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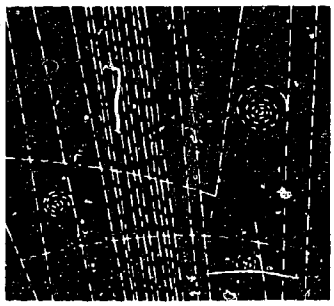
ABSTRACT

This study assesses students' understanding of the relationship between science, technology, and society, and compares the responses of science-oriented and non-science oriented high school seniors. (Non-science oriented students are those who did not take either chemistry or physics.) A sample of 1,493 seniors took the Test on the Social Aspects of Science (TSAS) as part of the Test Every Senior Project. The 52 items on the TSAS are grouped into five areas: the relationship between science and technology, the interaction of science and society, the nature of science, the characteristics of scientists, and the scientist's role in society. A chi square comparison between the science and the non-science oriented students was made on each of the test items in these groups. Science-oriented students showed a more positive attitude toward science, a better understanding of the nature of the scientific enterprise, and a more realistic conception of the characteristics of scientists. Non-science oriented students were weakest in areas related to the nature of science and the characteristics of scientists. Curriculum for both science and non-science oriented students needs to more effectively emphasize the social aspects of science. (PR)



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TEST EVERY SENIOR PROJECT

UNDERSTANDING THE SOCIAL ASPECTS OF SCIENCE

Willard W. Korth

That science has had a tremendous impact on modern culture is only too evident. Science educators need to be concerned with the importance of this fact for citizens in general and students in particular. All educated people, whether they become directly associated with the scientific enterprise or not, need an understanding of certain basic facts, concepts, and methods of science and their influence upon our way of life. Furthermore, students should be familiar with the implications of important new scientific and technological developments so that they may act intelligently on vital issues of the present and future. Finally, all students should recognize that while science influences society, society also influences the scientific enterprise.

Several studies have explored students conceptions of the social aspects of science. Allen (1959), using an Attitude Inventory with a sample of high school seniors, concluded that the students had positive and constructive attitudes toward science. However, an item analysis suggested that on many important matters related to a public image of science and the scientist there was misunderstanding, confusion, and possibly ignorance exhibited by substantial numbers of seniors responding to the issues and problems implied by the statements in the Attitude Inventory. This was especially true for those items bearing on the scientist and his work and on the nature of science. Mead and

Metraux (1957) analyzed a nationwide sample of essays written by high school students in response to incomplete statements. They concluded that while the official image of the scientist was very positive, this is not so when the student's personal choices are involved. Science in general is represented as a good thing. However, when the question becomes one of personal contact with science, the image is overwhelmingly negative. Earlier studies by Baker (1956) and Wilson (1954) also seem to indicate that students lack an understanding of the nature of science and its social implications.

As part of the Test Every Senior Project an attempt was made to assess students' understanding of the social aspects of science. For the purposes of this investigation, the social aspects of science are defined as those components of science which deal with the interaction between science and society and those features which are related to the social nature of the scientific enterprise itself. A theoretical model of the social aspects of science was developed through an extensive study of the relevant literature. This model consists of three major assertions with a series of statements expanding each assertion. The three assertions which form the basis of this instrument are:

(1) Science and technology interact with each other and with society.

(2) The scientific enterprise is an internally regulated social institution.

(3) The changes in society resulting from advanced science and technology may produce social, economic, and political problems which must be managed through appropriate social and political processes.

The instrument used in this study consists of 52 statements related to the three areas listed on page 2. Every student was asked to respond to each statement on a five point scale ranging from strongly disagree to strongly agree. A recent study by Schwirian (1968) has demonstrated that, even though they are short, such Likert-type scales discriminate between individuals and are fairly reliable. In a previous study (Korth, 1968) it was found that this instrument, the Test on the Social Aspects of Science (TSAS), had an estimated reliability for the total test of .71 based on the use of the Kuder Richardson Formula 20. The test can be divided into three parts. Part I consists of 19 items related to the interaction among science, technology, and society. Part II is made up of 21 items concerned with the social nature of the scientific enterprise. Twelve items related to the social responsibilities of scientists make up Part III. The estimated reliability on each of the three parts of the test was .43, .53, and .40 respectively.

One of the questions explored in the Test Every Senior Project was concerned with whether students who take the elective science courses in high school have a different conception of the scientific enterprise and the interaction of science and society than students who avoid these courses. It is recognized that there are substantial differences in the make up of these two groups. The students who elect additional science courses are usually the brighter students who are more highly academically motivated and are more likely to be college bound. However, the social aspects of science are of concern to all future citizens whether they are oriented toward science related careers or not. It was, therefore, felt

that if there were substantial differences between these two groups, it might point out serious deficiences in the science curriculum as it concerns the total range of high school students.

For the purpose of this study science oriented (SO) students are defined as those students who have elected to take chemistry and/or physics during their high school experience. Non-science oriented (NSO) students are those who did not take either chemistry or physics. The sample used here consisted of 1,493 students who took the Test on the Social Aspects of Science (TSAS) as part of the Test Every Senior Project. The division of students into groups is given in Table 1.

TABLE 1

DIVISION OF STUDENTS INTO GROUPS
FOR TSAS ANALYSIS

	Boys	Girls	Total
Science-oriented (SO)	485	380	865
Non-science oriented (NSO)	256	372	628
	741	752	1,493

Analysis of the results was performed on an item by item basis by grouping responses into three categories: (1) strongly disagree - disagree; (2) uncertain; and (3) strongly agree - agree and then comparing groups through the use of a chi square. Related items were finally grouped according to topics and comparisons were made concerning specific areas of interest.

Significant differences at the .01 level were found between science-oriented and non-science oriented students on 10 of the 19 items on Part I

relating to the interaction of science, technology, and society. On Part II, concerning the nature of the scientific enterprise, significant differences were found on 16 of the 21 items. There was also a significant difference on eight of the twelve items on Part III related to the social responsibilities of science and scientists. The fact that science-oriented students differed significantly from non-science oriented students on 34 of the 52 items indicates that the two groups have quite different views of science as it relates to society.

In order to gain additional information regarding the nature of these differences, test items were grouped according to specific topics and comparisons made between science-oriented and non-science oriented students in each of these areas. The five topics selected for analysis are discussed in the following sections of this paper.

Topic I. The students conception of the relationship between science and technology is assessed in the following items:

26. In modern industrial societies science and technology have little to do with each other.

28. The steam engine was one of the most important developments in the history of science.

34. The greatest accomplishments of science consist of the many useful products it has produced.

37. Researchers in science use the theories and laws discovered by workers in technology.

44. Technology often provides the tools and techniques that lead to new discoveries in science.

TABLE 2

COMPARISON OF SCIENCE-ORIENTED AND NON-SCIENCE ORIENTED STUDENTS REGARDING THE INTERRELATION OF SCIENCE AND TECHNOLOGY

(Percent of Students Responding)

	Science-oriented				Non-science oriented				Chi-	
Item	D	U	A	NR	D	U	A	NR	square	Sign.
26	90.3	5.1	3.9	0.7	78.3	14.3	7.1	0.3	45.2	.001
28	22.6	18.5	58.2	0.9	21.3	18.0	60.3	0.5	0.9	n.s.
34.	22.1	10.9	66.4	0.7	15.8	9.1	74.2	1.0	11.9	.01
37	23.2	34.0	42.0	0.7	13.7	41.5	43.5	1.3	31.0	.001
44	5.4	7.9	85.3	1.4	4.1	12.9	81.4	1.6	7.6	.05

The most interesting result here concerns the low percentage of students in both groups who seem to understand the nature of science and technology. Less than one-fourth of the students in both groups recognize the steam engine as largely a technological achievement (Item 28). The response to Item 34 seems to indicate that many students view science in terms of products rather than in terms of acquiring knowledge. While there was a significant difference between the two groups, approximately 22% of the science-oriented students disagreed with the statement. The large number of students who marked uncertain on Item 37 can be interpreted as further evidence of their lack of understanding of the interrelation of science and technology.

Topic II. The interaction of science and society

1. The many changes our culture is undergoing today have largely been caused by advances in science and technology.

13. Scientists are strongly influenced by the attitude and interests of the general public.

21. Because of the high cost of scientific research it would seem wise to cut down on research that does not appear to have any practical value.

23. The economic prosperity of most nations today deponds on their ability to discover and use scientific knowledge.

29. Science would advance more efficiently if it were more closely controlled by the government.

33. Many of today's social, economic, and political problems require the use of science and technology for their solution.

38. The political climate of a nation has little effect upon its scientists since they are pretty much isolated from the rest of society.

40. Social and economic changes will probably be needed to keep pace with the rapid advance of science and technology.

47. New scientific knowledge affects society only through the practical use made of it.

48. In a democracy the public should ultimately control the support of science and the use of its achievements.

49. It would be a good idea to slow down science until society has had a chance to adjust to the changes science has brought about.

TABLE 3

COMPARISON OF SCIENCE-ORIENTED AND NON-SCIENCE ORIENTED STUDENTS ON ITEMS RELATED TO THE INTERACTION OF SCIENCE AND SOCIETY

(Percent of Students Responding)

	Science-oriented				Non-science oriented				Chi-	
Item	D	U	A	NR	D	U	A	NR	square	Sign.
1	3.3	1.2	94.9	0.5	4.8	2.4	92.5	0.3	5.4	n.s.
13	39.4	18.8	41.1	0.6	33.3	21.6	44.6	0.6	20.7	.001
21	57.2	12.3	29.9	0.6	43.9	15.9	39.8	0.5	26.4	.001
23	7.6	9.5	82.2	0.8	11.1	11.1	77.1	0.6	7.5	.05
29	70.5	18.0	10.7	0.7	59.8	22.6	17.2	0.4	7.9	.05
33	11.4	11.7	76.3	0.7	14.5	13.5	71.2	0.8	5.1	n.s.
38	83.7	7.3	8.4	0.7	70.8	14.3	13.6	1.3	35.0	.001
40	7.9	8.3	82.7	1.0	8.9	12.6	77.3	1.3	8.2	.05
47	42.8	9.5	46.4	1.3	35.1	11.1	52.2	1.6	9.0	.05
48	47.5	17.0	34.0	1.5	40.4	17.3	40.4	1.9	8.2	.05
49	79.7	9.7	9.3	1.3	65.1	14.5	18.9	1.6	23.8	.001

There is an indication of an anti-science attitude on the part of non-science oriented students especially as it is related to those areas of science which promise little immediate practical value. For example, significantly more non-science oriented students agreed with the statement that it might be wise to cut down on research that does not appear

to have any practical value (Item 21), and although a minority, the non-science students were more likely to agree that science should be slowed down until society has a chance to adjust to the changes it has brought about (Item 49). The non-science oriented students also had a greater tendency to agree with Item 29, that science would advance more efficiently if it were controlled more closely by the government. One interesting result was in the fact that over 40% of all students disagreed with the statement (Item 48) that in a democracy the public should ultimately control the support of science and the use of its achievements.

Topic III. Understanding the nature of science

2. Statements are not accepted as scientific knowledge unless they are absolutely true.

3. Scientists have advanced knowledge by consistently following, step by step, a definite procedure called the scientific method.

22. The principal aim of science is to provide the people of the world with the means for living better lives.

24. Science is primarily a method for inventing new devices.

30. Many of the scientific theories of the past have been disproved or modified as they have been found inadequate. However, the theories and laws of modern science are accurate and are likely to endure in their present form.

43. The aim of science is to increase man's knowledge of the physical and and biological world.

45. The scientific investigation of human behavior is of little value since it must involve the personal opinion of the investigator.

51. A fundamental rule of science is that discoveries should have some practical value.

TABLE 4

COMPARISON OF SCIENCE-ORIENTED AND NON-SCIENCE ORIENTED STUDENTS ON UNDERSTANDING THE NATURE OF SCIENCE

(Percent of Students Responding)

	Science-oriented				Non-science oriented				Chi-	
Item	D	U	A	NR	D	U	A	NR	square	Sign.
2	39.9	6.6	52.8	0.7	27.0	13.2	59.3	0.5	37.2	.001
3	22.5	8.2	68.4	0.7	18.0	18.9	60.4	0.6	37.6	.001
22	10.8	7.3	81.1	0.7	8.6	7.3	83.4	0.6	7.5	.05
24	68.4	8.9	21.8	0.9	55.7	10.5	33.4	0.5	29.0	.001
30	57.9	13.9	27.5	0.7	40.9	26.5	32.3	0.3	49.0	.001
43	9.3	7.7	82.1	0.9	11.3	8.6	78.5	1.6	2.4	n.s.
45	81.5	8.7	8.8	1.0	66.1	14.6	17.8	1.4	46.6	.001
51	43.0	14.6	41.2	1.3	23.3	17.2	57.4	2.1	62.1	.001

There was a significant difference (at the .01 level) between science-oriented and non-science oriented students on six of the eight items in this area. Science-oriented students were more likely to disagree that statements are not accepted as scientific knowledge unless they are absolutely true (Item 2). There was also a higher probability that they would disagree with Items 24, 30, 45, and 51. One would predict that greater exposure to science courses would promote a better understanding of the aims of science and its methods. In general, this idea is supported by the data.

However, an alternative explanation can be offered. Perhaps these differences are largely due to a lack of understanding on the part of non-science oriented students rather than due to a high degree of sophistication on the part of students who have taken chemistry and/or physics. It should be noted that over half of the science-oriented students agreed that scientific knowledge had to be absolutely true (Item 2), and less than 60% understood the tentative nature of scientific theory as indicated by

their responses to Item 30. In fact, the science-oriented subjects were more likely to accept the notion of a scientific method (Item 3) than were the other students.

Topic IV. The characteristics of scientists

11. Winning the esteem of his associates is one of the main incentives of the scientist.

14. A scientist is likely to be unbiased and objective, not only in his own field of work, but in other areas as well.

18. Most scientists are not interested in public recognition for their discoveries.

27. Scientists often question established social and political ideas. This is true because most scientists are political radicals and atheists.

39. Scientists have no business investigating topics that may question people's religious beliefs.

46. The honesty and accuracy commonly attributed to scientists' reports of their work is largely due to the fact that scientists as a group tend to be more honest than other types of people.

TABLE 5

COMPARISON OF SCIENCE-ORIENTED AND NON-SCIENCE ORIENTED STUDENTS ON UNDERSTANDING THE CHARACTERISTICS OF SCIENTISTS

(Percent of Students Responding)

	Science-oriented				Non-science oriented				Chi-	
Item	D	U	A	NR	D	U	A	NR	square	Sign.
11	67.9	11.7	19.6	0.8	53.2	19.4	26.9	0.5	35.3	.001
14	37.9	22.9	38.4	0.8	24.8	27.5	47.3	0.5	29.2	.001
18	38.5	23.4	38.0	0.1	40.8	22.6	35.8	0.8	1.1	n.s.
27	80.9	13.8	4.3	0.9	58.5	29.1	11.8	0.5	95.2	.001
39	73.4	12.3	13.5	0.8	53.2	17.3	28.3	1.3	70.0	.001
46	56.8	20.5	21.8	1.0	45.7	25.8	27.0	1.6	17.4	.001

The data in Table 5 indicates that there are rather substantial differences between the two groups on 5 of the 6 items in this category. However, the distinctions are not clear-cut. On one hand, the responses to Items 14 and 46 suggest that science-oriented students have a more realistic view of the characteristics of scientists. Their responses to Items 27 and 37 appear to indicate a more positive attitude toward scientists freedom to investigate.

However, responses to Items 11 and 18 by the same subjects reflect some misconception of the scientists attitude toward recognition for his achievements. The best indication of a lack of understanding of the characteristics of scientists is found in the comparatively large number of students who marked the uncertain category (especially in Items 14, 18, 27, and 46).

Topic V. The scientists role in society

5. Scientists should be concerned with the potential harm that might result from their discoveries.

7. The judgment of scientists on political matters should be highly respected since they are likely to approach such problems with a scientific attitude.

12. Most of the evil in the world today is the responsibility of scientists since they have developed the knowledge that has lead to such problems as nuclear weapons, pollution, etc.

25. Scientists are usually more poorly informed on political matters than other educated citizens since their work tends to isolate them from the rest of society.

31. A scientist should withhold a discovery from the world if he thinks it may have undesirable social consequences.

50. The scientist generally has little control over the use society may make of his discoveries.

52. Many of today's social and political problems are related to science and technology. Since scientists are experts in this field we should accept their judgment in such matters.

TABLE 6

COMPARISON OF SCIENCE-ORIENTED AND NON-SCIENCE ORIENTED STUDENTS IN UNDERSTANDING THE SCIENTISTS ROLE IN SOCIETY

(Percent of Students Responding)

	Science-oriented				Non-science oriented				Chi-	
Item	D	U	A	NR	D	U	A	NR	square	Sign.
5	18.4	5.9	75.1	0.5	18.7	7.0	73.8	0.5	0.8	n.s.
7	64.3	16.0	18.9	0.8	52.7	21.2	25.3	0.6	20.0	.001
12	77.1	6.2	16.0	0.7	61.4	9.7	28.1	0.8	44.1	.001
25	71.5	15.8	12.1	0.7	63.0	19.4	17.4	0.3	11.6	.01
31	28.4	22.2	48.5	1.0	25.3	17.0	57.0	0.6	11.4	.01
50	26.2	15.7	57.0	1.1	27.4	17.5	53.5	1.7	1.4	n.s.
52	51.0	18.4	29.4	1.3	34.3	24.1	39.3	2.2	33.8	.001

The responses to Items 7 and 52 indicate the the non-science oriented student is more willing to accept the judgment of scientists on social and political matters than is the science oriented student. However, he is also more likely to blame scientists for contempory problems (Item 12) and to believe that scientists are more poorly informed on political matters than other educated citizens (Item 25).

Conclusion

The Test on the Social Aspects of Science attempts to assess students' understanding of the relationship between science, technology, and society. In this paper five areas of interest have been selected and comparisons made between the responses of science-oriented and non-science oriented high school seniors. The range of topics available for study have not been completely covered. Instead, the study has been confined to those areas which appear to show the greatest differences and those of greatest interest in curriculum development.

In general, science-oriented students show a more positive attitude toward science, a better understanding of the nature of the scientific enterprise, and a more realistic conception of the characteristics of scientists. Non-science oriented students show their most pronounced weaknesses in those areas related to the nature of science (Table 4) and the characteristics of scientists (Table 5).

The results of this study indicate that many students who do not take chemistry and/or physics have serious misconceptions concerning the nature of science, the scientific enterprise, and the interaction between science and society. In present day society an understanding of these factors is needed by all citizens in order to understand the impact of science on the contemporary world. While the results show that science-oriented students have a different

viewpoint toward science and the scientist than other students, there is evidence that many students who have taken chemistry and/or physics lack an understanding of some of the important social aspects of science. Many of them confuse science with technology, express their agreement with the idea of a scientific method, fail to grasp the nature of scientific knowledge, and have a tendency to think of science in terms of material products rather than as the acquisition of knowledge.

The results of this study suggest two major implications concerning science curriculum development. First, high school students who do not elect chemistry and/or physics have little opportunity to learn about the social aspects of science, an area which promises to be an important component in their future. This emphasizes the increasing need for science related courses for non-science oriented students to help equip them to cope with a society that is highly oriented toward science and technology. Second, since many science-oriented students demonstrate a lack of understanding in the same areas, there is reason to question the effectiveness of present day science courses as they relate to the relationship between science and social issues. If learning about how science relates to students' lives is an important objective of science instruction, it appears that science educators need to critically examine present offerings in regard to their contribution to this phase of general education.

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