourteen categories of the instrument were devided arbitrarily into two separate forms because of the large number of items (126). Forms A and B were developed such that either form could be administered in a 40 minute classroom period.

Forms A and B were then given to two classes of sophomore education students enrolled in an elementary science methods course at Memorial University of Newfoundland. It was felt that these students' knowledge of the characteristics of scientists would lie somewhere between high school students and scientists. The students were given the response mode ranging from strongly agree--1, agree--2, disagree--3, to strongly agree--4, and don't know--5. The "don't know" category was added to determine if students did not have any knowledge of attitude statements in the questionnaire. Form A was given to 26 students and Form B to 22 students. The students were asked to check the "don't know" response only if they felt that they didn't have enough knowledge to agree or disagree with an attitude statement.

It was decided beforehand that if more than thirty percent of the students checked "don't know" for a particular item, this item would be dropped from the instrument. This procedure eliminated only four items, all from Category V of Form B which dealt with the characteristics of scientists outside of their professional life. The four items were dropped since college students responses were taken to serve as an indication that high school students wouldn't have enough knowledge to express attitudes on these items.

The "don't know" choice was not included in the final form of the instrument because it was felt that some students would check this response frequently when asked to respond to attitude statements. Also, the "don't know" response could not be dealt with statistically in terms of the scores on a particular category.

The elimination of the "don't know" choice left a "forced choice" response format. The instrument then consisted of Form A (60 items) and Form B (66 items). Subjects were asked to respond to each item as strongly agree--1, agree--2, disagree--3, and strongly disagree--4 for negative items. The scoring for positive attitude statements was reversed for each item. Each of the categories in Forms A and B had an even number of attitude statements with a minimum of six items for each category. Half of the items for each category were negative attitude statements and half were positive attitude statements.

Reliability of the Instrument

Form A consisting of 60 items for Categories I-A, I-B, I-C, II-A, II-B and II-C was given to a class of 35 grade eleven high school students. Form B consisting of 66 items for Categories III-A, III-B, IV-A, IV-B, IV-C, IV-D, V and two items on the media's image of the scientist, was administered to a second class of 25 grade eleven high school students. The sample for the reliability study consisted of two grade eleven science classes from Queen Elizabeth Regional High School, Foxtrap, Newfoundland.

The test-retest method was used to obtain an estimate of the reliability of the items in each category. There was a two week period between the two administrations of the instruments. Pearson correlation coefficients calculated for each of the categories are reported in Tables III and IV. The calculations were based on sum scores for each of the categories for each individual for the two occasions.

Test-Retest correlations from Table II show low correlations for Categories I-B and I-C, 0.248 and 0.439, respectively. The low reliability for these two subscales resulted in a reduced reliability (0.438) for Form A of the Characteristics of Scientists Survey. It was felt by the researcher that some items which showed essentially random responses by students in these categories contained words which may not have been meaningful to high school students, for example, validity, scientific establishment and others. Those items along with some items for Category IV-A ($r = 0.438$) were revised by writing them in language that was at a lower reading level than previously.

The final instrument consisted of: Form A (60 items) with items for Categories I-A, I-B, I-C, II-A, II-B, II-C and two items related to students' beliefs about the media's image of scientists, and; Form B

(66 items) with items for Categories III-A, III-B, IV-A, IV-B, IV-C, IV-D, and V. (see appendix B). The response mode for negative items was of the form: 1--strongly agree, 2--agree, 3--disagree and 4--strongly disagree. The scoring above was reversed for positively worded items.

TABLE III

TEST RETEST CORRELATIONS FOR FORM A

	Title of Category	Correlation r
I-A.	Scientific Integrity of Scientists	0.628
I-B.	Critical Requirements of Scientists	0.248
I-C.	Operational Adjustments of Scientists	0.439
II-A.	Intrinsic Motivation of Scientists	0.554
II-B.	Altruistic Motivation of Scientists	0.523
II-C.	Extrinsic Motivating of Scientists	0.646
VI.	Students Beliefs about Media's Image of Scientists (2 items)	0.533
Total Test-Retest Correlations for Form A		0.438

N = 35

TABLE IV

TEST-RETEST CORRELATIONS FOR FORM B

	Title of Category	Correlation r
III-A.	Philosophical Beliefs of Scientists about a Real and Knowable Universe	0.664
III-B.	Religious Beliefs of Scientists	0.830
IV-A.	Scientists' Role as Public Informer	0.485
IV-C.	Scientists' Appreciation of Relationships between Science and Society	0.633
IV-D.	Scientists' Appreciation of the Contributions of Science and Technology to Social Progress and Melioration.	0.525
V.	Characteristics of Scientists Outside of their Professional Life.	0.782
Total Test-Retest Correlation for Form B		0.659

N = 25

CHAPTER IV

SAMPLES, PROCEDURES AND METHODS

There were essentially two different aspects of the study which required different samples and different procedures. These aspects were related to (1) scientists' understanding of the characteristics of scientists as measured by the instrument, Characteristics of Scientists Survey, and (2) students' understanding of the characteristics of scientists as measured by the instrument, Characteristics of Scientists Survey, and a Semantic Differential--Scientist. The development of these instruments and data for their reliability and validity were described in the previous chapter.

The samples used in the study consisted of scientists working in Newfoundland employed by the University, Government and Industry, and classes of Grade eleven high school students in selected high schools throughout the province of Newfoundland.

The scores on the instrument, Characteristics of Scientists Survey, were summed for items in each category. This procedure gave 14 category scores for each administration of the instrument. The scores for each category were analyzed using multivariate analysis of variance to determine if there were significant differences (1) within groups of scientists, (2) within groups of students, and (3) between students and scientists.

Student responses for the 34 descriptive scales in the Semantic

Differential--Scientist were treated fairly descriptively. A series of one-factor analyses of variance was done for students grouped according to town size, sex, and science class. For each factor, the mean scores of various groups of students were graphed for comparison purposes.

Samples used in the Study

Scientists

The sample used in this study for the purposes of examining scientists' scores on the instruments, Characteristics of Scientists Survey, consisted of all scientists in departments of chemistry, biology, physics and geology at Memorial University and some non-academic biologists and geologists working in Newfoundland. The number of questionnaires sent and the percentage return are reported in Table V.

Of the 71 questionnaires sent to biologists, 25 were sent to non-academic biologists, and of the 62 questionnaires sent to geologists, 46 were sent to non-academic geologists working for mining companies and the government of Newfoundland. Since there were very few non-academic physicists and chemists in the province, these were not sampled.

Students

Grade eleven high school student scores on the Characteristics of Scientists Survey and the Semantic Differential entitled Scientist were sampled through a random selection of fifteen grade eleven science classes, chosen from a list of high schools, grouped into three categories according to size of community in which the schools were located. Classes were chosen randomly by using tables of random

TABLE V

NUMBER AND PERCENTAGE RETURN OF QUESTIONNAIRES

SENT TO SCIENTISTS

Type of Scientist	No. Sent	No. Received	Percentage Return
Chemists	29	19	65 %
Biologists	71	32	45 %
Physicists	31	22	70 %
Geologists	62	34	55 %
Total	193	107	56 %

TABLE VI

STUDENTS INVOLVED IN THE STUDY GROUPED ACCORDING TO TOWN SIZE, SCIENCE CLASS AND SEX

Group	Number of Students
Town Size	
1. Less than 2000	198
2. 2000 - 20,000	169
3. Greater than 20,000	143
Total	510
Science Class	
1. Chemistry Students	105
2. Biology Students	146
3. Physics Students	100
4. Earth Science Students	87
5. Physical Science Students	72
Total	510
Sex	
1. Male	259
2. Female	251
Total	510

numbers. Thus, the sample consisted of five classes (one for each of Biology, Chemistry, Geology, Physics and Physical Science) chosen from each of three town sizes: small (less than 2000), medium (2000 - 20,000) and large (greater than 20,000), for a total of 15 classes. See Table V for a summary of the students who completed the questionnaire.

Procedures

Scientists' Responses

The instrument, Characteristics of Scientists Survey, was sent to scientists in the province of Newfoundland in order to measure their understanding of the characteristics of scientists relating to each category of items of the instrument. Scientists were sent both Form A and Form B with the items for each category randomly distributed throughout each form of the instrument. Items for each category were randomly positioned by referring to a table of random numbers. About a month prior to sending the questionnaire to scientists, Dr. Richard Reis, a science educator of the Faculty of Education at Memorial University, met with the various science departments of the University. He discussed the purposes of the questionnaire and solicited the scientists' cooperation in conducting the study. Also, a letter (see Appendix D) was sent to scientists explaining the purposes of the questionnaire. After a period of three weeks, a followup letter (see Appendix D) was sent to scientists to remind them of the purposes of the instrument and to solicit more returns.

Scientists were asked to respond to each of the attitude statements relating to colleagues in their respective fields. Thus, biologists were asked to respond with reference only to biologists, chemists with reference to chemists, and similarly for physicists and geologists.

The response format was: 1--strongly agree, 2--agree, 3--disagree, and 4--strongly disagree for negative statements, and the numbering was reversed for positive attitude statements. The responses of each scientist were summed for items relating to each of the 14 categories. Thus, for each scientist 14 category scores were obtained. A discussion of what scoes on each of the categories represent appears in the third chapter.

The 14 category scores were used as a basis for comparisons between the different groups of scientists . Multivariate analysis of variance was used in comparing scientists' scores grouped according to type of scientist, highest degree and years experience. A composite of all scientists' responses was made to obtain a "description" of the characteristics of scientists relating to each of the 14 categories. Student responses were then compared to the "composite" of all scientist responses to test for differences in the way scientists viewed themselves, and the way scientists were viewed by students.

Students' Responses

In order to obtain student responses to items on Characteristics of Scientists Survey, the instrument was sent to fifteen classes of grade eleven high school students. The purpose of the instrument was to measure high school students' understanding of the characteristics of scientists relating to each of the 14 categories of items as described in Chapter Three.

The principal of each of the 15 schools that were randomly selected was contacted by telephone and his permission was requested to administer the instrument to each grade eleven science class involved in the study. After the schools were contacted, packages consisting of copies of the instrument accompanied by copies of the Semantic Differential on the Scientist were sent to teachers of each of the science classes involved in the study. Included in each package was a letter (see Appendix D) to the teacher explaining the purpose of the questionnaire and describing the procedures for administration of the instruments. Also, the teacher of each class was asked to fill out an information sheet on school, community, and teacher information, which contained questions about the size of the school and the community, number of science courses taught in grade eleven, and background and qualifications of the teacher.

The teacher was asked to divide his class randomly and to administer to one half of his class Form A, and to the other half Form B of the instrument, Characteristics of Scientists Survey. All students in each class were given the Semantic Differential--Scientist. Thus, each student involved in the study received Form A or Form B of the instrument (as described in Chapter Three) plus the Semantic Differential on the Scientist.

Student responses for items of each category were summed to give seven category scores for each student. Students who completed Form A received scores for Categories I-A, I-B, I-C, II-A, II-B, II-C and items pertaining to the media's image of scientists. Students who completed Form B received scores for Categories III-A, III-B, IV-A, IV-B, IV-C, IV-D and V as described in Chapter Three. The scoring was obtained by assigning numbers 1, 2, 3 and 4 to strongly agree, agree, disagree and strongly disagree respectively for negative statements and reversing the numbering for positive attitude statements.

Multivariate analysis of variance was used to compare the scores of different groups of students grouped according to sex, size of home town, science class (Biology, Chemistry, etc.), socio-economic status and other factors (e.g.grade ten average) to see if there were any differences among groups of students pertaining to their understanding of the characteristics of scientists as measured by the instrument, Characteristics of Scientists Survey, and the Semantic Differential entitled Scientist.

Comparisons were also made between scientists' and students' scores on the instrument to determine if there were significant differences in the scientists' views of their colleagues and high school students' views as measured by the instruments.

The Methods of Analysis

The data for the statistical analysis consisted of (1) fourteen category scores for student responses, seven for Form A and seven for Form B, (2) student responses on the Semantic Differential and (3) fourteen category scores for all scientists. The basic data of the study is ordinal in nature since it comes from fourteen Likert-type scales and a Semantic Differential.

Ordinal scales of the type used in this study are considered to be weak measurements (Stevens, 1951). Stevens argues that measurement scales are models of object relationships and, for the most part, rather poor models which can lead far astray from the truth if scores they yield are added when they should only be counted. Opposing this view, Baker, Hardyck, and Petrinovich (1966) have argued for the use of strong statistics such as the t test and F tests used in analysis of variance procedures. They experimented with transformations in data for different measurement scales--ordinal, interval and ratio. Their findings indicated that strong statistics such as the t and F tests are more than adequate to cope with weak measurements, and that associated probabilities are little affected by the kind of measurement scale used.

In studies similar in nature to the present study, several factors may interact to produce an effect on the respondents' scores. The interaction of various factors or independent variables has to be considered in the interpretation of findings. This, together with the findings of Baker, Hardyk, and Petrinovich (1966), led to the decision to use parametric methods in the analysis of data for this study. Multivariate analysis of variance (MANOVA) is a statistical technique which enables one to consider the effects of several factors independently, while also testing for significant interactions between various factors.

The analysis of multivariate data used in this study is an approach suggested by Cramer and Bock (1966). They recommended an overall, or multivariate, test be carried out on all the variables simultaneously by testing the hypothesis of equal mean vectors, $H_0: \mu_1 = \mu_2$. The generalized means test is the Wilk's lambda which determines a probability level for the null hypothesis of equality of population centroids (mean vectors) on the assumption of multivariate normal populations with equal dispersions. Rejection of H_o: $\mu_1 = \mu_2$ allows one to infer that $\mu_{j1} \neq \mu_{j2}$ is the case for at least one value of j. Following a rejection, Cramer and Bock (1966) recommended that univariate analysis of variance be run for each variable separately. Empirical studies by Hummel and Sligo (1971) compared univariate and multivariate analysis of variance procedures for multivariate data. Their findings (as to error rates per comparison and experimentwise error rates) support Cramer and Bock (1966) in suggesting the approach consisting of a multivariate analysis of variance followed by univariate analyses of variance as being more useful than a series of univariate analyses of variance.

The hypotheses in this study were analyzed using the above procedure. The variables used were the fourteen category scores. The MANOVA program was used to provide an overall test of significance using Wilk's lambda criterion based on Rao's approximate F test (Cramer and Bock, 1966). The multivariate test was used as the basis for rejection of the null hypothesis. If the multivariate test showed significance, then the univariate F tests were examined to find where the differences were apparent. The 0.05 level of significance was used to test the null hypotheses.

Student responses for the 34 descriptive scales in the Semantic Differential--Scientist were analyzed using a series of one-factor analyses of variance. Students' scores were grouped according to three factors; town size, sex, and science class. Mean scores for various levels of each factor were graphed.

In addition to making statistical comparisons for hypothesis testing, the mean category scores of various groups of students and scientists were described to obtain an understanding of the characteristics of scientists as perceived by students and scientists. The mean scores for each category were described in terms of what high and low scores for categories actually represented, which has been discussed in some detail in the third chapter. The results of the above multivariate analysis of variance and a description of mean category scores for groups of students and scientists are presented in the following chapter.

The computer services at Memorial University allowed for the use of a suitable MANOVA program (Clyde Computer Services, 1969) which was used to do all the different computations in the analysis of data of the study.

CHAPTER V

DATA ANALYSIS AND RESULTS

In the first section of this chapter the statistical analysis of results of the study is considered in relation to the three major hypotheses as presented on page 3. To test the hypotheses of no significant differences among various groups of students and various groups of scientists, and between scientists and students, the fourteen category scores on the instrument, Characteristics of Scientists Survey, were analyzed using multivariate analysis of variance.

The multivariate F test at the 0.05 level of significance was used as a basis for rejection of the null hypothesis. If the multivariate F test was significant, univariate F tests for each category were reported to indicate where significant differences existed.

A descriptive analysis of what the mean category scores of groups of scientists and students actually represent is dealt with in the second part of this chapter. The mean scores are described in relation to the meaning of high and low scores for each category as presented in the description of the categories in Chapter Three. (see pages 29-35).

A description of the students' image of a scientist, as measured by the 34 descriptive scales on the Semantic Differential--Scientist , is presented in the final part of this chapter. Various groups of students were compared using one-factor analysis of variance, and the mean scores were graphed for comparison purposes.

Multivariate Analysis of Scientists' Scores and Students' Scores for Hypothesis Testing

Scientists' Scores and Hypothesis One

All scientists involved were asked to complete a questionnaire--Characteristics of Scientists Survey--consisting of 126 items contributing to 14 subscales or 14 category scores. The 14 category scores were the dependent variables in the analysis. The independent variables are referred to as factors throughout the analysis and discussion of results. In relation to scientists' scores, the effect of three factors, (1) type of scientist, (2) highest degree received, and (3) years experience were investigated.

Hypothesis one postulated no significant differences in the perceived characteristics of scientists, as revealed on the instrument Characteristics of Scientists Survey, among groups of professional scientists in various fields. Multivariate analysis of variance was used to test the null hypothesis of no mean differences between groups of scientists on all 14 variables simultaneously. F ratios were computed for the multivariate tests of equality of group mean vectors. The multivariate F tests for 3 two-factor interactions and the three main effects of factors are reported in Table VII.

Examination of Table VII reveals that the multivariate F ratios were not significant at the 0.05 level. There were no significant two-factor interactions between the three factors examined--type of scientist, highest degree received, and years experience. Also, there were no significant main effects differences for either of these factors. Thus,

TABLE VII

ANALYSIS OF VARIANCE FOR COMPARISON OF SCIENTISTS' SCORES GROUPED ACCORDING TO TYPE OF SCIENTIST, HIGHEST DEGREE AND YEARS EXPERIENCE

Multivariate F tests

Factors	Variables	df for Hypothesis	df for Error	F	P less than
1. TS x HD	All 14	84.000	463.419	1.201	0.124
2. TS x YE	All 14	84.000	463.419	0.896	0.727
3. HD x YE	All 14	56.000	332.805	0.731	0.923
4. TS	All 14	42.000	244.017	0.987	0.501
5. HD	All 14	28.000	170.000	0.995	0.479
6. YE	All 14	28.000	164.000	1.019	0.447

TS = type of scientist, 4 levels, 1 = chemists, 2 = biologists, 3 = physicists and 4 = geologists.
HD = highest degree of scientist, 3 levels, 1 = B.Sc., 2 = M.Sc. and 3 = Ph.D.
YE = years experience, 3 levels, 1 = 1-5 years, 2 = 6-10 years and 3 = greater than 10 years.

N = 107 scientists.

it was concluded that the field of study (e.g.biology, chemistry, physics and geology) of the scientist, the number of years experience, and the highest degree earned had no effect on the scientists' scores on the instrument, Characteristics of Scientists Survey. Therefore, the null hypotheses of no differences between groups of scientists' scores are accepted. The univariate F tests for category scores were not reported since none of the multivariate F tests was significant at the 0.05 level.

A possible limitation placed on the interpretation of the results for scientists is the lack of a large representative sampling of scientists. There was also a relatively low percentage return (56%) of the questionnaires sent to scientists. The results may have been different if more questionnaires were returned. Thus, there exists the possibility of a biased sample for those scientists who returned the questionnaire. This possibility will be explored further in Chapter VI.

Group means and standard deviations for all scientists are reported in Table XX, (page 80) where comparisons are made between scientists' and students' scores.

Students' Scores and Hypothesis Two

Student scores on the instrument, Characteristics of Scientists Survey, consisted of fourteen category scores (14 dependent variables), seven for Form A and seven in Form B. A stratified random sample of 15 grade eleven science classes was selected and students in each class were randomly divided in half and one group was administered Form A and the other group Form B. Of the total number of students (510) who completed the questionnaire, 257 received Form A and 253 received Form B. A summary of the number of students involved in the study according to town size, sex and science class is given in Table VI on page 47.

In the analysis of student scores seven factors (independent variables) were investigated to determine if any of these affected student responses on the instrument. Possible interactions among factors were also investigated. The seven factors were:

1. Science class.
2. Sex.
3. Hometown size.
4. Grade ten average.
5. Number of different high school science courses taken or taking.
6. Socio-economic status.
7. The length of their science teacher's teaching experience.

The analysis of students' scores consisted of a series of three-factor and two-factor analyses of variance for each of the seven dependent variables in Form A and for each of the seven dependent variables in Form B. The nature of multivariate analysis of variance allowed for the test of all seven variables (of either Form A or Form B) to be carried out simultaneously, each time a two or three-factor analysis was executed. As with the scientists' scores, the multivariate F tests at the 0.05 level of significance were taken as the basis for rejection of the null hypotheses of equality of group mean for the various groups of student scores that were compared.

Tables VIII - XIV present the results of the multivariate analysis of variance that were carried out for Forms A and B of the student scores.

TABLE VIII

ANALYSIS OF VARIANCE FOR COMPARISON OF STUDENT SCORES GROUPED ACCORDING TO TOWN SIZE, SEX AND SCIENCE CLASS

Multivariate F tests

Factors	All Seven Variables	df for Hypotheses	df for Error	F	P less than
1. TS x Ses x SC	Form A	56.000	1341.503	0.734	0.929
	Form B	56.000	1309.176	1.140	0.227
2. Sex x SC	Form A	28.000	791.038	1.735	0.001*[1]
	Form B	28.000	791.038	0.607	0.947
3. TS x SC	Form A	56.000	1114.655	1.136	0.233
	Form B	56.000	1087.729	1.365	0.040*[1]
4. TS x Sex	Form A	14.000	438.000	0.534	0.913
	Form B	14.000	438.000	1.285	0.212
5. TS	Form A	14.000	438.000	1.225	0.253
	Form B	14.000	438.000	1.724	0.054
6. Sex	Form A	7.000	219.000	1.947	0.064
	Form B	7.000	219.000	1.419	0.199
7. SC	Form A	28.000	791.038	2.043	0.001*[2]
	Form B	28.000	791.058	0.805	0.753

TS = town size, 3 levels, 1 = small (less than 2000), 2 = medium (2000 - 20,000), 3 = large (greater than 20,000).
Sex, 2 levels, male = 1, female = 2.
SC = science class, 5 levels, 1 = chemistry, 2 = biology, 3 = physics, 4 = earth science and 5 = physical science.

*Significant at the 0.05 level
[1]See table XV for univariate F tests.
[2]See table XVIII for univariate F tests

TABLE IX

ANALYSIS OF VARIANCE FOR COMPARISON OF STUDENT SCORES GROUPED ACCORDING TO SEX, NUMBER OF SCIENCE COURSES AND GRADE TEN AVERAGE.

Multivariate F tests

Factors	All Seven Variables	df for Hypothesis	df for Error	F	P less than
1. Sex x NC x GTA	Form A	28.000	841.516	0.749	0.824
	Form B	28 000	823.488	0.925	0.579
2. NC x GTA	Form A	28.000	841.516	1.222	0.199
	Form B	28.000	823.488	1.354	0.105
3. Sex x NC	Form A	14.000	466.000	1.696	0.280
	Form B	14.000	456.000	0.709	0.766
4. Sex x GTA	Form A	14.000	466.000	1.059	0.209
	Form B	14.000	456.000	0.602	0.864

sex, 2 levels, 1 = male, 2 = female.
NC = number of different high school science courses the student has taken. 3 levels, 1, 2 and 3.
GTA = grade ten average, 3 levels, 1 = less than 60, 2 = 61-70 and 3 = greater than 70.

TABLE X

ANALYSIS OF VARIANCE FOR COMPARISON OF STUDENT SCORES GROUPED ACCORDING TO TOWN SIZE, SEX AND SOCIO-ECONOMIC STATUS.

	Multivariate F tests				
Factors	All Seven Variables	df for Hypothesis	df for Error	F	P less than
1. TS x Sex x SES	Form A	28.000	841.516	0.712	0.864
	Form B	28.000	816.277	0.962	0.523
2. Sex x SES	Form A	14.000	466.000	1.033	0.193
	Form B	14.000	456.000	1.532	0.096
3. TS x SES	Form A	28.000	841.516	0.842	0.703
	Form B	28.000	816.277	0.789	0.775

TS = town size, 3 levels, 1 = less than 2000, 2 = 2000 - 20,000, 3 = greater than 20,000.
Sex = 2 levels, 1 = male, and 2 = female.
SES = socio-economic status, 3 levels, 1 = less than 29.71 - 34.07, and 3 = greater than 34.07, according to Blishen's scale (1967).

TABLE XI

ANALYSIS OF VARIANCE FOR STUDENT SCORES GROUPED ACCORDING TO SCIENCE COURSE, GRADE TEN AVERAGE AND SOCIO-ECONOMIC STATUS

Multivariate F tests

Factors	All Seven Variables	df for Hypotheses	df for Error	F	P less than
1. GTA x SES	Form A	28.000	744.166	1.081	0.354
	Form B	28.000	726.138	1.055	0.388
2. SC x SES	Form A	56.000	1114.655	1.081	0.321
	Form B	56.000	1087.729	1.355	0.045*[1]
3. SC x GTA	Form A	56.000	1114.655	1.473	0.015*[2]
	Form B	56.000	1087.729	1.611	0.003*[2]
4. GTA	Form A	14.000	412.000	1.163	0.301
	Form B	14.000	402.000	1.298	0.205
5. SES	Form A	14.000	412.000	2.164	0.013*[3]
	Form B	14.000	402.000	1.109	0.348

SC = science course, 5 levles, 1 = chemistry, 2 = biology, 3 = physics, 4 = earth science, 5 = physical science.
GTA = grade ten average, 3 levels, 1 = less than 60, 2 = 61-70, and 3 = greater than 70.
SES = socio-economic status, 3 levels, 1 = low (less than 29.71), 2 = medium (29.71-34.07), 3 high (greater than 34.07), according to Blishen's Scale (1967).

*Significant at the 0.05 level.
[1]See table XVII for univariate f tests.
[2]See table XVI for univariate f tests.
[3]See table XVIII for univariate f tests.

TABLE XII

ANALYSIS OF VARIANCE FOR COMPARISON OF STUDENT SCORES GROUPED ACCORDING TO: 1. TOWN SIZE AND GRADE TEN AVERAGE; 2. TOWN SIZE AND NUMBER OF SCIENCE COURSES; 3. NUMBER OF SCIENCE COURSES AND SOCIO-ECONOMIC STATUS

Multivariate F tests

Factors	All Seven Variables	df for Hypothesis	df for Error	F	P less than
1. TS x GTA	Form A	28.000	873.966	0.738	0.837
	Form B	28.000	855.938	1.311	0.131
2. TS x NC	Form A	28.000	873.966	1.328	0.120
	Form B	28.000	855.938	1.229	0.192
3. NC x SES	Form A	28.000	873.966	1.277	0.154
	Form B	28.000	855.938	0.732	0.843

TS = town size, 3 levels, 1 = less than 2000, 2 = 2000 - 20,000 and 3 = greater than 20,000.
GTA = grade ten average, 3 levels, 1 = less than 61, 2 = 61-70, 3 = greater than 70.
NC = number of different high school science courses taken by the student. 3 levels, 1,2 and 3.
SES = socio-economic status, 3 levels, 1 = less than 29.71, 2 = 29.71 - 34.07, and 3 = greater than 34.07, according to Blishens'scale (1967)

TABLE XIII

ANALYSIS OF VARIANCE FOR COMPARISON OF STUDENT SCORES GROUPED ACCORDING TO SCIENCE COURSE AND NUMBER OF DIFFERENT HIGH SCHOOL SCIENCE COURSES TAKEN BY THE STUDENT

Multivariate F tests

Factors	All Seven Variables	df for Hypotheses	df for Error	F	P less than
1. NC x SC	Form A	56.000	1276.210	1.208	0.091
	Form B	56.000	1254.669	1.070	0.339
2. NC	Form A	14.000	472.000	1.468	0.119
	Form B	14.000	464.000	0.848	0.617

NC = number of courses, 3 levels, 1 = 1 science course, 2 = 2 different high school science courses, and 3 = 3 different high school science courses.
SC = science course, 5 levels, 1 = chemistry, 2 = biology, 3 = physics, 4 = earth science and 5 = physical science.

TABLE XIV

ANALYSIS OF VARIANCE FOR COMPARISON OF STUDENT SCORES GROUPED ACCORDING TO THEIR TEACHER'S EXPERIENCE

Multivariate F test

Factor	All Seven Variables	df for Hypothesis	df for Error	F	P less than
1. TE	Form A	14.000	496.000	1.669	0.059
	Form B	14.000	486.000	1.099	0.355

TE = teacher's experience, 3 levels, 1 = 1-3 years, 2 = 4-10 years and 3 = greater than 10 years.

In these tables only the multivariate F tests are reported. If a multivariate F test showed significance at the 0.05 level for either an interaction or a main effect, the univariate F tests are reported in a second table, to indicate the category or categories for which the differences were apparent.

An examination of Tables VIII, IX and X reveals that there were no significant three-factor interactions between; (1) town size, sex and science class; (2) sex, number of science courses and grade ten average; and (3) town size, sex and socio-economic status. However, there were significant two-factor interactions of sex and science class for variables in Form A ($p < 0.001$), and of town size and science class for variables in Form B ($p < 0.040$). Univariate F tests for these interactions are reported in Table XV.

The results of multivariate tests for other possible two-factor interactions which were not tested in the multivariate three-factor tests are reported in Tables XI, XII, XIII and XIV. Examination of Table XI reveals there were significant two-way interactions for science class and grade ten average on Form A ($p < 0.015$) and Form B ($p < 0.003$). Also, there was a significant interaction of science class and socio-economic status for Form B ($p < 0.045$). The univariate F tests showing the categories for which these interactions were present are reported in Tables XVI and XVII.

In the analysis of student scores, two-factor interactions were encountered for categories II-A and I-B of Form A. Table XV reports a significant interaction ($p < 0.001$) between sex and science class for category II-A. Scheffe's method of multiple comparisons (Glass and

TABLE XV

ANALYSIS OF VARIANCE FOR COMPARISON OF STUDENT SCORES GROUPED ACCORDING TO: (1) SEX AND SCIENCE CLASS; (2) TOWN SIZE AND SCIENCE CLASS.

Multivariate F tests

Factors	Variables	df, for Hypothesis	df for Error	F	P less than
1. Sex x SC	Form A (1-7)	28.000	791.038	1.735	0.001*
2. TS x SC	Form B (8-14)	56.000	1184.662	1.365	0.040*

Univariate F tests

Variables	Mean Square	F**	P less than
1. Cat I-A	22.642	1.396	0.236
2. Cat I-B	13.661	2.054	0.236
3. Cat I-C	7.595	1.068	0.373
4. Cat II-A	44.569	6.411	0.001*
5. Cat II-B	9.202	1.295	0.273
6. Cat II-C	5.966	1.865	0.117
7. Cat VI	1.125	0.320	0.864
8. Cat III-A	5.049	0.760	0.638
9. Cat III-B	10.090	1.760	0.270
10. Cat IV-A	19.385	2.491	0.013*
11. Cat IV-B	2.166	0.508	0.850
12. Cat IV-C	3.590	0.900	0.517
13. Cat IV-D	8.936	1.403	0.096
14. Cat V	32.195	1.869	0.066

sex, 2 levels, 1 - male, 2 = female
SC = science class, 1 = chemistry, 2 = biology, 3 = physics, 4 = earth science, 5 = physical science.
TS = town size, 3 levels, 1 = less than 2000, 2 = 2,000-20,000 3 = greater than 20,000.

*Significant at the 0.05 level
**Degrees of freedom for variables 1-7 = (4,225), for variables 8-14 = (8,225).

Stanley, 1970) was used to determine the source of the interaction. Girls in physical science (N = 23, $\overline{x}$ = 30.870) scored significally lower on category II-A than: (1) girls in biology (N = 46, $\overline{x}$ = 34.592); (2) girls in chemistry (N = 26, $\overline{x}$ = 33.831); (3) girls in earth science (N = 19, $\overline{x}$ = 33.580); and (4) boys in physical science (N = 14, $\overline{x}$ = 33.900). The low score of girls in physical science for category II-A meant this group felt, to a lesser degree than other groups, that the motivation to become a scientist is due to intrinsic factors such as curiosity and the desire to know.

In category I-B of Form A (see Table XVI), there was a significant interaction ($p < 0.032$) of science class and grade ten average. Physical science students (N = 15, $\overline{x}$ = 23.533) with a medium (61-70) grade ten average scored significantly lower than: (1) physics students with a medium grade ten average (N = 15, $\overline{x}$ = 27.270); and (2) chemistry students with a medium grade ten average (N = 9, $\overline{x}$ = 26.400). The lower mean score on category I-B for physical science students with a medium grade ten average indicated this group felt, to a lesser extent than the other groups, that scientists are critically-minded in their work.

Two-factor interactions for categories in Form B are also reported in Table XV, XVI, and XVII. Analysis of data for students' scores revealed significant interactions between: (1) town size and science class for category IV-A; (2) science class and grade ten average for categories III-A and III-B; and (3) science class and socio-economic status for categories III-B and IV-D.

An interaction of town size and science class for category IV-A was due to differences between chemistry students from small towns (N = 5,

TABLE XVI

ANALYSIS OF VARIANCE FOR COMPARISON OF STUDENT SCORES GROUPED ACCORDING TO SCIENCE CLASS AND GRADE TEN AVERAGE.

Multivariate F tests

Factors	All Seven Variables	df for Hypothesis	df for Error	F	P less than
1. SCxGTA	Form A (1-7)	56.000	1114.655	1.473	0.015*
	Form B (8-14)	56.000	1087.729	1.611	0.003*

Univariate F tests

Variables	Mean Square	F**	P less than
1. Cat I-A	12.861	0.792	0.610
2. Cat I-B	13.404	2.158	0.032*
3. Cat I-C	5.460	0.766	0.633
4. Cat II-A	9.015	1.243	0.276
5. Cat II-B	6.756	0.990	0.445
6. Cat II-C	5.047	1.772	0.084
7. Cat VI	4.474	1.446	0.179
8. Cat III-A	15.077	2.630	0.009*
9. Cat III-B	17.392	2.629	0.009*
10. Cat IV-A	11.015	1.716	0.096
11. Cat IV-B	3.834	1.203	0.299
12. Cat IV-C	4.028	1.095	0.368
13. Cat IV-D	7.338	1.208	0.296
14. Cat V	16.360	1.321	0.234

SC = science course, 5 levels, 1 = chemistry, 2 = biology, 3 = physics, 4 = earth science, 5 = physical science.
GTA = grade ten average, 3 levels, 1 = less than 60, 2 = 61-70, 3 = greater than 70.

*Significant at the 0.05 level
**Degrees of freedom for variables 1-7 = (8,212), for variables 8-14 = (8,207).

TABLE XVII

ANALYSIS OF VARIANCE FOR COMPARISON OF STUDENTS SCORES GROUPED ACCORDING TO SCIENCE CLASS AND SOCIO-ECONOMIC STATUS

Multivariate F Test

Factors	All Seven Variables	df for Hypothesis	df for Error	F	P less than
SC x SES	Form B	56.000	1087.729	1.355	0.045*

Univariate F Tests

Variables	Mean Square	F**	P less than
1. Cat III-A	10.060	1.755	0.088
2. Cat III-B	13.165	1.990	0.049*
3. Cat IV-A	5.843	0.910	0.509
4. Cat IV-B	2.350	0.737	0.659
5. Cat IV-C	6.553	1.781	0.082
6. Cat IV-D	14.697	2.420	0.016*
7. Cat V	4.913	0.397	0.922

SC = Science Class, 5 levels, 1 = chemistry, 2 = biology, 3 = physics, 4 = earth science, and 5 = physical science.
SES = Socio-Economic Status by Blishen's Scale (1967) 1 = low (less than 29.07), 2 = medium (29.71--34.07), and 3 = high (greater than 34.07).

*Significant at the 0.05 level
**Degrees of freedom = (8,207).

$\bar{x}$ = 33.750) and earth science students from medium sized towns (N = 12, $\bar{x}$ = 27.612). The small number (5) of chemistry students from small towns is a possible explanation for the interaction. However, this group felt more strongly than the earth science students (as evidenced by a higher mean score for category III-A) that scientists have strong obligations to keep the public informed about their work.

Significant interactions (at the 0.05 level) of science class and grade ten average for categories III-A and III-B were encountered in the analysis of the data. In category III-A, Scheffe's method showed differences between physical science students of medium grade ten average (N = 15, $\bar{x}$ = 27.611) and earth science students of high grade ten average (N = 16, $\bar{x}$ = 29.861) grouped with physics students of medium grade ten average (N = 18, $\bar{x}$ = 29.440). The lower mean score on category III-A for the physical science students meant this group felt, to a lesser extent than the other two groups, that most scientists believe in order and balance in nature and think that the universe is real and knowable. Scheffe's method of multiple comparisons showed no "two-group" contrasts that were significant at the 0.05 level for students' scores on category III-B. However, there were significant differences between the two highest mean scores grouped and contrasted with the two lowest mean scores grouped. Physical science students with a medium grade ten average (N = 15, $\bar{x}$ = 37.278) grouped with biology students of low grade ten average (N = 21, $\bar{x}$ = 26.318) scored significantly higher than physics students of low grade ten average (N = 6, $\bar{x}$ = 34.167) and physical science students of low grade ten average (N = 12, $\bar{x}$ = 34.133). The higher mean scores on category III-B for the physical science and biology students indicated that this group felt more strongly, than the other two groups, that most scientists are religious in that they believe in God and appreciate the church.

Univariate F's for interactions of science class and socio-economic status are reported in Table XVII, page 70. Scheffe's method of multiple comparisons was used to determine the source of the interaction for categories III-B and IV-D. In category III-B, physical science students of low socio-economic status (N = 13, $\bar{x}$ = 29.356) scored significantly lower than: (1) chemistry students of medium socio-economic status (N = 9, $\bar{x}$ = 36.143); (2) biology students of low socio-economic status (N = 33, $\bar{x}$ = 36.318); (3) earth science students of low socio-economic status (N = 14, $\bar{x}$ = 36.037); and (4) physical science students of high socio-economic status (N = 9, $\bar{x}$ = 36.889). The lower mean score of the physical science students of low socio-economic status indicated that this group did not feel as strongly as the other three groups that most scientists were religious people.

In category IV-D, physics students of high socio-economic status (N = 20, $\bar{x}$ = 25.778) grouped with physical science students of high socio-economic status (N = 9, $\bar{x}$ = 26.600) scored significantly higher than earth science students of medium socio-economic status (N = 17, $\bar{x}$ = 23.344) grouped with chemistry students of high socio-economic status (N = 25, $\bar{x}$ = 23.492). The higher mean score on category IV-D indicates that the physics and physical science students of high socio-economic status felt more strongly, than the other two groups, that most scientists recognize the importance of the contributions made by science and technology to social progress and melioration.

The analysis of students' scores revealed that out of the three three-factor and the 15 two-factor interactions that were examined for all 14 category scores, only four two-factor interactions were found to be significant at the 0.05 level. The four interactions have been discussed in this section of the results. These interactions were: (1) sex and science class for category II-A; (2) science class and grade ten average for categories I-B, III-A and III-B; (3) town size and science class for category IV-A; and (4) science class and socio-economic status for categories III-B and IV-D. All interactions involved the science class of the students, and most of the interactions were due to lower or higher scores for groups of physical science students. Some of the interactions could have been the result of small numbers in the interacting groups. The number of category scores for which there were interactions is relatively small. For each of the 14 category scores, 15 two-factor interactions were tested for (a total of 210 possibilities), and only 4 two-factor interactions affecting seven category scores were significant at the 0.05 level. There were no significant three-factor interactions.

Multivariate F tests were significant at the 0.001 level for main effects of science class (see Table VIII, page 60) on category scores in Form A. Analysis of student scores grouped according to science class revealed significant differences for categories I-A, I-B, I-C, II-A and II-B. However, scores for categories I-B and II-A involved interactions of science class with grade ten average, and science class with sex, respectively. A summary of significant main effects for category scores in which there were no two-factor or three-factor interactions is given in Table XVIII.

Scheffe's method of multiple comparisons indicated that chemistry students (N = 61, $\bar{x}$ = 38.869) scored significantly higher than earth science students (N = 39, $\bar{x}$ = 36.487) on category I-A. The higher mean score for chemistry students on category I-A is an indication that this group felt more strongly than the earth science students that most scientists value scientific integrity highly in their work. Scientific integrity included such factors as honesty and open-mindedness.

In category I-C, physical science students (N = 37, $\bar{x}$ = 39.378) scored significantly lower than chemistry students (N = 61, $\bar{x}$ = 39.852), biology students (N = 66, $\bar{x}$ = 39.515), and physics students (N = 54, $\bar{x}$ = 39.444). The lower mean score for the physical science students indicated this group did **not** feel as strongly as the other three groups that most scientists have positive attitudes towards the operational adjustments (e.g. dedication, initiative, resourcefulness and others) necessary for a successful life in the scientific community.

Multiple comparisons for category II-B showed that scores of physical science students (N = 37, $\bar{x}$ = 24.162) were significantly lower than chemistry students (N = 61, $\bar{x}$ = 26.149) and biology students (N = 66, $\bar{x}$ = 26.015). The physical science students felt less strongly than the other two groups that most scientists are motivated to do science by a cultural concern to contribute to knowledge and human welfare.

All significant differences (at the 0.05 level) in student scores were between students of chemistry, physics and biology and those of either earth science or physical science. Examination of Table XVIII shows that the mean scores of earth science students on categories

TABLE XVIII

SUMMARY OF SIGNIFICANT MAIN EFFECTS FOR CATEGORY SCORES IN WHICH THERE WERE NO SIGNIFICANT TWO-FACTOR OR THREE-FACTOR INTERACTIONS

Factors	Variables	Score Range	Group Means					Univariate F**	P less than
			$\bar{x}_1$	$\bar{x}_2$	$\bar{x}_3$	$\bar{x}_4$	$\bar{x}_5$		
I. Science Class	1. Cat I-A	12-48	38.869	37.788	37.870	36.487	37.027	2.453	0.046*
	2. Cat I-C	12-48	39.852	39.515	39.444	38.231	37.378	6.380	0.001*
	3. Cat II-B	8-32	26.049	26.015	25.685	25.282	24.162	3.460	0.009*
				x_a	x_b	x_c		F***	
II. Socio-Economic Status	4. Cat II-C	8-32		22.362	24.150	23.192		3.223	0.042*
	5. Cat VI	2-8		6.183	5.113	5.536		5.146	0.006*

$\bar{x}_1$ - chemistry students
$\bar{x}_2$ - biology students
$\bar{x}_3$ - physics students
$\bar{x}_4$ - earth science students
$\bar{x}_5$ - physical science students

$\bar{x}_a$ low socio-economic status
$\bar{x}_b$ medium socio-economic status
$\bar{x}_c$ high socio-economic status

*Significant at the 0.05 level
**Degrees of freedom for variables 1-3 is (4,252)
***Degrees of freedom for variables 4-5 is (2,248)

I-A, I-C, and II-B were lower than the mean scores of students in chemistry, physics and biology classes. In all three categories chemistry students had the highest mean scores, and for two of the categories (I-C and II-B) physical science students had the the lowest mean scores.

Table XVIII also reports significant differences for socio-economic groupings on student scores for categories II-C and VI. Scheffe's method of multiple comparisons indicated significant differences ($p < 0.05$) for all possible contrasts of low, medium and high socio-economic status groups. Students from low socio-economic backgrounds (N = 81, x = 22.362) had the lowest mean score and students from medium socio-economic status (N = 70, x = 24.150) had the highest mean score. The group mean for high socio-economic status (N = 106, x = 23.192) was approximately half way between the other two groups. The lower mean score on category II-C for students of low socio-economic status meant this group did not feel as strongly as the other two groups that most scientists were motivated to science as a result of external factors such as financial rewards and prestige.

Scheffe's method indicated that the mean score of category VI for low socio-economic students ($\bar{x}$ = 6.183) was significantly higher than the mean scores of medium socio-economic students ($\bar{x}$ = 5.113) and high socio-economic students ($\bar{x}$ = 5.536). The higher mean score of students from low socio-economic backgrounds indicated that this group felt more strongly than the other two groups that most scientists are much like they appear in science fiction movies and stories.

<u>Hypothesis two stated that there are no significant differences in the perceived characteristics of scientists, as revealed on the</u>

instrument, Characteristics of Scientists Survey, among various groups of eleventh grade students. The null hypothesis is rejected at the 0.05 level of significance in 10 of the fourteen categories because of: (1) differences between student scores due to the effect of science class for categories I-A, I-C, and II-B; (2) differences between socio-economic groups for scores on categories II-C and VI, and (3) differences due to two-factor interactions for categories I-B, II-A, III-A, III-B, IV-A, and IV-D which are discussed on pages 66-73 of this chapter. However, the null hypothesis of no differences in groups of students' scores holds true for four of the categories. The categories in which no differences between groups of student scores were observed were IV-B,IV-C, and V.

Comparison of Scientists' Scores and Students' Scores for Hypothesis Three

A major objective of this study was to compare the understanding of the characteristics of scientists possessed by students with that of practising scientists. As a basis for comparison, a similar instrument, Characteristics of Scientists Survey, was presented to both groups. Respondents were asked to reply to attitude statements of the format 1--strongly agree, 2--agree, 3--disagree and 4--strongly disagree for negative statements. The scoring for positive attitude statements was reversed such that positive attitudes would contribute to higher scores.

Students were asked to respond to items on the basis of whether they thought the statement applied to most scientists. Scientists were requested to respond on the basis of whether they felt the statement applied to most of their colleagues in each of their respective fields; i.e. chemists were asked about their understanding of most chemists, and similarly for physicists, biologists, and geologists.

Students' and scientists' scores for all fourteen categories were compared for two groupings: (1) all scientists vs. all students and (2) all scientists' vs. students' scores grouped according to science class. Multivariate one-factor analysis of variance was used to test for differences between scientists' scores and students' scores. The multivariate F test at the 0.05 level was used as a basis for rejection of the null hypothesis of equality of group mean vectors.

Table XIX presents the results of the multivariate analysis of variance for the comparisons of all scientists' scores and all students' scores, two groups. The multivariate F tests for both Form A and Form B were significant at the 0.001 level. Univariate F tests showed significant differences between scientists and students for categories I-A, I-C, II-B, III-A, III-B, IV-B, and IV-C. However, there were no differences between all scientists' scores and all students' scores for categories I-B, II-A, II-C, IV-A, IV-D, V and VI. The means and standard deviations of scores for all scientists and all students are reported in Table XX.

As indicated by Table XIX, analysis of data indicated seven categories which produced significant differences ($p < 0.05$) between the scores of all scientists and all students. Students scored significantly higher than scientists on six of the seven categories. Students scored lower than scientists on category III-A which dealt with the philosophical beliefs of scientists. In general, positive attitudes contribute to higher scores, and it appeared that students possessed more positive images of scientists than scientists themselves possessed.

TABLE XIX

ANALYSIS OF VARIANCE FOR COMPARISON OF ALL SCIENTISTS' SCORES WITH ALL GRADE ELEVEN HIGH SCHOOL STUDENTS' SCORES

Multivariate F tests

Factors	Variables	df for Hypothesis	df for Error	F	P less than
Grouping	Form A (1-7)	7.000	356.000	8.998	0.001*
(2 levels)	Form B (8-14)	7.000	351.000	24.417	0.001*

Univariate F tests

Variables	Mean Square	F**	P less than
1. Cat I-A	72.778	4.884	0.028*
2. Cat I-B	19.841	2.787	0.096
3. Cat I-C	254.338	31.791	0.001*
4. Cat II-A	3.221	0.395	0.530
5. Cat II-B	163.404	26.290	0.001*
6. Cat II-C	2.605	0.792	0.374
7. Cat VI	7.344	3.000	0.084
8. Cat III-A	477.639	73.087	0.001*
9. Cat III-B	552.273	80.962	0.001*
10. Cat IV-A	0.326	0.049	0.824
11. Cat IV-B	59.370	16.894	0.001*
12. Cat IV-C	18.978	5.443	0.020*
13. Cat IV-D	3.293	0.537	0.464
14. Cat V	2.770	0.237	0.626

Grouping, 2 levels, 1 = grade eleven students, 2 = scientists

*Significant at the 0.05 level.
**Degrees of freedom for variables 1 - 7 = 1,362; for variables 8 - 14 = 1,357.

TABLE XX

MEANS AND STANDARD DEVIATIONS FOR COMPARISON OF ALL SCIENTISTS' SCORES AND ALL STUDENTS' SCORES

Variables	Score Range	Scientists Mean	Scientists S.D.	Students Mean	Students S.D.
1. Cat I-A	12 - 48	36.785	3.334	37.767	4.058
2. Cat I-B	8 - 32	25.495	2.493	26.008	2.737
3. Cat I-C	12 - 48	37.243	2.774	39.078	2.851
4. Cat II-A	10 - 40	33.093	3.202	33.300	2.691
5. Cat II-B	8 - 32	24.140	1.830	25.611	2.721
6. Cat II-C	8 - 32	23.598	1.995	23.412	1.732
7. Cat VI	2 - 8	5.346	0.616	5.658	1.818
8. Cat III-A	10 - 40	31.065	2.707	28.544	2.490
9. Cat III-B	12 - 48	32.570	2.299	35.282	2.733
10. Cat IV-A	10 - 40	29.252	2.473	29.187	2.603
11. Cat IV-B	6 - 24	17.551	1.992	18.440	1.823
12. Cat IV-C	6 - 24	18.140	1.581	18.643	1.976
13. Cat IV-D	8 - 32	24.757	2.318	24.548	2.541
14. Cat V	14 - 56	41.879	3.137	41.687	3.526

For students, n = 257 for variables 1 - 7, and n = 252 for variables 8 - 14.
For scientists, n = 107 for variables 1 - 14.

A higher mean score for all students on category I-A indicated students felt more strongly than scientists that most scientists value scientific integrity highly in their work. Scientific integrity included such factors as objectivity, honesty, suspended judgment and idea-sharing. Students also scored higher than scientists on category I-C indicating that they felt more strongly than scientists, that most scientists have positive attitudes toward the operational requirements of a successful life in the scientific community. Operational requirements included such factors as dedication and commitment, initiative and resourcefulness, and relations with colleagues such as cooperation, humility and tolerance.

The mean score for all students was significantly higher than the mean scores for all scientists on category II-B. This indicated that students agreed more strongly than scientists that scientists are highly motivated to do science by a cultural concern to contribute to knowledge and human welfare.

For category III-A, dealing with the philosophical beliefs of scientists pertaining to a real and knowable universe, the mean score of all students was lower than the mean score of all scientists. The higher score for scientists indicated they felt more strongly than students that most scientists believe in order and balance in nature, and think that the universe is, within limits, comprehensible and knowable.

Students scored significantly higher than all scientists for categories III-B, IV-B and IV-C. For III-B, a higher mean score for all students meant students thought that scientists were more religious than scientists themselves felt they were. A higher mean score of students on categories IV-B and IV-C indicated students' attitudes differed from scientists' as to the role of scientists in society. For category IV-B, students felt more strongly than scientists that most scientists have a strong role to play in making decisions about how science is used. A higher mean score for all students on category IV-C indicated that students also felt more strongly than scientists that most scientists recognize the need to develop a proper relationship between science and society as being important for the proper development of science.

Multivariate analysis of scientists' scores (see Table VII, page 5) showed no significant differences in scientists' scores grouped according to type of scientist, years experience and highest degree received. However, analysis of students' scores revealed significant differences (see Table XVIII, page 75) in student scores for categories I-A, I-C and II-B, grouped according to science class. Also, four interactions of science class with other factors were described (see pages 66-73) for categories I-B, II-A, III-A, III-B, IV-A and IV-D. Because of differences in students' scores due to science class, comparisons were made between all scientists' and students' scores grouped according to science class; i.e. chemistry, biology, physics, earth science and physical science. Results of the multivariate analysis of variance are presented in Table XXI. The multivariate F tests for Forms A and B showed significant differences at the 0.05 level. Univariate F tests were significant at the 0.05 level for categories I-A, I-B, I-C, II-B, VI, III-A, III-B and IV-C. The mean scores of all scientists and of students grouped according to science class are reported in Table XXII.

Scheffe's method of multiple comparisons revealed that the scores

TABLE XXI

ANALYSIS OF VARIANCE FOR COMPARISON OF ALL SCIENTISTS' SCORES AND GRADE ELEVEN HIGH SCHOOL STUDENTS' SCORES GROUPED ACCORDING TO SCIENCE CLASS

Multivariate F tests

Factors	Variables	df for Hypothesis	df for Error	F	P less than
Grouping	Form A (1-7)	35.000	1483.160	3.364	0.001*
(6 levels)	Form B (8-14)	35.000	1462.126	5.075	0.001*

Univariate F tests

Variable	Mean Square	F**	P less than
1. Cat I-A	45.474	3.107	0.009*
2. Cat I-B	43.370	6.525	0.001*
3. Cat I-C	89.130	11.797	0.001*
4. Cat II-A	14.896	1.858	0.101
5. Cat II-B	48.837	8.060	0.001*
6. Cat II-C	2.463	0.747	0.589
7. Cat VI	6.007	2.491	0.031*
8. Cat III-A	100.441	15.359	0.001*
9. Cat III-B	114.310	16.702	0.001*
10. Cat IV-A	3.482	0.527	0.756
11. Cat IV-B	12.943	3.657	0.003*
12. Cat IV-C	10.302	3.000	0.001*
13. Cat IV-D	12.885	2.137	0.061
14. Cat V	7.330	0.627	0.680

grouping, 6 levels, 1 = chemistry students, 2 = biology students, 3 = physics students, 4 = earth science students, 5 = physical science students, and 6 = all scientists.

*Significant at the 0.05 level
**Degrees of freedom: for variables 1-7 = 5,358; for variables 8-14 = 5,353.

TABLE XXII

GROUP MEANS FOR COMPARISON OF SCIENTISTS' SCORES WITH STUDENTS' SCORES GROUPED ACCORDING TO SCIENCE CLASS

Variables	Score Range	Group Means						F**	P less than
		$\bar{x}_1$	$\bar{x}_2$	$\bar{x}_3$	$\bar{x}_4$	$\bar{x}_5$	$\bar{x}_6$		
1. Cat I-A	12-48	38.869	37.788	37.870	36.487	37.027	36.785	3.107	0.009*
2. Cat I-B	8-32	26.984	26.242	26.426	24.641	24.811	25.495	6.525	0.001*
3. Cat I-C	12-48	39.852	39.515	39.444	38.231	37.378	37.243	11.797	0.001*
4. Cat II-A	10-40	33.639	33.697	33.519	32.795	32.243	33.093	1.858	0.101
5. Cat II-B	8-32	26.049	26.015	25.685	25.282	24.162	24.140	8.060	0.001*
6. Cat II-C	8-32	23.197	23.667	23.259	23.359	23.595	23.598	0.747	0.589
7. Cat VI	2- 8	5.607	5.515	5.370	5.744	6.324	5.346	2.491	0.031*
8. Cat III-A	10-40	28.957	28.519	28.600	28.625	27.853	31.065	15.359	0.001*
9. Cat III-B	12-48	35.543	35.152	35.133	35.000	35.824	32.570	16.702	0.001*
10. Cat IV-A	10-40	29.543	29.114	29.444	28.792	29.088	29.252	0.527	0.756
11. Cat IV-B	6-24	18.652	18.443	18.267	18.542	18.235	17.551	3.657	0.003*
12. Cat IV-C	6-24	19.217	18.532	18.844	18.542	18.000	18.140	3.000	0.001*
13. Cat IV-D	8-32	24.957	24.367	25.244	23.771	24.588	24.757	2.137	0.061
14. Cat V	14-56	41.761	41.684	41.556	41.188	42.471	41.879	0.627	0.680

$\bar{x}_1$ = chemistry students, $\bar{x}_2$ = biology students, $\bar{x}_3$ = physics students, $\bar{x}_4$ = earth science students, $\bar{x}_5$ = physical science students, and $\bar{x}_6$ = scientists.

*Significant at the 0.05 level
**Degrees of freedom for variables 1-7 = (5,358), for variables 8-14 = (5,353).

of only chemistry students differed significantly from scientists for categories I-A and I-B. Chemistry students felt more strongly than scientists, as evidenced by a higher mean score for category I-A, that most scientists value scientific integrity highly in their work. Scientific integrity included such factors as objectivity, suspended judgment, open-mindedness and idea sharing. For category I-B, chemistry students also felt more strongly than scientists that most scientists are very critically minded in their work.

For category I-C, chemistry students, biology students and physics students scored significantly higher than all scientists. There were no differences in physical science and earth science students' scores and the scores of all scientists. The higher mean scores on category I-C for students in physics, chemistry and biology indicated that these groups felt more strongly than scientists that most scientists have positive attitudes toward the operational requirements (e.g. dedication and commitment, initiative and resourcefulness, and cooperation with peers) of a successful life in the scientific community.

Multiple comparisons showed that the mean scores of students in chemistry, physics and biology were significantly higher (at the 0.05 level) than the mean score of all scientists on category II-B. The higher mean scores on category II-B indicated these students felt more strongly than scientists that scientists are highly motivated to do science as a result of a cultural concern to improve human welfare. As for category I-C, there were no significant differences in the mean scores of physical science students, earth science students and all scientists on category II-B.

Scheffe's method of multiple comparisons for category VI indicated that the mean score of only one group--physical science students--was significantly different from the mean score of all scientists. The higher mean score for the physical science students on category VI indicated this group felt more strongly than scientists that most scientists are much like they appear in science fiction movies and stories.

For categories III-A and III-B of Form B, the mean score of each of the five classes of students was significantly different (at the 0.05 level) from the mean score of all scientists, as calculated by Scheffe's method of multiple comparisons. All student groups scored significantly higher than all scientists for category III-A and significantly lower on category III-B. A description of what these differences mean is presented on page 81 of this section.

Multiple comparisons for category IV-B indicated no significant differences between any one group of students contrasted with all scientists. However, there was a significant difference between the mean of all students' scores contrasted with the mean of all scientists' scores. This difference has been described on page 82 of this section.

Finally, multiple comparisons of the mean scores of groups of students and all scientists for category IV-C indicated that chemistry students was the only group which scored significantly higher (at the 0.05 level) than all scientists on that category. Chemistry students felt more strongly than scientists that most scientists recognize the need to develop a relationship between science and society as being important for the proper development of science.

To summarize, Hypothesis Three (<u>no significant differences in</u>

the perceived characteristics of scientists, as revealed on the instrument, Characteristics of Scientists Survey, between professional scientists and eleventh grade high school students) is rejected, since the multivariate F tests were significant at the 0.001 levels for both Forms A and B. Univariate F tests showed significant differences at the 0.05 level for scientists' and student scores on categories I-A, I-B, I-C, II-B, III-A, III-B, IV-B, IV-C and VI. With the exception of category III-A, students' mean scores for these categories were higher than the mean scores of all scientists. Generally, positive attitudes tended to contribute to higher scores (except for category VI), and the results indicated that students had more positive attitudes towards most scientists than the scientists in this study. Students in either chemistry or physical science tended to differ from scientists more so than other groups. For categories in which significant differences appeared between scientists and students, chemistry students scored highest on categories I-A, I-B, I-C, II-B, III-A, IV-B and IV-C. Physical science students scored higher than any other group on categories VI and III-B.

Although no significant differences were observed among students' scores for categories III-A and III-B, each group of students differed significantly from scientists when mean scores were contrasted using Scheffe's method of multiple comparisons. Categories III-A and III-B dealt with the philosophical and religious beliefs of scientists.

It is also of importance to emphasize here that no differences were observed between scientists' scores and students' scores for five of the fourteen categories. These categories were II-A, II-C, IV-A, IV-D and V. A description of these categories is presented on pages 29-35 of chapter three. Also, a discussion of what the mean scores for these and other categories represent appears in the following section of this chapter.

Descriptive Analysis of the Mean Scores for Categories

In measuring students' and scientists' understanding of the characteristics of scientists, two aspects were of interest. The first aspect dealt with hypothesis testing of differences in category means for various groups. The second aspect is of interest because it is concerned with the actual meaning of category scores. The question arises as to what the means scores for categories actually tell us about students' and scientists' understanding of the characteristics of scientists.

The instrument, Characteristics of Scientists Survey, consisted of 14 subscales or 14 categories. The criteria upon which these categories are based have been described in some detail in the third chapter (see pages 29-35). The instrument consisted of 126 items for two Forms, A and B. Form A consisted of 60 items contributing to categories I-A, I-B, I-C, II-A, II-B, II-C and VI, and Form B consisted of 66 items contributing to categories III-A, III-B, IV-A, IV-B, IV-C, IV-D and V. Items for the categories were randomly distributed throughout each form of the instrument. Each category consisted of an even number of items, half worded negatively (contributing to a low score) and half worded positively (contributing to a high score). This balance reduced the possibility of the respondent being influenced to respond either positively or negatively.

The response mode for all items was of the format 1—strongly agree, 2—agree, 3—disagree, 4—strongly disagree. When items for each category were summed, the scoring for negatively worded items was kept as above, but the scoring was reversed for positive items such that generally positive statements would contribute to higher scores.

For example, consider a category consisting of 8 items,4 worded positively and 4 worded negatively. If a respondent strongly agreed (4) or agreed (3) with all positively worded statements and strongly disagreed (4) or disagreed (3) with all negatively worded items, his score would be in the range 16-8. Thus the score range for a category consisting of 8 items is 8-32 with a low score range of 8-16, a medium score range of 17-23 and a high score range of 24-32.

For the purposes of the following discussion it must be emphasized that low scores and high scores for categories are interpreted in the light of what these scores represent as described in Chapter Three. It is relatively easy to interpret mean scores that fall into the high or low score range. In these cases(where the standard deviations are small) a majority of respondents agreed or disagreed that most scientists possessed the characteristics measured by the category. However, as the mean score for a group approaches the median, or falls in the median range, some difficulty arrises as to its actual interpretation. This is a problem common to most forms of attitude measurement. However, for a forced-choice instrument of the type used in this study, the interpretation of scores within the median range is less ambiguous than for instruments consisting of items with neutral responses. A mean score for a group (on any of the categories of the instrument used in this study) which lies within the median range for a category is interpreted to mean that there was no common agreement among members of the group that most scientists could be categorized into either what the low or what the high score for that category represented.

The mean scores of groups of students and scientists are presented in Tables XX and XXII (see pages 80 and 84). The score ranges for each of the 14 categories are also reported in these tables. Examination of Table XX (page 80) indicates that the mean scores of all scientists and all students for eight of the 14 categories were in the high score range. The mean scores for the six remaining categories were in the median score range, although all were within one point of the lowest score in the high score range.

A summary of the meaning of students' and scientists' scores on each category may be obtained by referring to Table II (page 29), Table XX (page 80) and Table XXII (page 84). A description of what high and low scores represent is presented on pages 29-35 of chapter three. A discussion of the meaning of scores where significant differences occured among various groups was given under hypothesis testing which made up the first major part of this chapter.

A discussion of the category scores in which no significant differences were observed, for any of the groups contrasted, is presented below. There were no differences in groups of scientists' scores and students' scores for categories II-A, II-C, IV-A, IV-D and V.

Category II-A consisted of 10 items, five worded positively and five worded negatively. This category investigated attitudes about the intrinsic motivation of scientists. Both students and scientists felt strongly, as evidenced by scores in high score range (30-40) for scientists ($\bar{x}$ = 33.093) and all students ($\bar{x}$ = 33.300), that the motivation to become a scientist is based mainly on intrinsic factors such as curiosity about nature, and fascination, excitement and enthusiasm about scientific study.

For categories II-C, IV-A and V, students' and scientists' mean scores were in the median range. On category II-C, for both students and scientists, there was no common agreement that the motivation to become a scientist was or was not due to external factors such as financial rewards and prestige. On category IV-A, for both scientists and students, there was no common agreement among members that most scientists felt they have or do not have strong obligations toward the public to keep them informed about their work.

In category V the means of all scientists and all students were in the median score range. This indicated there was no common agreement among students or scientists that most scientists did or did not participate in a variety of activities outside of their line of work or that they have or did not have a high interest in home, family or social life.

One other category in which no significant differences were observed between scientists and student groups was category IV-D. The mean scores for categories IV-D for all students and for all scientists were in the high score range (24-32) for the category. These mean scores indicated that, generally, scientists and students agreed rather strongly that most scientists recognized the importance of the contributions made by science and technology to social progress and melioration.

Analysis of Student Responses on the Semantic Differential - Scientist

In order to pursue further students' understanding of the characteristics of scientists, a Semantic Differential questionnaire was given to the same random sample of grade eleven students who completed the Likert-type scales of the instrument, Characteristics of Scientists Survey which were discussed in the previous sections of this chapter.

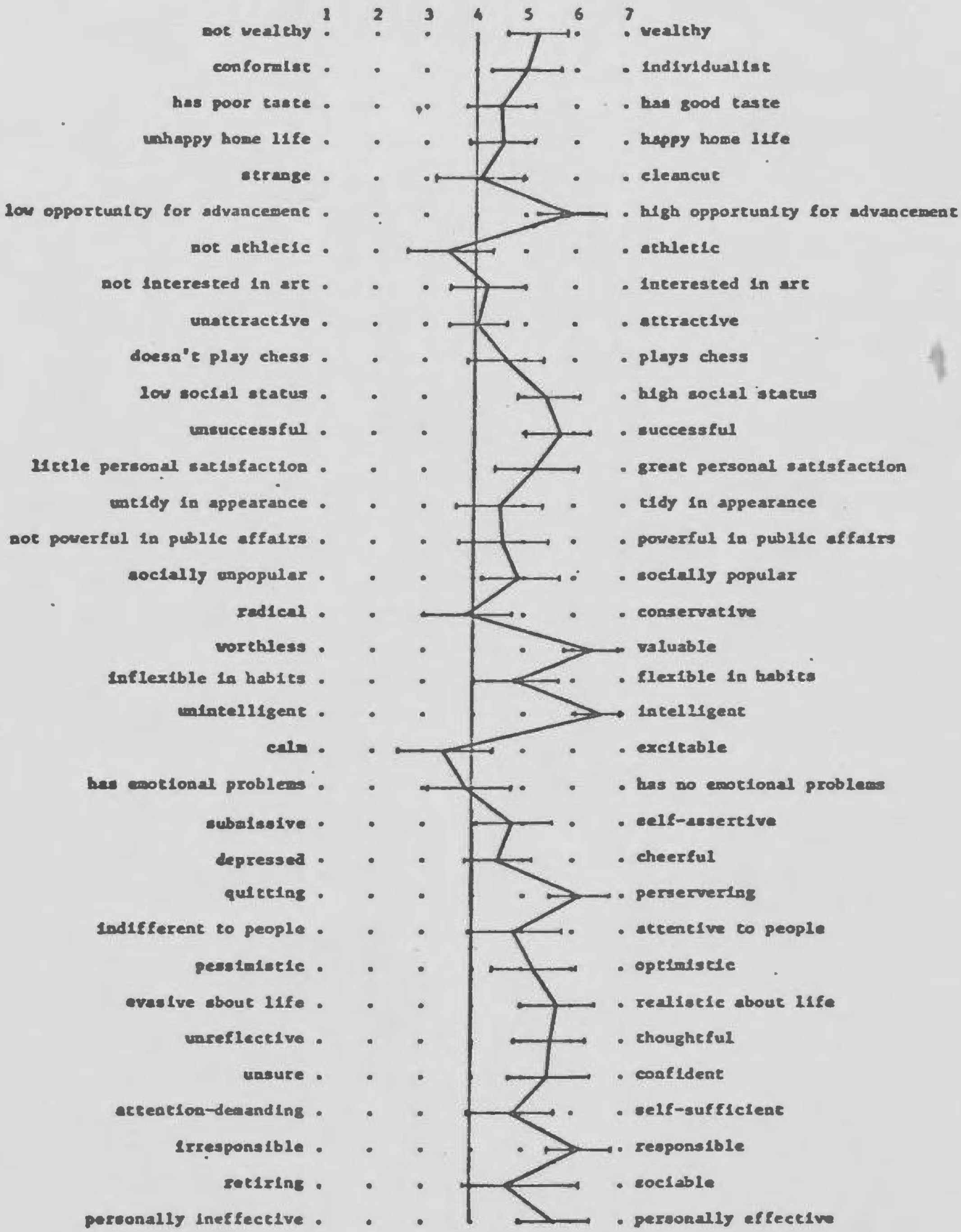
On the Semantic Differential entitled "scientist", students were asked to indicate the appropriateness of 34 pairs of descriptive terms as they apply to scientists in general, (see Appendix A). The terms were arranged in two-ended, seven point rating scales. Student responses were analyzed using multivariate one-factor analysis of variance for three factors--town size, sex and science class. The mean scores for all 34 scales for various levels of each factor (e.g. male and female for the factor sex) were graphed for comparisons between the groups.

In order to develop a composite picture of how students view scientists, the mean scores of all students for each of the 34 scales were plotted on a graph, (see Figure I). The graphic illustration gives a clear presentation of how students rated scientists on each of the scales. The neutral position on the graph received a rating of 4, and a vertical line is drawn to clearly define this position for all the bipolar scales.

According to Figure I, grade eleven high school students' image of the scientist is outstanding in several respects. Students see him prominently as being highly intelligent, a responsible person who is very valuable to society. At the same time, he is a calm individualist

FIGURE 1

MEANS AND STANDARD DEVIATIONS FOR ALL STUDENTS' RESPONSES ON THE SEMANTIC DIFFERENTIAL--SCIENTIST



Students (N = 504).

who is slightly radical, and he may even have a few emotional problems.

It is evident from Figure I that, generally, students have a very positive image of scientists, since high scores tend to represent more positive attitudes. The scientist is seen as being relatively wealthy with a high opportunity for advancement. He is a very perservering individual who is moderately thoughtful and confident about his work. He has fairly high social status and is very successful doing work from which he receives much personal satisfaction. Even though the scientist is highly intelligent, he is not particularly interested in art.

The scientist is seen as moderately optimistic, slightly cheerful and somewhat realistic about life. He is less than moderately sociable, but he is seen as being more socially popular than sociable. However, politically, he is thought not to have much power in public affairs. There is an air of strangeness about him, and he is not seen as being very attractive nor tidy in appearance. He is a bit above the neutral position with respect to good taste and is not rated very highly with respect to having a happy home life. In his spare time, he probably plays a little chess, but is not seen as being athletic.

He scores fairly high for personal effectiveness, while scoring moderately high for self-sufficiency and self-assertiveness. He is relatively flexible in his habits.

In summary, there emerges a picture of the scientist as a highly intelligent individual devoted to his work, at the expense of interest in art and family. The scientist derives great personal satisfaction, a sense of success, reasonably high social status, and a modest income from his work. In public matters, the scientist is influential, but not particularly powerful. He is extreme in some of his views and may even have a few emotional problems. However, he is a very valuable person, who is moderately confident, optimistic and realistic about life. There emerges a picture of strength of personality which is a little extreme, a little strange, somewhat contradictory, and therefore, hard to understand.

Figure 2 presents a graphic picture of the means of all males and all females plotted on a seven point scale. The general image is very similar to that described for Figure 1. However, when the mean scores of students grouped according to sex were compared, significant differences appeared for certain scales. The multivariate F test for comparison of males' and females' scores was significant at the 0.05 level, and the univariate F tests showed significant differences (at the 0.05 level) for the seven scales indicated in Figure 2.

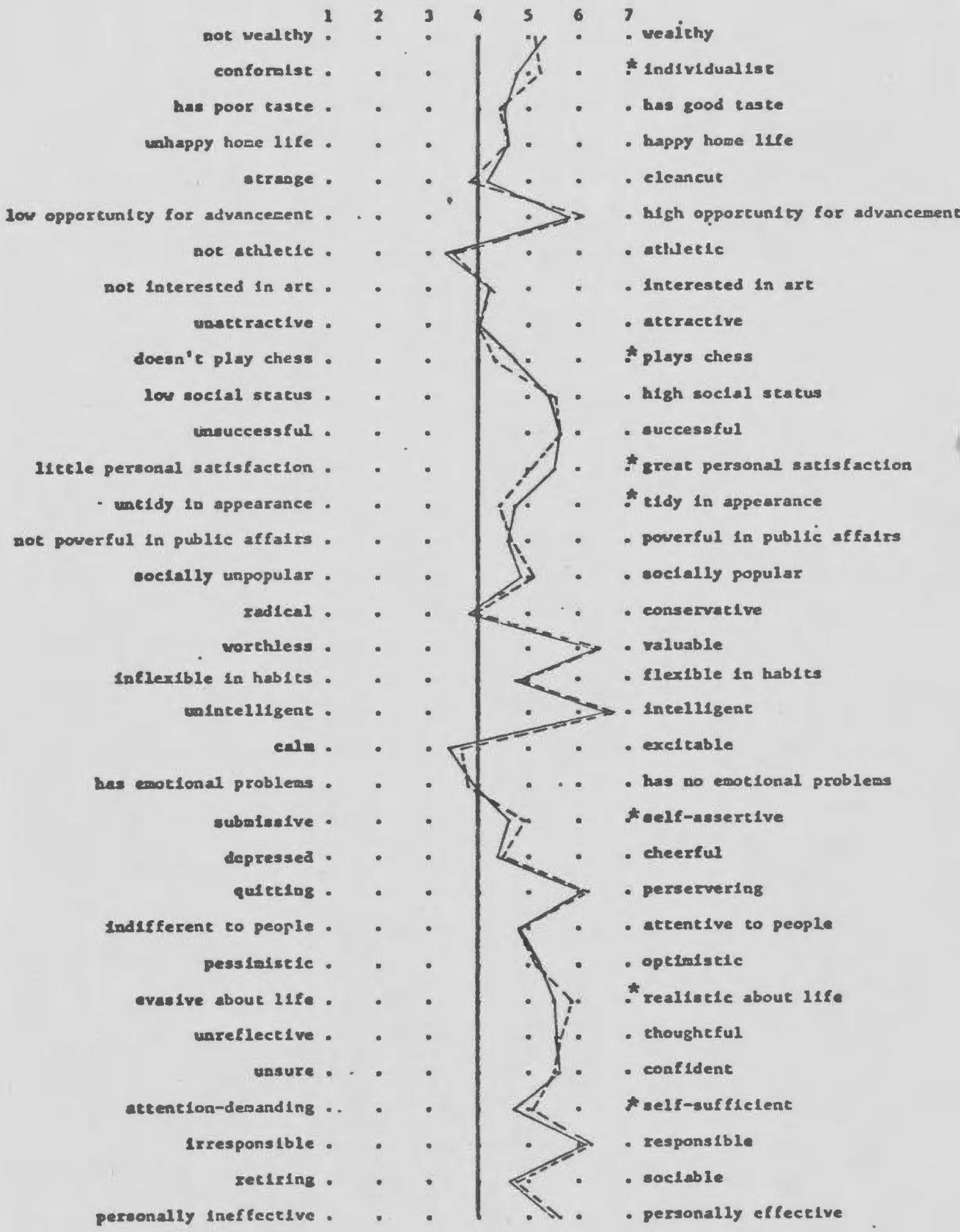
Males felt more strongly than females that scientists played chess in their spare time, that they got great personal satisfaction from their work and also that they were tidy in appearance. However, females rated scientists higher than males as being individualistic, self-assertive, self-sufficient, and realistic about life.

As in Figures 1 and 2, the means of students' responses grouped according to hometown size (Figure 3) and science class (Figure 4) present the same general picture as described for Figure 1. However, there were significant differences on some of the scales for the various groups examined.

Multivariate F tests were significant at the 0.05 level for students

FIGURE 2

MEAN SCORES FOR COMPARISON OF MALE AND FEMALE STUDENT RESPONSES ON THE SEMANTIC DIFFERENTIAL--SCIENTIST



*Significant at the 0.05 level.

Key: ——— Male(n = 260); ------- Female(n = 244).

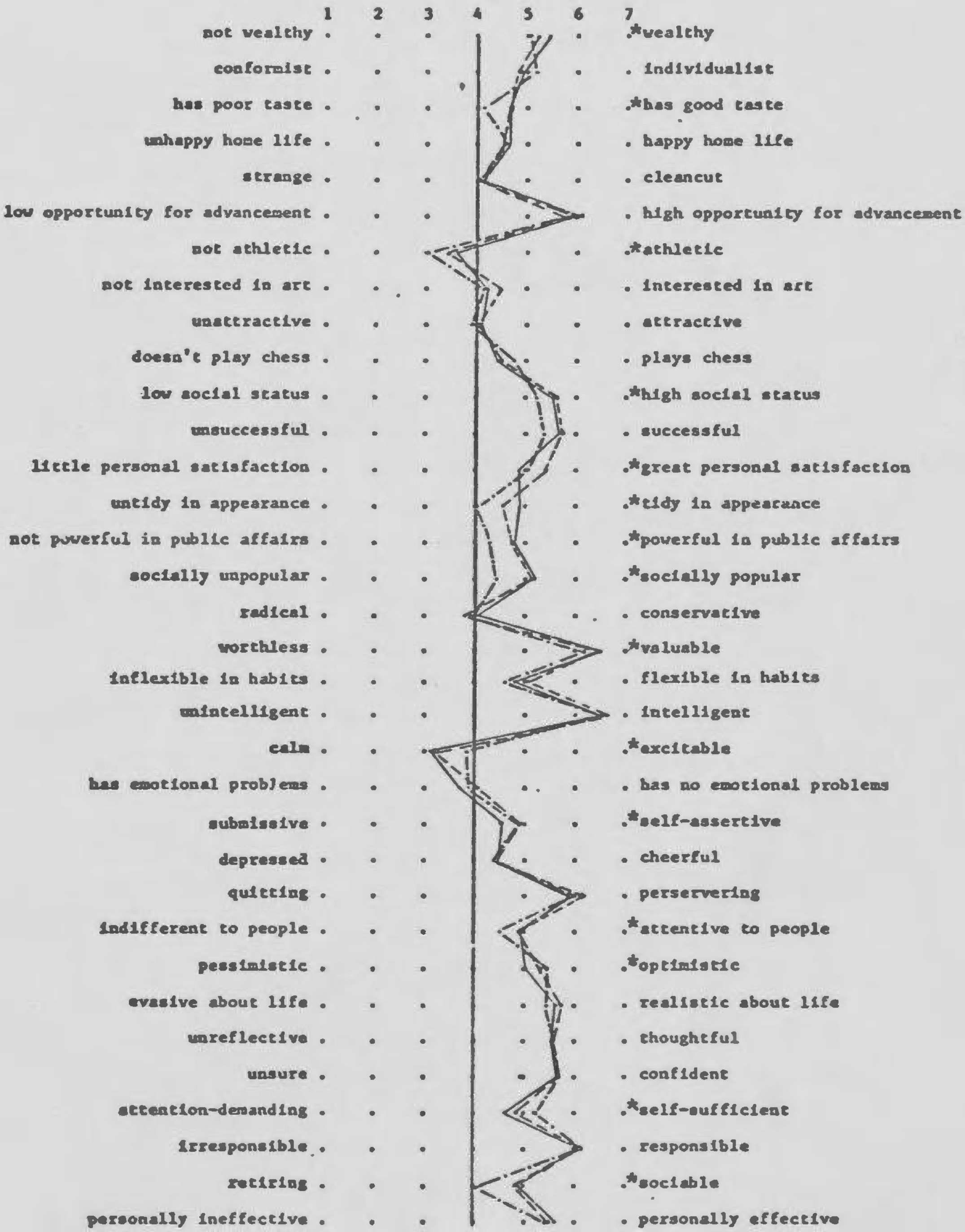
grouped according to town size and science class. The scales for which the univariate F tests were significant ($p < 0.05$) are marked with an asterisk in Figures 3 and 4. For univariate F's which showed significance, Scheffe's method of multiple comparisons (Glass and Stanley, 1970) was used to test for group means which differed at the 0.05 level.

In Figure 3, students from large towns rated scientists significantly lower than students from small towns on seven scales. The seven scales were concerned with the scientists as being wealthy, having good taste, tidy in appearance, powerful in public affairs, socially popular and valuable. Also students in large towns rated scientists lower than students both in small and medium sized towns on three other scales: social status, sociable, and attentive to people. Significantly lower mean scores on the above scales indicated that, generally, students from large towns had a less positive image of the scientist than students from small or medium sized towns. However, students from large towns felt that scientists were more optimistic, excitable, self-sufficient and more self-assertive than was felt by students from small and medium-sized towns. These differences were indicated by significant mean differences ($p < 0.05$) between groups for the scales discussed.

In Figure 4, there were significant differences between science classes for nine of the 34 scales. Students disagreed as to how much of an individualist the scientists was. Earth science and physical science students thought him to be less of an individualist than students in chemistry, biology and physics (as indicated by a significantly lower mean for earth science students). Also, students in earth

FIGURE 3

MEAN SCORES FOR THE EFFECT OF TOWN SIZE ON STUDENT RESPONSES ON THE SEMANTIC DIFFERENTIAL--SCIENTIST



*Significant at the 0.05 level.

Key: ——— Small town students(n = 187);
-------- Students from middle sized towns(n = 170);
-·-·-·-· Large town students(n = 142).

science rated scientists lower than the other three groups as being less self-assertive. Earth science students rated scientists significantly lower than chemistry students on perserverence. Also, earth science students and students of physical science felt (as significantly lower mean scores indicated) to a lesser degree than physics students that scientists were thoughtful. Earth science and physics students felt that scientists were less sociable than physical science students thought they were. Earth science students seemed to have a less positive image of scientists than the other four groups of students.

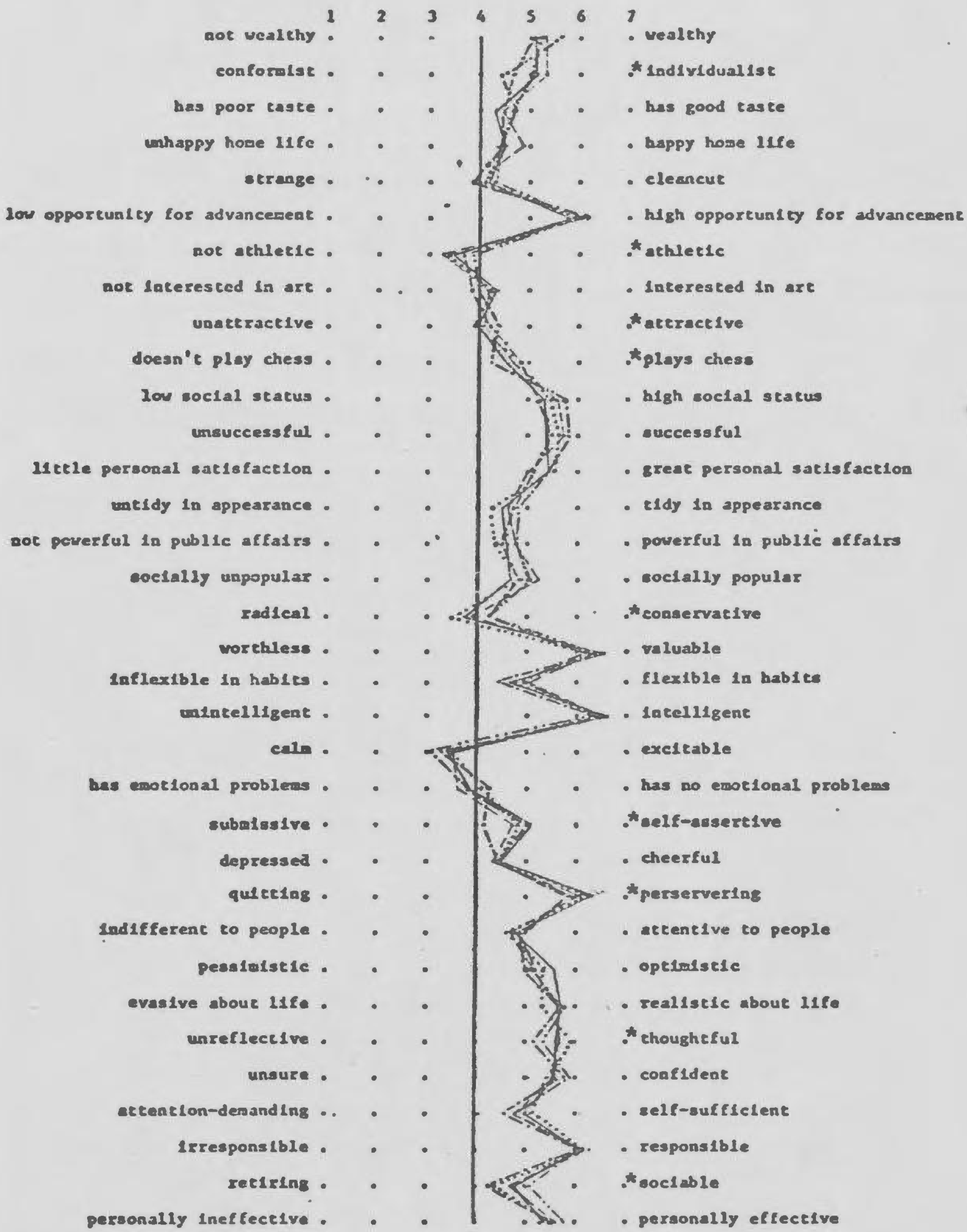
However, earth science students rated scientists higher than did chemistry students as to appearing attractive, and higher than did physical science students as to playing chess. Earth science and physical science students felt scientists were more conservative than physics students felt they were (as indicated by significantly higher means for the first two groups). Physical science students felt scientists were more athletic than did biology students.

Students responses on the Semantic Differential--Scientist were generally very positive. Students rated the scientist toward the positive end of the scale for 27 out of the 34 two-ended scales. The bipolar scales consisted of opposing descriptive terms concerned with the characteristics of scientists, but relating more so to aspects of their personality than to their work.

In general, students see the scientist as a person with strong personal characteristics in that he is personally effective, responsible, confident, perservering, intelligent, and successful. He is also a very valuable person. Negatively, the scientist is seen as a bit strange,

FIGURE 4

MEAN SCORES FOR THE EFFECT OF SCIENCE CLASS ON STUDENT RESPONSES ON THE SEMANTIC DIFFERENTIAL--SCIENTIST



*Significant at the 0.05 level.

Key: ———— Chemistry students(n = 100); -------- Biology students (n = 150); .... Physics students(n = 100); -.-.-.- Earth Science students(n = 85); -..-..- Physical Science students(n = 69).

not athletic, slightly unattractive and not particularly interested in art. He is also seen as being calm and slightly radical, with probably some slight emotional problems.

The very positive image of the scientist as portrayed on the Semantic Differential--Scientist is in agreement with the relatively high scores of students for categories on the instrument--Characteristics of Scientists Survey. Although the Semantic Differential measured aspects relating to the scientist's personality, and the other instrument assessed attitudes about the work and life of a scientist, responses on both instruments tended to suggest generally positive attitudes as to students' understanding of the characteristics of scientists.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND IMPLICATIONS

Summary

Past research indicated that high school students have lacked a clear understanding of the characteristics and roles of scientists in society and in the scientific community. Most of the studies were outdated (1950's) and instruments used were generally narrow in scope. No previous research study compared students' and scientists' responses on a similar instrument. This study attempted to determine what students' understanding of scientists is and in what ways their understanding may be inaccurate and incomplete.

A major task of this study was to develop an appropriate instrument to determine as accurately and completely as possible students' and scientists' understanding of the characteristics of scientists. The instrument, Characteristics of Scientists Survey, consisted of 14 subscales or 14 category scores. All categories of items were validated by professional judgment and reliability studies were carried out to ensure a suitable instrument. Because of the length of the instrument, the 14 categories were arbitrarily divided into two Forms (A and B) each containing seven categories. This division made it feasible to administer either Form A or Form B in a 40 minute classroom period. The instrument was broad in scope, assessing a wide range of characteristics of scientists pertaining to the work they do and the life they lead. It assessed attitudes pertaining to such factors as the scientific attitude of scientists, the motivation of scientists, their philosophical and religious beliefs, and their life away from work. For a summary of all 14 categories see Table II (page 29) and for a complete description of the categories see pages 30-35. A second instrument was used for measuring in greater detail students' attitudes about the personal characteristics of scientists. This instrument, Semantic Differential--Scientist, consisted of 34 descriptive bipolar scales.

The instrument, Characteristics of Sciensists Survey, was used to determine the characteristics of scientists as perceived by scientists and students. The effects of factors such as type of scientist (i.e. biologist, physicist, chemist or geologist), highest degree received, and years of experience on scientists' scores were examined. The effects of factors such as town size, sex and science class on students' responses were investigated.

Samples in the study consisted of 510 students and 107 scientists. Students were sampled through a random selection of fifteen grade eleven science classes, chosen from a list of Newfoundland high schools, grouped into three categories according to size of community in which schools were located. Scientists who took part in the study were from the departments of chemistry, biology, physics and geology at Memorial University and some non-academic biologists and geologists working in Newfoundland.

Students were administered either Form A or Form B of the instrument --Characteristics of Scientists Survey plus the Semantic Differential--Scientist. Scientists were given both Form A and Form B of the instrument. Each form consisted of items (60 items in Form A and 66 items in Form B) contributing to seven of the 14 categories. The response mode was strongly agree--1, agree--2, disagree--3, and strongly disagree--4 for negative items, and reversed for positively worded items.

Data from the study were analyzed using multivariate analysis of variance. The 14 category scores were treated as the 14 dependent variables. The multivariate F test at the 0.05 level of significance was taken as a basis for rejection of the null hypotheses. If the multivariate F test showed significance at the 0.05 level, univariate F tests were examined to find the category or categories for which differences were apparent.

The following hypotheses were tested in the study:

I. There are no significant differences in the perceived characteristics of scientists, as revealed on an appropriate instrument, among various groups of professional scientists.

II. There are no significant differences in the perceived characteristics of scientists, as revealed on an appropriate instrument, among various groups of eleventh grade students.

III. There are no significant differences in the perceived characteristics of scientists, as revealed on an appropriate instrument, between professional scientists and eleventh grade high school students.

In addition to statistical testing of the three hypotheses, a descriptive analysis of the meaning of category scores was also presented.

The means and standard deviations of all students' responses on the 34 scales of the Semantic Differential--Scientist were graphed. Also students' responses were analyzed in relation to factors of sex, town size and science class, using one-factor analysis of variance, and mean scores of various groups were graphed for comparison purposes.

Conclusions and Discussion

The conclusions and discussion presented in the following section are based on the data analysis and results from Chapter V. The results in this study were obtained from two instruments: (1) students' and scientists' responses on the instrument--Characteristics of Scientists Survey--consisting of 14 category scores; and (2) students' responses on the Semantic Differential--Scientist.

Responses on the instrument--Characteristics of Scientists Survey--involved hypothesis testing for group differences in category means and a second but related aspect pertaining to what the mean scores for categories actually tell us about scientists' and students' understanding of the characteristics of scientists. Responses on the Semantic Differential--Scientist added to a clearer understanding of high school students' image of the scientist.

Results of Hypothesis Testing

Hypothesis One. Multivariate analysis of variance revealed no significant differences between groups of scientists on any of the 14 variables (category scores). There were no interactions or main effects of the factors--type of scientist, highest degree received, and years experience. This indicated close agreement among academic scientists as to their perceptions of the characteristics of scientists and their role in the scientific community and society. Biologists, chemists, physicists and geologists did not differ significantly in their views as to the scientific attitudes of scientists, their motivation, their philosophical and religious beliefs, their role in society and their non-professional life styles.

A limitation in the interpretation of scientists' results is the lack of a large representative sampling of scientists. There exists the possibility of a biased sampling for two reasons: (1) the original sample of scientists contacted was small and not very representative of all scientists, and (2) there was a relatively low percentage return (56%) of questionnaires from scientists who were contacted. The results may have been different if more questionnaires had been returned. Since the questionnaires were returned anonymously there was no way of sampling those who did not return the instrument to see if there was indeed biased sampling. The sampling aspect is dealt with in the section on recommendations for further research.

From written comments on some of the instruments returned, it appeared that some scientists lacked a clear understanding as to the actual purposes of the study. Some indicated doubt about the usefulness of results of the study, while others felt that learning about the characteristics of scientists at work and away from work should not have any part in the high school curriculum. Some scientists had positive feelings about the study, and indicated that the questionnaire was interesting and comprehensive in most respects.

Hypothesis Two. Multivariate analysis of variance of students' scores led to the rejection of the null hypothesis of no differences in groups of students' scores for categories of the instrument--*Characteristics of Scientists Survey*.

The effects of seven factors (independent variables) on students' scores were investigated--science class, sex, hometown size, grade ten average, number of different high school science courses taken or taking, socio-economic status and the length of their teachers' teaching experience. The null hypothesis was rejected for 11 of the 14 categories because of: (1) differences between student scores due to the effect of science class for categories I-A, I-C and II-B; (2) differences between socio-economic groups interactions for categories I-B, II-A, III-A, III-B and IV-A and IV-D.

Interaction effects are dealt with in the first part of this discussion. All interactions involved the science class of the student, and most of the interactions were due to lower or higher scores for groups of physical science students. The number of category scores for which there were significant interactions is relatively small. For each of the 14 category scores, three three-factor and 15 two-factor interactions were tested and only four two-factor interactions affecting seven categories were significant at the 1.05 level. Nevertheless, interactions which involved science class suggested the need for a closer examination of these high school science courses as to possible causes of these interactions.

For five categories of students' scores there were significant effects with no interactions. These were due to differences in science classes for categories I-A, I-C and II-B and due to socio-economic groups for categories II-C and VI.

The conclusions for differences in science classes are:

1. Chemistry students felt more strongly than earth science students that most scientists valued scientific integrity highly in their work. Scientific integrity included such factors as honesty, suspended judgment,

open-mindedness, rationality, idea sharing and willingness to change opinions.

2. Chemistry, biology and physics students felt more strongly than physical science students that most scientists had positive attitudes toward the operational requirements of a successful life in the scientific community. Operational requirements of a successful life in science included such factors as dedication or commitment to the job, initiative and resourcefulness, and relations with colleagues such as cooperation and tolerance.

3. Chemistry and biology students felt more strongly than physical science students that scientists were motivated to do science by a cultural concern to contribute to knowledge and human welfare.

The conclusions for differences in socio-economic groups are:

1. Students of low socio-economic status did not feel as strongly as students from medium and high socio-economic status that most scientists were motivated to do science as a result of external factors such as financial rewards and prestige.

2. Students from low socio-economic status felt more strongly than students from medium or high socio-economic backgrounds that most scientists were much like they appear in science fiction movies and stories.

Seven factors were investigated to determine possible effects on students' scores. Science class produced the greatest differences in students' scores. Generally, students in chemistry, physics and biology classes had more positive attitudes (as higher mean category scores indicated) toward scientists than physical science and earth science students. Also, the interactions discussed earlier seemed to be due mostly to lower mean scores for sub-groups of students in the physical science classes. The length of their teachers' teaching experience, the number of science courses students had taken, their sex, their grade ten average and the size of their home town did not significantly affect students' responses on the instrument--Characteristics of Scientists Survey. The teacher variable couldn't be investigated to a significant extent because the small sample of teachers (15) was fairly homogeneous in that 14 were males, all had at least a bachelor's degree, and 13 of the 15 had completed at least 20 semester credits in in university science courses. Further investigation of the teacher variable is suggested in the section on recommendations for further research.

This study was not designed to investigate causes as to why students differed according to science class and socio-economic status. However, one can speculate on why differences occured. Students in chemistry, biology and physics expressed more positive attitudes than physical science and earth science students possibly because of differences in the high school science curricula. It is speculated that students in chemistry, biology and physics have more opportunity to develop scientific attitudes through laboratory activities than non-academic students who usually take the earth science and physical science courses. Most of the differences in student groups appeared in the area of scientific attitudes. Besides differences due to the science curricula, it is likely that earth science and physical science students differed in their attitudes because more of these students were of lower socio-economic status and they probably had lower IQ's than students enrolled in chemistry, physics and biology. Also, low socio-economic students were probably less concerned about the influences of science and scientists and this could have contributed to their differing attitudes. In order to determine specific causes as to why groups of students differed according to science class and socio-economic status more research is needed.

Hypothesis Three. Multivariate analysis of variance led to the rejection of the null hypothesis which stated that there were no differences in scientists' scores and students' scores. Since no significant differences were found among groups of scientists, their scores were all grouped to form a composite for each of the fourteen categories. Thus, for each category the mean of students' scores grouped according to science class was compared to the mean of all scientists' scores. Students' scores were divided according to science class because of the differences that were observed between science classes as discussed under hypothesis two.

Students of various science classes differed significantly from scientists in their attitudes on categories I-A, I-B, I-C, II-B, VI, III-A, III-B, IV-B and IV-C.

The following were conclusions based on differences observed:

1. Chemistry students felt more strongly than scientists that most scientists valued scientific integrity highly in their work. Scientific integrity included such factors as objectivity, suspended judgment, open-mindedness and idea sharing.

2. Chemistry students felt more strongly than scientists (as indicated by significantly higher mean scores), that most scientists were highly critical about their own work and the work of other scientists. The

higher scores of the chemistry students tend to suggest that very positive impressions of the characteristics of scientists are possessed by this group. However, they were probably more positive than accurate, if the scientists' scores present a more accurate picture.

3. Chemistry, physics and biology students felt more strongly than scientists that most scientists had positive attitudes toward the operational adjustments (i.e.dedication and commitment, initiative and resourcefulness, and cooperation with peers) of a successful life in the scientific community. This indicated that to some extent these students thought scientists were happier with their work than was felt by scientists.

4. Chemistry, physics and biology students felt more strongly than scientists, that most scientists were highly motivated in their work by altruistic concerns such as cultural concerns to contribute to knowledge and improve human welfare.

5. Physical science students felt more strongly than scientists that most scientists were much like they appear in science fiction movies and stories. The mean scores of other classes were in the median range indicating there was no common agreement among members of each group whether most scientists were or were not like they appeared in science fiction movies and stories.

6. Scientists scored significantly higher than all students on Cat III-A, which indicated they felt more strongly than students that most scientists believed in order and balance in nature, and that the universe is, within limits, comprehensible and knowable.

7. Groups of students in all science classes scored significantly higher than scientists on the category dealing with the religious beliefs of scientists. This indicated that students thought scientists were more religious than was felt by scientists. Numbers 6 and 7 indicated that all five student groups were significantly different from scientists in their views about the philosophical and religious beliefs of scientists.

8. All students felt more strongly than scientists that most scientists have a strong role to play in making decisions about the uses of science. Students generally felt that scientists should be involved more in political decision making about the applications of science.

9. All students (chemistry students in particular) felt more strongly than scientists that most scientists recognized the need to develop a relationship between science and society as being important for the proper development of science. Thus, significantly higher mean scores for all students'over scientists in numbers 8 and 9 indicated students attitudes differed from those of scientists as to the proper role of the scientist in relation to the scientific institution and society.

Students in chemistry scored higher than other groups for seven of the nine categories in which scientists' scores were significantly different from students' scores. Positive attitudes tended to contribute to higher scores. The results indicated that generally students held more positive attitudes about the characteristics of scientists and their roles in society and the scientific community than was held by the scientists in this study.

Description of Category Means. For some categories no significant differences were observed for any of the groups contrasted. There were no differences in groups of scientists' and students' scores for categories II-A, II-C, IV-A, IV-D and V.

On categories II-C, IV-A and V the mean scores of students and scientists were neither high nor low but were close to the median with relatively large standard deviations. This indicated that there was no common agreement among students or scientists that most scientists could be categorized into either what the low or what the high score for the category represented. The meaning of high and low scores for categories was described under the development of the instrument, (pages 30-35).

The following conclusions are appropriate for categories in which no significant differences between students' and scientists' were observed:

1. For both students and scientists, there was no common agreement that the motivation to become a scientist was or was not due to external factors such as financial rewards and prestige.

2. There was no common agreement among students or scientists that most scientists felt they had or did not have strong obligations toward the public to keep them informed about their work.

3. There was no common agreement among students or scientists that most scientists did or did not participate in a variety of activities outside of their line of work or that they have or did not have high interest in home, family and social life.

For the remaining two categories where no significant differences occurred, scientists' and students' mean scores were in the high-score range with low standard deviations. These categories were II-A and IV-D, for which the following was concluded.

4. <u>Both students and scientists felt strongly that the motivation to become a scientist was based mainly on intrinsic factors such as curiosity about nature, and fascination, excitement and enthusiasm about scientific study</u>.

5. <u>Both scientists and students agreed rather strongly that most scientists recognized the importance of the contributions made by science and technology to social progress and melioration</u>.

<u>Student Scores on the Semantic Differential</u>

Students scores on the Semantic Differential--<u>Scientist</u> were based on responses to 34 pairs of descriptive terms arranged in a two-ended seven point rating scale. From the graphed means of all students' responses, there emerged the picture of the scientist as a highly intelligent individual, devoted to his work at the expense of interest in art and family. The scientist is seen to derive great personal satisfaction, a sense of success, reasonably high social status, and a modest income from his work. He is seen as being influential but not particularly powerful in public affairs. He is a bit radical in some of his views and may even have a few slight emotional problems. However, he is a very valuable person, who is moderately confident, optimistic and realistic about life. The high school students' image of the scientist is one of a strength of personality which is a little extreme, a little strange, somewhat contradictory, and therefore hard to understand.

While overall responses for all groups indicated a very positive image, specific differences due to sex, town size and science class existed on some of the 34 scales. For a detailed description of these differences, refer to pages 95 - 101 of Chapter V.

Student responses on the Semantic Differential were generally very positive. Students rated scientists toward the positive end of the scale, for 27 out of the 34 scales. Student images in this study were similar in some respects to the college student images of scientists as reported in the study by Beardslee and O'Dowd (1961). However, students in this study were generally more positive in their attitudes about the scientist.

The very positive image of the scientist as portrayed on the Semantic Differential--Scientist is consistent with relatively high scores of student groups for categories on the instrument--Characteristics of Scientists Survey. Responses on both instruments tended to suggest general positive attitudes as to students' understanding of the characteristics of scientists. The lower scores of scientists for some categories of the instrument--Characteristics of Scientists Survey--indicated that students' images may be more positive than realistic. Generally, students of chemistry, biology and physics hold a more positive image of scientists than students in earth science or physical science. However, student responses on the instruments may have been more positive than their true attidudes. Since responses may have had a certain expectancy this limitation of attitude measurement must be considered in the interpretation of results.

Implications

For Curriculum. This study measured Students' and Scientists' understanding of the characteristics of scientists and made comparisons within and between both groups. The students who took part in the study were grade eleven students who were nearing the end of their high school career. It appears that high school students from different science classes had differing views as to the characteristics of scientists. Students in biology, chemistry and physics had somehow formed impressions of the characteristics of scientists which were very positive. In most cases their views were more positive than those of scientists themselves. Students in earth science and physical science held images of scientists which were slightly more negative than students in biology, chemistry and physics.

In particular the views of students seemed to indicate confusion about the actual motivation of scientists. Most students felt more strongly than scientists that scientists were motivated by a cultural concern to contribute to knowledge and improve human welfare. Students had misunderstandings about the philosophical and religious beliefs of scientists and their scores differed from scientists in these areas. Also, students had stronger attitudes than scientists, as to the role of the scientist in society. This was probably due to a lack of understanding as to the role of the scientist in the scientific community and in society.

Students' views of the personal characteristics of scientists were generally very positive, however there was confusion among students as to whether scientists were strange, untidy, sociable and above or below normal in some other respects. All of the above have implications for future science curriculum development.

Some implications for curriculum change are:

1. There is a need for greater contact between scientists and students.

Most students have seen scientists only in movies or read about them in science fiction books and comics, or seen them on television. Schools should probably make an attempt to have a scientist or scientists visit them and discuss some topic of interest in science. Also, where feasible arrangements should be made for classes of students to visit scientists and observe them at work in their laboratories. The process of interacting in the laboratory setting could help to overcome the stereotype of the scientist as unsociable, inhuman and generally ineffectual. Personal contact of scientists with students followed by discussion and interaction would also contribute to students overall understanding of the characteristics of scientists.

2. Students hear mostly about the "atypical" scientist, or the great scientists such as Einstein and Newton in school. This has no doubt contributed to a very positive impression of what scientists can do. However, there is a need for more student understanding concerning the "typical" or normal scientist as described by Kuhn (1962) who is doing his duty, researching some aspects of a particular paradigm.

Some journals which would probably be of assistance to science teachers are <u>Science</u>, <u>Physics Today</u>, and <u>Nature</u>. Topics discussed in these journals deal with the work of the present day scientist at the frontier in his field. However, the "science" is not overly sophisticated nor too abstract.

3. Implications of the study also support the need for more student understanding as to the scientific attitudes of scientists, their need to be objective and critical, to be open-minded, to suspend judgment, to share ideas and others. Curricula that emphasize the processes and

methods of science, that create the atmosphere of scientific exploration and discovery are recommended for students. Thus, the type of curricula which teaches students about science, through "sciencing" and playing the role of the scientist would be helpful in this respect.

4. Students expressed confusion and misunderstanding as to the nature of the scientists' role in decision making and informing the public about the uses and abuses of science.

Students need to know more about the actual role of the scientist in this scientific age. Some time needs to be spent in science teaching on discussions as to the nature of the influences scientists (and technologists) are having on society and daily life. Essays on science and society could be used as a basis for discussion. Students in the lower grades as well as the high school grades need to be made aware of the influences that science and scientists are having in this scientific age. All students need to have some understanding of the characteristics of men and women who have played and are continuing to play a role in scientific exploration and discovery.

Further Research.

Some possible implications for further research are:

1. This study was limited to a relatively small sample of scientists. Similar studies are needed involving larger more representative samples of scientists. Scientists in this study were mainly academic biologists, physicists, chemists and geologists. Future studies should be more concerned with wider, more representative samples of non-academic and academic scientists. Also scientists in interdisciplinary areas, and medical research scientists should be sampled.

2. A suggestion for further research includes a specific modification in the use of the instrument. Scientists in this study were asked to rate colleagues with reference to their specific fields. They responded as to whether they agreed or disagreed that an attitude statement was applicable to "most" of their colleagues. The possibility of a bias existed in responses. Moreover, scientists expressed confusion as to the exact interpretation the word "most" as used in attitude statements. Further studies in which larger samples are necessary could make use of the instrument by removing the word "most" and having the scientist respond on an individual basis. These studies could probably be followed up or carried out in greater depth through the use of interviewing techniques.

3. There is a need for a larger sampling of students. Even though this study involved about five hundred students, it was felt that a much larger random selection of students would have given a more realistic picture of how students viewed scientists. Some evaluation of students' attitudes regarding science and scientists needs to be done in grades nine, ten, and lower grades, as was done for the grade eleven students in this study. Investigation in sex differences between male and female attitudes and between students grouped according to science class needs to be explored in greater depth. Further research is needed as to the nature of students' understanding of the characteristics of scientists pertaining to the scientific attitudes of scientists, and the role of the scientist in the scientific community and society.

A research question which arises is, do high school experiences in science contribute toward growth in attitudes as well as in knowledge? Evaluation of affective growth of students is virtually ignored in most schools.

4. No attempt was made in this study to measure teacher attitudes on the instrument--Characteristics of Scientists Survey. Assessment of teacher attitudes about the characteristics of scientists plus the comparison of teacher and student attitudes is a research area that needs to be pursued. This could provide information on how teacher attitudes affect students' understanding of the characteristics of scientists.

5. Further research is needed in attitude measurement specifically relating to science and scientists. It is alarming to realize that the social scientists have largely neglected research on attitudes about science and scientists, specifically in view of the way both are presently influencing our way of life.

A major task of this study was the development of a valid and reliable instrument which could be used to measure attitudes. The instrument, Characteristics of Scientists Survey, has the potential to contribute to further research into attitude measurement. The instrument could also be of some use to the classroom teacher who is interested in measuring student attitudes in general. Likert-type scales of the type developed in this study are very appropriate for the following kinds of investigations (Edwards, 1957): (1) if our interest is in comparing the mean attitude change as a result of introducing some experimental variable, (2) if we are interested in comparing the mean attitude change of two or more groups, and (3) if we wish to correlate scores on an attitude scale with scores on other scales or other measures of interest. These are problems common to educational research.

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APPENDICES

APPENDIX A

QUESTIONNAIRE ON SCIENTISTS, PART I

The purpose of this questionnaire is to find out the impressions that you have of scientists by having you judge the occupation against a series of descriptive scales. In filling out this questionnaire, please make your judgments on the basis of what you feel about this occupation.

If you feel that the occupation is very closely related to one end of the scale, you should place your check mark as follows:

has a pretty wife ✓:_:_:_:_:_:_ wife is not pretty or

has a pretty wife _:_:_:_:_:_:✓ wife is not pretty

If you feel that the occupation is quite closely related to one or the other end of the scale (but not extremely), you should place your check mark as follows:

low social status _:✓:_:_:_:_:_ high social status or

low social status _:_:_:_:_:✓:_ high social status

If the occupation seems only slightly related to one side as opposed to the other side (but not extremely), you should place your check as follows:

intelligent _:_:✓:_:_:_:_ unintelligent or

intelligent _:_:_:_:✓:_:_ unintelligent

The direction toward which you check, of course, depends upon which of the two ends of the scale seems most characteristic of the occupation you are judging.

If you consider the occupation to be neutral on the scale, both sides of the scale equally associated with the occupation, or if the scale is completely irrelevent, unrelated to the occupation, then you should place your check mark in the middle space.

pessimistic _:_:_:✓:_:_:_ optimistic

IMPORTANT:

1. Place your check marks in the middle of spaces, not on the boundaries.

   This: _:✓:_:_   Not this: _✓_:_:_

2. Be sure you check every scale, do not omit any.
3. Never put more than one check mark on a single scale. Do not worry or puzzle over individual items, It is your first impression, the immediate "feelings" about the occupation that we want. On the other hand, please do not be careless, because we want your true impressions.

SEMANTIC DIFFERENTIAL--SCIENTIST

wealthy__:__:__:__:__:__:__not well to do

conformist__:__:__:__:__:__:__individualist

has good taste__:__:__:__:__:__:__has poor taste

unhappy home life__:__:__:__:__:__:__happy home life

cleancut__:__:__:__:__:__:__strange

low opportunity for advancement__:__:__:__:__:__:__high opportunity for advancement

athletic__:__:__:__:__:__:__not athletic

not interested in art__:__:__:__:__:__:__interested in art

attractive__:__:__:__:__:__:__unattractive

plays chess__:__:__:__:__:__:__doesn't play chess

high social status__:__:__:__:__:__:__low social status

unsuccessful__:__:__:__:__:__:__successful

great personal satisfaction__:__:__:__:__:__:__little personal satisfaction

tidy in appearance__:__:__:__:__:__:__untidy in appearance

powerful in public affairs__:__:__:__:__:__:__not powerful in public affairs

socially unpopular__:__:__:__:__:__:__socially popular

radical__:__:__:__:__:__:__conservative

worthless__:__:__:__:__:__:__valuable

adaptable in habits__:__:__:__:__:__:__inflexable in habits

unintelligent__:__:__:__:__:__:__intelligent

calm__:__:__:__:__:__:__excitable

has emotional problems__:__:__:__:__:__:__has no emotional problems

self-assertive__:__:__:__:__:__:__submissive

depressed__:__:__:__:__:__:__cheerful

persevering__:__:__:__:__:__:__quitting

indifferent to people__:__:__:__:__:__:__attentive to people

optimistic__:__:__:__:__:__:__pessimistic

evasive about life__:__:__:__:__:__:__realistic about life

thoughtful__:__:__:__:__:__:__unreflective

unsure__:__:__:__:__:__:__confident

self-sufficient__:__:__:__:__:__:__attention-demanding

irresponsible__:__:__:__:__:__:__responsible

sociable__:__:__:__:__:__:__retiring

In summary, what do you think is the personal effectiveness of the SCIENTIST?

personally effective__:__:__:__:__:__:__personally ineffective

APPENDIX B

Part II

CHARACTERISTICS OF SCIENTISTS SURVEY

(FORM A)

STUDENT INFORMATION

Please fill out the following in Section I of the RESPONSE SHEET. Do not write in this booklet.

1. Sex:

Male	Female
1	2

2. Science courses you have taken or are now taking.

Chemistry	Biology	Physics	Earth Science	Physical Science
1	2	3	4	5

3. Science class in which this exercise is being done:

Chemistry	Biology	Physics	Earth Science	Physical Science
1	2	3	4	5

4. Grade X mark in the course under question 3.

<50	51-60	61-70	71-80	81-90	90-100
1	2	3	4	5	6

5. Grade ten average.

< 50	51-60	61-70	71-80	81-90	90-100
1	2	3	4	5	6

Please fill in the above information in Section I of the Response Sheet.

DIRECTIONS TO STUDENTS

This part of the quedtionnaire consists of a number of statements about scientists. Please indicate the extent of your agreement or disagreement with each statement by completely filling in the appropriate space in the accompanying Response Sheet.

1 .... I STRONGLY AGREE that this statement applies to MOST scientists.

2 .... I AGREE that this statement applies to MOST scientists.

3 .... I DISAGREE that this statement applies to MOST scientists.

4 .... I STRONGLY DISAGREE that this statement applies to MOST scientists.

INDICATE ALL your answers in the special squares provided in the Response Sheet - please DO NOT write in the Questionnaire Booklet.

Example: Given the statement:

X. Most scientists believe in God.

If you think that this statement applies to MOST scientists, then place 1 (Strongly Agree) or 2 (Agree) in the square for that statement, ie.

[1] or [2]

X X

If you think that most scientists do not believe in God or that only some scientists believe in God, then place 3 (Disagree) or 4 (Strongly Disagree) in the square for that statement, ie.

[3] or [4]

X X

CHARACTERISTICS OF SCIENTISTS SURVEY

1. Most scientists will report all of their experimental observations even if some are in conflict with the hypothesis they are attempting to test.

2. A scientist is unwilling to share his ideas with other scientists unless he receives useful ideas from them in return.

3. Scientists often repeat experiments several times to determine if the results are consistent.

4. Imagination and insight are required in order to become a successful scientist.

5. The scientist's motivation for studying the universe is mainly curiosity - the desire to know.

6. Scientists find most of their work to be very monotonous.

7. Scientists are not interested in acquiring knowledge that will be of some practical use to society.

8. Most scientists do not aspire to become authorities in an area of scientific knowledge.

9. Scientists hope to have some world-wide recognition for their work.

10. Scientists are not attracted to a science career with the hope of obtaining a high income.

11. Most scientists share their findings with scientists from foreign countries.

12. Before scientists publish a piece of research, they seldom show it to their colleagues for examination and criticism.

13. If most scientists are honest, it is mainly because they know their work will be checked by other scientists.

14. A scientist is willing to share his ideas among his colleagues because this contributes significantly to the overall development of science.

15. Most scientists make interpretations which are biased in favor of the hypothesis they want to test.

16. An essential characteristic of a scientist is the ability to ask the "right questions" about phenomena observed.

17. Scientists must expect to repeat their experiments many times before adequate results can be obtained.

18. Scientists boast about discoveries they make.

19. Most scientists are not interested in pursuing knowledge for its own sake.

20. Scientists are guided in their work by an unselfish interest in improving the welfare of others.

21. Scientists are strongly motivated to elect science as a career because it is a very satisfying type of work.

22. A major reason scientists elect science as a career is because of the high prestige it offers.

23. Scientists seldom question or criticize the results of their work.

24. Most scientists are careful to give credit to other scientists whose ideas have contributed to their work.

25. Competition among scientists limits the sharing of ideas.

26. Most scientists feel that women simply do not have the ability or temperament to become good scientists.

27. Scientists are very thorough in demanding evidence from experiments before drawing conclusions.

28. Scientists need much guidance from their colleagues while carrying out their research.

29. Scientists are unable to accept criticisms from other scientists.

30. When faced with unresolved problems in nature, scientists are driven by curiosity to seek solutions.

31. Scientists are not enthusiastic about their work.

32. Scientists who elect science as an occupation feel that there are many benefits to be obtained for man through the expansion of scientific knowledge.

33. Scientists elect science as a field because they obtain a strong sense of pride in making discoveries.

34. Most scientists desire to make discoveries that will bring them fame.

35. Scientists seldom cooperate with one another to work as a team on a research project.

36. Scientists are motivated to carry out their research regardless of possible harmful effects to others.

37. Scientists are very thorough in demanding evidence before drawing conclusions.

38. Often scientists force interpretations from a limited amount of data.

39. Scientists seldom criticize each others work.

40. Conversations among scientists often include questions about scientific theories and research procedures.

41. Scientists are required to spend a great deal of time in trying to resolve problems encountered in their research.

42. Scientists feel there is much unnecessary duplication of effort and expenditures in related scientific fields.

43. Scientists work quietly behind the scenes and are not really concerned about public recognition for their work.

44. Scientists long to know and understand natural phenomena.

45. Scientists are not interested in discovering patterns or relationships that exist in nature.

46. Scientists are not motivated in their work by a desire to improve the human environment.

47. Scientists elect science as a career because they feel there is much they can do in science to benefit mankind.

48. Adequate financial rewards are not of major importance in getting scientists to do the best possible job.

49. Scientists choose science as a career with the hope of obtaining a high income.

50. A scientist is usually prepared to modify his ideas if new evidence appears that cannot be explained in terms of existing theories.

51. In general, scientists tend to be less critical of their own work than they are of the work of other scientists.

52. Scientists often question each other as to whether proposed research procedures and conclusions are appropriate.

53. Scientists need to be imaginative in designing research equipment and techniques.

54. As a group, scientists are less self-confident than other professionals such as doctors and lawyers.

55. Scientists are not eager to accept the challenge of probing into the unknown.

56. Most scientists feel that working in a laboratory is an exciting way to earn a living.

57. Most scientists hope to receive a nobel prize in their field.

58. People who choose science as a career do so because it provides an intellectually stimulating type of work.

59. Most scientists are much like they appear in movies.

60. Television and movies present an incorrect image of scientists in general.

Part II

CHARACTERISTICS OF SCIENTISTS SURVEY

(FORM B)

CHARACTERISTICS OF SCIENTISTS SURVEY

1. Scientists do not believe in life after death.

2. Scientists believe that the church is a monument to human ignorance.

3. Scientists assume events that happen today have no relation to events in the past.

4. Scientists think that certain events in nature are unpredictable.

5. Scientists seldom make their personal views on scientfic issues known to the public, for fear of losing their job.

6. Scientists think that the public is not capable of understanding their work.

7. Scientists feel that once the basic ideas have become generally known, that scientists should not determine how discoveries may be applied.

8. Scientists feel that their unbounded inquiry has had a bad effect on society's moral standards.

9. Generally, scientists think that a return to a simpler, less mechanized world would result in a happier, more contented people.

10. Scientists are likely to spend less of their leisure time talking to other scientists than to non-scientists.

11. As compared to other professionals such as doctors and lawyers, scientists are more active and concerned about political and social issues.

12. Scientists believe that they can formulate explanations for their observations of natural phenomena.

13. Scientists assume that all natural phenomena have natural causes.

14. Scientists assume nature may change suddenly.

15. When a scientist makes a prediction he is assuming that nature is consistent.

16. Scientists believe the idea of God is mere superstition.

17. Scientists believe that some events which occur in the universe have supernatural causes.

18. Scientists believe that the church is necessary for the preparation of the souls of men for eternal life.

19. Scientists feel that they have a duty to keep the public informed about the kind of work they are doing.

20. Scientists feel that their findings should not be made known to the public if they will create controversy or misunderstanding.

21. Scientists feel that they should make the major decisions about the uses of science.

22. Scientists feel that science will only develop properly if their work is recognized by the public.

23. The scientist assumes a social responsibility when he decides to do research in an area in which his findings could be destructive to society.

24. Most scientists feel that the results of modern technology are responsible for much of man's personal discontent and frustration.

25. Scientists feel that their research becomes more meaningful if they have a chance to see how well their findings work in an applied situation.

26. Compared to the general population, scientists participate less in active sports.

27. Scientists devote enough time to their spouses and children.

28. Scientists seldom attend movies.

29. Scientists believe that certain natural phenomena may never be understood by man.

30. Scientists work to discover absolute truths.

31. Scientists prefer to accept the idea of natural evolution of man over the idea of supernatural creation.

32. Scientists believe that the idea of God provides the best explanation of our natural world.

33. Scientists believe that the church is an institution which functions for the good of man in helping to build sound moral character.

34. Scientists believe that more use should be made of the media to keep people informed about their work.

35. Scientists believe that they need to specify to the public, the social implications of their work.

36. Scientists feel that the public and politicians must make the decisions about how science is used.

37. Scientists feel that the results of scientific work are mainly useful to scientists, they are not useful to the average person.

38. Scientists are not aware that discoveries in science are doing much to rapidly improve our way of life.

39. Scientists appreciate the extent to which their discoveries form the basis for the development of new products.

40. On their vacations, most scientists spend much of their time thinking about their work.

41. Scientists spend little time viewing television.

42. Scientists think that some natural phenomena are too complex ever to be explained by science.

43. Most scientists feel that it is not appropriate for man to tamper with the order and intentions of nature.

44. As scientists probe nature, the beauty and balance they discover, strengthens their belief in God.

45. Scientists believe that man is capable of understanding most natural phenomena.

46. Scientists feel that fellow scientists don't exert enough pressure on them to make scientific information known to the public.

47. Scientists feel that it is unprofessional to "popularize" their work to the public.

48. Scientists feel they have the responsibility to interpret the possible consequences of their work to the public.

49. Most scientists feel that how scientific discoveries are used is not the responsibility of scientists but of the public and politicans.

50. Scientists think they should be involved in political decision making about the applications of science.

51. Scientists feel that politicans should not have a role in deciding what type of research is to be done.

52. Scientists appreciate the freedom to tackle significant research problems.

53. Most scientists feel that man's lot is slowly improving with the use of more scientific knowledge.

54. Scientists appreciate the extent to which technological advance can aid in their research work.

55. On their vacation, scientists are more likely to take a trip around the country than to visit a scientific exhibit.

56. Scientists seldom read about science at home.

57. Most scientists are so involved in their work, they don't know what's going on in the world.

58. Scientists are not likely to be very religious people.

59. Scientists think that it is simple-minded to picture God in control of the universe.

60. Scientists think that the public is not interested in understanding the basic ideas behind their work.

61. Scientists believe they must assume the role of watchdog, in determining how science is applied.

62. Most scientists feel that the results of modern science are responsible for much of man's personal discontent and frustration.

63. Scientists enjoy spending time with their children.

64. Generally, scientists tend to shy away from public meetings and socials.

65. In their spare time, many scientists like to work around the house.

66. Scientists have very few hobbies.

APPENDIX C

VALIDITY CHECK

Judges are asked to please rate the items of the questionnaire on the following criteria and scales:

A. CLARITY in meaning of the item,

1. UNCLEAR - needs major revision
2. CLEAR - but needs minor revision
3. CLEAR AS WRITTEN

B. APPROPRIATENESS of the item for the designated category,

1. INAPPROPRIATE - not worth including
2. APPROPRIATE - but needs minor change.
3. CRUCIAL - should be included.

ITEMS	CLARITY			APPROPRIATENESS		
	1.	2.	3.	1.	2.	3.
1.	___	___	___	___	___	___
2.	___	___	___	___	___	___
3.	___	___	___	___	___	___
4.	___	___	___	___	___	___
5.	___	___	___	___	___	___
6.	___	___	___	___	___	___
7.	___	___	___	___	___	___
8.	___	___	___	___	___	___
9.	___	___	___	___	___	___
10.	___	___	___	___	___	___
11.	___	___	___	___	___	___
12.	___	___	___	___	___	___
13.	___	___	___	___	___	___
14.	___	___	___	___	___	___
15.	___	___	___	___	___	___

etc.

Please rate with a check (✓).

Space below may be used for comments.

APPENDIX D

MEMORIAL UNIVERSITY OF NEWFOUNDLAND
St. John's, Newfoundland, Canada

artment of Curriculum and Instruction

May 8, 1973

Dear Teacher:

Enclosed are copies of the questionnaire mentioned in our recent telephone conversation. The questionnaire consists of Part I - Semantic Differential, and Part II - Characteristics of Scientists Survey, Forms A and B.

The suggested procedure for administration of the questionnaire is to explain to students what is meant by scientists (ie. biologists, chemists, physicists, or geologists, who spend at least some of their time doing research) before giving Part I. Give all students Part I and explain how to score. Please ask them not to omit any items.

After students have completed Part I, give half of the class Part II - Form A and the other half, Part II - Form B, and explain how to score. Collect Part I, when it is completed by all students, and collect the response sheets for Forms A and B at the end of the period. The students may keep their copies of Characteristics of Scientists Survey (Part II). The questionnaire can be completed in one forty minute period, with approximately 10 minutes for Part I and 30 minutes for Part II.

The teacher is asked to please fill out the sheet on school, community, and teacher information, and return it along with Part I and the response sheets for Forms A and B of Part II, in the self-addressed envelope.

This school is one of a sample of schools selected to do this survey. Your co-operation as a science teacher is greatly appreciated. Could you please return the necessary information by May 25th, if all possible?

Results of the survey will be made available to you later in the year.

Thanking you in advance for your participation in this project.

Yours truly,

Dr. Richard Reis

Dr. Richard Reis

MEMORIAL UNIVERSITY OF NEWFOUNDLAND
St. John's, Newfoundland, Canada

artment of Curriculum and Instruction

May 8, 1973

Dear Scientist:

As a follow-up to our conversation earlier this year I am enclosing a copy of an instrument designed to measure a person's understanding of the characteristics of scientists. The instrument is the first important step in a research project designed to determine the accuracy of high school students' understanding of the life and work of scientists.

The responses of scientists about their own roles and the roles of their colleagues is a type of "yardstick" to which comparisons of students in high school biology, chemistry, physics, earth science and physical science can be made. This information can serve as a basis for further curriculum developments in science education designed to correct any misunderstandings (as in Mead's Study, 1957) that students may have. Without full cooperation from you as a scientist, this study couldn't possibly be a success.

The instrument consists of two parts which originally made up two separate forms that were given to a large random sample of grade eleven students.

Attempts are being made to contact all scientists in the province. The questionnaire is anonymous, but full participation is essential, if biases are to be eliminated. Will you please fill out the response sheet as directed and return it in the self addressed envelope by the end of May, if at all possible. You may keep the survey booklet.

A report of the results will be sent to all scientists contacted, by mid-September of this year.

Thanking you in advance for your cooperation.

Yours truly,

Dr. Richard Reis
Assistant Professor

MEMORIAL UNIVERSITY OF NEWFOUNDLAND
St. John's, Newfoundland, Canada

rtment of Curriculum and Instruction

June 2, 1973

Dear Scientist:

This note is a follow-up to the letter recently sent to you concerning a questionnaire on the characteristics of scientists. Please excuse the necessity to resort to a form letter but since all responses are anonymous it is not possible to be specific in addressing this letter. If you have filled out and returned the questionnaire, my many thanks. If you have not, this is a special appeal to ask you to do so even though, as I am aware, you are quite busy with other matters.

Some of you have raised certain questions concerning the validity of the questionnaire, indicating at least that you would strongly agree with the statement that "scientists freely criticize each other's work". It is not possible to comment here on all questions raised, but I feel that a few words of explanation are in order. One criticism has been that the questions seem forced and that the answers to some of the questions are obvious. Considerable thought was given to whether or not the response choices should be limited to those provided - which do appear to force answers - or whether a more open response format with, for example, a "don't know" or "neutral" category, available. The latter was rejected first, on the grounds that it would be very difficult to handle this response statistically, and second, that if the questions were worded properly, scientists could move out of a "forced category" by disagreeing that a particular statement applies to a majority of scientists. In this sense the questionnaire does not force a stereotype from the respondent and, in fact, allows him to reject a stereotype if he feels this is appropriate.

I agree that some of the questions may appear naive to scientists. You are asked to consider that the same questionnaire was given to 11th grade students and some of the questions which may seem obvious to you may not appear so to them.

The questionnaire was validated by giving an original copy to a scientist from each of the departments and to two science educators in the Faculty of Education. They were asked to rate each question as to its appropriateness and clarity with respect to a specific category. Only questions where there was a high degree of agreement among the judges were included.

This questionnaire should be considered a first step and I invite you to feel free to make any comments you wish on the back of the response sheet.

I hope this answers some of your questions. I will send you a complete report of our results sometime later in the year. Again my thanks for your co-operation.

Sincerely yours,

Dr. Richard Reis

Dr. Richard Reis
Assistant Professor