DOCUMENT RESUME

ED 391 641 SE 056 657

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TITLE High School Students' Views about Technology.
PUB DATE Apr 95
NOTE 20p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (San Francisco, CA, April, 1995).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Beliefs; Foreign Countries; High Schools; *High School Students; Interviews; Science and Society; *Sciences; *Technology
IDENTIFIERS Newfoundland

ABSTRACT

In this technologically expanding world it is important for teachers and other educators to be aware of students' existing conceptions of technology and to provide appropriate avenues for change. This study interviewed high school students (n=26) in Newfoundland, Canada, about their beliefs of science and technology. Questions were asked regarding examples, processes, and purposes of science and technology; relationships between them; characteristics and responsibilities of scientists and technologists; and relationships between science and technology with society. The majority of students made the distinction between examples of technology and examples of science confidently and correctly. This was also true for the distinction between the processes involved in doing science and technology. Although most students were aware that technology is concerned with the improvement of human life, they did not distinguish technology and science at all well in this regard. Many of the students held the well known stereotype of the scientist as a white coated, unkempt, bespectacled male but, surprisingly, about half of the students considered technologists to be just as likely female as male. Both scientists and technologists were seen as having a responsibility to help people. The general impression gained is that there is a need for improvement in students' understanding of technology and technologists. (MKR)

HIGH SCHOOL STUDENTS' VIEWS ABOUT TECHNOLOGY

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Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Francisco, April, 1995.

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In the last fifteen years or so a large literature has developed that emphasizes the importance of including considerations of technology in the context of STS within the science curriculum. In the last few years technology educators have also argued that their subject deserves a pivotal position in the school curriculum, and that this should be much more broadly based than mere inclusion as an aspect of science education. In each case the literature is largely exhortational, with only a relatively small empirical base. There is not even a commonly accepted definition of technology. Donelly (1992), for example, notes ten different definitions, and suggests that these are generally uninformative. However, in the study reported here, we were concerned with the views of students, rather than those of educators. What do students consider technology to be? Is it different from science, and if so how? To add to the small literature on this we conducted an interview study involving 26 high school students in the province of Newfoundland in eastern Canada.

The most extensive research in this field is that reported by Aikenhead, Fleming and Ryan in a series of publications (Aikenhead, Fleming and Ryan (1987); Fleming (1987) and Aikenhead (1987)) based on their study involving over 10,000 Canadian high school students . The final version of their instrument (VOSTS) is a large collection of items relating to eight dimensions of STS, one of which relates particularly to the meaning of technology. In our experience, the structure of these items is relatively complex, and even graduate students have difficulty with wording and subtle nuances. Nevertheless, their findings are informative, and in the analysis section of our paper we have attempted to relate our findings to them. Briefly, at this time, the students in their sample did not distinguish well between scientists and technologists, and they tended to be confused between the roles of each.

In a subsequent study (Zoller et al.,1990), also conducted in Canada, four VOSTS items were administered to 101 high school students enrolled in an STS course and a control group of 276 non-STS students. The results showed that the STS students had a better understanding of the role played by society in controlling technological development.

Two British studies offer some information. Nash, Allsop and Woolnough (1984) administered a questionnaire to 91 fifteen year old students who were involved in a technology course. They found that most of these students differentiated technology from science in that,

for example, "There is more design work and constructing and developing designs in technology." In another study Solomon (1988) found that more than half of a sample of 284 sixteen year old students who had completed a school leaving STS course defined technology in terms of equipment, tools or machinery, despite being asked in the context of a non-mechanical example.

Finally, a series of studies involved a common written instrument (Pupils Attitudes Towards Technology, or PATT) that was developed in the Netherlands. Wolthers, deClerk, Ratt and deVries (1990) report data from the use of this instrument in three studies. In the first they found that the majority of a sample of 500 students in Holland, aged between 12 and 13 years of age, associated technology with machinery and equipment. In a second study, carried out on 1167 sixteen-plus students in India, they found that boys and girls exhibited similar attitudes towards technology. A third study, conducted in Poland with a sample of 600 students, showed an overwhelming representation of technology as production. Finally, Rennie (1987) administered PATT to 229 year eight students in the Perth, Australia metropolitan area. These students showed substantial ignorance of both the meaning and long history of technology, as well as its pervasiveness in everyday life. A large proportion of this sample, including most of the girls, showed poor awareness and understanding of technology.

Clearly, then, there is a small but disturbing literature relating to students' understanding of the meaning of technology. The present study investigated this further.

SAMPLE AND PROCEDURES

The students involved in the study were drawn from five schools located in different parts of the island of Newfoundland in eastern Canada. The schools ranged from small to large in size, and were mixed in terms of urban and rural setting. The sample was selected to be as diverse as possible, in order to obtain a representative sampling of students' understandings. In each school a stratified random sample of six students was selected, such that there were three males and three females in each case. Further, each of these sub-groups contained a high, medium and low achiever in science. Because of tape-recording difficulties, four of these students were eliminated from the study, leaving a sample of thirteen males and thirteen females.

Nine of these were high achievers, ten were medium achievers and seven were low achievers in science. Ages ranged from 15 years five months to 18 years four months, with an average age of 16 years and six months.

Each student was interviewed individually through application of a common set of core questions, with opportunity for probing and clarification both by the interviewer and the student. Each interview took about 30 minutes, but no fixed time was allotted. In an attempt to ensure that the students were not conflating technology with science, equivalent questions relating to science and technology were asked. The core questions were grouped under the headings: "examples of science and technology; activities associated with science and technology; the purposes of science and technology; relationships between science and technology; responsibilities of scientists and technologists; and relationships between science and technology with society."

In developing the questions, criteria drawn from Guba and Lincoln (1981) were applied, such that each question was subjected to the following scrutiny:

a. Is this question necessary? How will the response be used? How will the response be analyzed?
b. Does the question cover the topic? Are additional questions necessary?
c. How will this question be interpreted? Are other facts needed before the question will make sense?
d. Do the respondents have the information necessary to answer the question? Has the interviewer allowed for differences? How reliable would the interviewer expect the responses to be?
e. How valid does the interviewer expect the responses to be? Is the question leading? Is it phrased in value-neutral terms? What has been taken for granted? What are the possible frames of reference?

The interview questions were validated initially by reference to several science teachers, and were refined further following individual pilot interviews with four students equivalent to those interviewed in the main study. In both the preliminary study and the main study, each interview was audiotaped and transcribed. Each transcript was transformed to a conceptual inventory following suggestions by Erickson (1979). Finally, the match between each transcript

and its associated conceptual inventory was validated by reference to two independent science teachers in each case.

RESULTS

Examples of science and technology

Each interview followed a similar pattern. After a minute or so of general conversation that was designed to promote a relaxed atmosphere, the student was asked if s(he) was familiar with the words science and technology. Each student affirmed this to be the case. This was then pursued with the questions "What does the word science mean to you?", and then "what does the word technology mean to you?" In each case the student was asked to provide illustrative examples, and subsequently to classify selected examples as science or technology. Students' responses to the question about science often reflected the science courses they were taking in school, for example "First of all, things in school." or "E gy, Chemistry and Physics." There were also responses that indicated trouble distinguishing science from technology such as "Experiments, studies and technical stuff like that." and "Well, like new technology, advancement, different experiments, new equipment." The question about technology produced replies ranging from "Uhm, like using a lot of machinery" to 'Well, computers more so than in science." Responses are summarized in Table one.

(insert Table 1)

Responses to some of the questions seemed merely to follow directly from placement of topics in school science. Thus, studying atoms and molecules was considered by all of the students to represent science, while computers were mainly associated with technology. Common appliances such as a television (25 responses), a toaster (20 responses), and a telephone (18 responses) as well as a steam engine, a space shuttle and new military equipment were appropriately considered to be more representative of technology. Surprisingly, most students did not associate a hammer with technology, and striped toothpaste was considered to be more allied to science than technology. In the words of one student, when asked to classify a

hammer, "I'd say science. Obviously it couldn't be technology 'cause its been around for a long, long time." The overall direction of these results are consistent in kind with Fleming (1987), but it is also worth noting that the students in the present study showed acceptable ability to distinguish examples of technology from examples of science.

The processes of science and technology

Drawing on Layton (1988), Fensham (1990) suggests that science involves discovering and uncovering new knowledge, while technology involves design and invention. In the present study, students' responses to the questions "What processes are involved in doing science?" and "What processes are involved in doing technology?", as well as their subsequent clarifications, indicated good understanding of the different emphases in science and technology. Thus, science was generally seen as involving discovering and uncovering knowledge (16 and 21 students, respectively) while technology was seen as more concerned with designing and inventing (18 and 15 students, respectively). Further, 23 students considered technology to be concerned with making products, while 12 considered this to be so for science. One student summed up the difference as he saw it with the following, "Technology is something that is advanced, is like disks, microchips and stuff like that. Equipment. Science is more the brain, how to figure stuff out and more about the body and chemicals." The overall results are shown in Table two.

(Insert Table 2)

The purposes of science and technology

In this section of the interview each student was asked initially "What is the purpose of science?", and "What is the purpose of technology?" Students were encouraged to expand upon their initial answers, and many students contributed several alternatives in each case. The most frequent responses are indicated in Table three.

(Insert Table 3)

Not surprisingly, students' views of the purposes of science and technology were closely related to their beliefs about the activities engaged in by scientists and technologists, respectively. Thus, the view of science as involving discovering and uncovering new knowledge is consistent with the purpose of science as "finding out about things" (19 students). Similarly, considering technology as involving designing, making and inventing (Table two) is consistent with the belief expressed at this point in the interview that technology includes "making life easier", "making things more advanced", and "inventing". One student said simply, the purpose of technology is "to make life easier and to make things happen faster and better." However, although the perceived purposes of technology were seldom confused with the perceived purposes of science, the converse was not true. Thus, a number of students confused the basic role of technology, to provide conditions that enhance life, with the basic role of science, to produce improved understanding of the world around us. In this vein, six students considered the purpose of science to be finding new medicines and cures for disease; three considered it to be helping people; and another three considered it to be to make the world a better place in which to live. These views are again consistent with the VOSTS results, and emphasize the difficulty that students have in distinguishing science from technology. This leads us naturally to our next consideration, a further probe of the relationship between science and technology.

The relationship between science and technology

The next core questions asked "Do science and technology depend on one another?", "Is one the application of the other?", and "Could one exist without the other?" Table four indicates that there were a range of views on this topic.

(Insert Table 4)

It was apparent that many students were unaware of both the long history of technology and the much shorter history of science. Thus, while 16 students considered that technology would not exist without science, only four believed that it would. To the contrary, the importance of technology to science was recognized by exactly half of the students, who typically expressed the view that although science would exist without technology we wouldn't

know as much about it. Two of these students took this much further when they suggested that without technology science would have no purpose.

This section of the interview elicited a range of views. Eight students considered science and technology to be related, but ten considered them to be independent. In the view of one student, "They're really two different things but you usually find them together." Eleven students considered science and technology to be different, but ten considered them to be just different ways of referring to the same thing. One student stated, "One is almost identical to the other in almost every way." Although to a lesser degree, these findings agree with Fleming (1987) in that many students are confused about the relationships between science and technology, and with Rennie's finding that many students do not have a clear conception of what is meant by technology (Rennie,1987). The net result of this confusion is that many students misunderstand what is meant both by technology and science.

Characteristics of scientists and technologists

At this point in the interview each student was told that the topic would change from science and technology themselves to the people who work at science and technology. They were asked what kind of picture came into their minds when they thought about a scientist, and further questions were then asked to probe their beliefs. This process was repeated with the word scientist replaced by the word technologist. Finally, students were shown six sketches, and asked to identify which most closely resembled their image of a scientist and a technologist, respectively. The overall responses are represented in Tables five and six.

(Insert Tables 5 & 6)

Table five indicates that students hold a range of views about both the physical and non-physical characteristics of scientists. The physical characteristics are very similar to those identified by Kahle (1989). Thus, scientists are likely to wear a white lab coat (14 responses), to be male (13 responses), to work in a laboratory (11 students) and to wear glasses. The students were considerably less sure of the physical characteristics of technologists. In general they had difficulty identifying who a technologist is. One student replied with the question, "You mean

someone who applies the science?" and another simply said "I don't know." However, they leaned towards a male image (11 responses), with an almost equal number (ten) suggesting that technologists may be male or female. This again supports previous data (Moore,1987).

In the present study, students' conceptions of non-physical attributes of scientists and technologists were identified and compared. Surprisingly perhaps, a number of students considered both scientists (10 responses) and technologists (13 responses) to be good at communicating, with four students suggesting that technologists would be better than scientists at this. A few students (four in each case) considered scientists and technologists to be motivated by money, while three students considered technologists to be concerned to improve life. However, on the whole students had no opinion about technologists' motivation, but they were firmly convinced (16 responses) that curiosity is the primary motivation of scientists. Both scientists and technologists were considered by some students (six and five, respectively) to demand great care in their work. Finally, the stereotypical conception of a technologist as being someone who works with machinery was fairly evident (eight responses), but this was not mentioned at all with respect to scientists.

Responsibilities of scientists and technologists

The interview continued with the question "What kinds of responsibilities do scientists have? Technologists?" Although this was intended as a two-part question, the students tended to consider scientists and technologists collectively, and no real differentiation was observed. The main findings are reported in Table seven.

(Insert Table 7)

Although there was a minority view that scientists and technologists are mainly concerned with becoming rich and famous (three students), the overwhelming response (18 students) was that the main responsibility of scientists and technologists is to benefit people. For example, according to one student "They like to make things for the general public to make life easier and more efficient," and another commented "...I think for the most part they are for the

good of the people." Both were considered to be responsible (four responses), dedicated (four responses) and responsible for ensuring the safety of their work (seven responses).

Relationships between science and technology with society

The final section of the interview began with the core questions "Does science and/or technology influence society?" and "Does society affect science and/or technology?" Subsequent discussions were wide-ranging, as Table eight indicates.

(Insert Table 8)

Students were well aware that science and technology have a big influence on society. This influence may be interpreted as being potentially double-edged, making life easier (17 responses) but also causing problems (four responses). Yet, about a third of the responses suggested that science and technology offer more benefits than problems. Many students believed that scientists and technologists themselves should decide what risks to take, but this was balanced by a recognition of the need to keep the public informed (15 responses). For example, "If the general public is not educated about science and technology they cannot have a say about them". This was reinforced by the widespread belief that society should be able to influence science and technology (18 responses), for example "Like the cure for cancer, I think if the motivation for it is the general population then eventually some scientists are going to sit down and find it." Fifteen students recognized that government has a large influence on the conduct of science and technology. On the whole there seemed to be a healthy balance between a recognition of the rights and responsibilities of scientists and technologists on the one hand and the public and government on the other, for example "Like there's all these products out in the last 30 years or so, and they're really screwing up the environment and that, you know, and you're going to get people being more conscious." These findings are not entirely consistent with those of the VOSTS study (Fleming, 1987), in which there was an almost equal split between those believing in a technocratic decision making model on the one hand and social control on the other.

DISCUSSION

This intensive interview study yielded a number of insights, some of which support the results of previous studies and others that add to existing knowledge.

With respect to students' ability to identify and discriminate between examples of technology and examples of science, both standard school content and everyday examples of science and technology were, with a few exceptions, readily distinguished. The majority of students made these distinctions confidently and correctly.

This was also true for the distinction between the processes involved in doing science and technology, respectively. Generally, the students distinguished between science as discovering/uncovering knowledge and technology as designing/inventing. However, the restrictive concept of technology as manufacture was also widely held.

Although most students were aware that technology is concerned with the improvement of human life, they did not distinguish technology and science at all well in this regard, as the primary role of science was also considered to be the improvement of life rather than the development of knowledge and understanding of the world around us. In general, this finding supports the findings of earlier studies by Fleming(1987) and Rennie(1987).

Many of the students in the present study held the well known stereotype of the scientist as a white coated, unkempt, bespectacled male but, surprisingly perhaps in the light of their widely held mechanical view of technology, about half of the students considered technologists to be just as likely to be female as male. There was also certainty about the non-physical characteristics of scientists, but there were no clear parallel views relating to technologists.

Both scientists and technologists were seen as having a responsibility to help people, and this carried over to a perception that the benefits of science and technology outweigh any problems that they may cause. Overall, it was felt that there should be a balance between a citizen driven and a scientist/technologist driven view of decision making on social issues relating to science and technology.

In conclusion, this study extends the literature on students' perceptions of scientists to include their views on technologists. The general impression gained is that there is a need for improvement in students' understanding of technology and technologists. In today's

technologically expanding w orld it is important for teachers and other educators to be aware of students' existing conceptions of technology, and to provide appropriate avenues for change.

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TABLE 1
EXAMPLES OF SCIENCE AND TECHNOLOGY

SCIENCE	NUMBER OF RESPONSES	TECHNOLOGY	NUMBER OF RESPONSES
atoms and molecules	26	television	25
studying DNA	23	computer	24
new medicine or new drug	15	toaster	20
biology	13	military equipment	20
chemistry	10	steam engine	18
striped toothpaste	10	telephone	18
electron microscope	10	hammer	12
physics	8	space shuttle	12
chemicals	8	machinery	11
computers	5	aritificial heart	7
hammer	5	electron microscope	5
telephone	4		
artificial heart	4		
environment	4		
medicine (occupation)	3		
the body	3		

TABLE 2
ACTIVITIES ASSOCIATED WITH SCIENCE AND TECHNOLOGY

PROCESS	SCIENCE	TECHNOLOGY	BOTH OR EITHER
Discovering	16	4	6
Designing	4	18	4
Making	3	14	9
Uncovering	21	2	3
Inventing	5	15	6

TABLE 3
PURPOSE OF SCIENCE AND TECHNOLOGY

SCIENCE	NUMBER OF RESPONSES	TECHNOLOGY	NUMBER OF RESPONSES
to find out things	19	to make life easier	12
to find medicines or cures for diseases	6	to make things more advanced	10
to help technology	4	inventions	3
to help people	3		
to make the world better	3		

TABLE 4
RELATIONSHIPS BETWEEN SCIENCE AND TECHNOLOGY

STATEMENT	NUMBER OF RESPONSES
Without science, technology would not exist	16
science would exist without technology but we wouldn't know as much about it	13
science and technology are two different things	11
science and technology are two different ways of referring to the same thing	10
science and technology are interdependent	10
science and technology are related	8
science would exist without technology	5
technology would exist without science	4
we need technology as tools for science	3

TABLE 5
CHARACTERISTICS OF SCIENTISTS

STATEMENT	NUMBER OF RESPONSES
smart or a "brain"	17
white lab coat	14
motivated by curiosity	13
there are more males than females	13
works in a lab	11
good at communicating	10
there are equal numbers of males and females	10
talk in technical terms	9
glasses	8
not good at communicating	7
work can be affected by their values	7
need high standards/careful	6
work alone	5
works with chemicals	4
like scientist in Back to the Future	3

TABLE 6
CHARACTERISTICS OF TECHNOLOGISTS

CHARACTERISTIC	NUMBER OF RESPONSES
there are more males than females	11
there are about equal numbers of males and females	10
good at Physics/math/science	5
need high standards/careful	5
good at working with their hands	4
better at communicating than a scientist	4
pictured as male	3
talk in technical terms	3
motivated by money	3
motivated to improve life	3

TABLE 7
RESPONSIBILITIES OF SCIENTISTS AND TECHNOLOGISTS

STATEMENT	NUMBER OF RESPONSES
mostly try to do good and benefit people	18
are responsible for the safety of their work	7
have a lot of responsibility	4
may become rich and famous for what they do	4
have to be dedicated to their work	4
help people and make money at the same time	3
a few are just trying to get rich and famous	3

TABLE 8
RELATIONSHIP BETWEEN SCIENCE AND TECHNOLOGY WITH SOCIETY

STATEMENT	NUMBER OF RESPONSES
science and technology have a big influence on society	19
society should be able to influence science and technology	18
science and technology affect careers/jobs	17
science and technology make life easier	17
the public should be informed about science and technology	15
the government influences science and technology	15
scientists and technologists themselves should decide what risks they take	14
science and technology respond to the needs/wants of society	14
problems associated with science and technology result from how we use them	14
science and technology affect entertainment	12
science and technology affect us everyday	9
science and technology cause more benefits than problems	8
science and technology will be more important in the future	8
other people decide how scientists' and technologists' work will be used	7
science and technology cause problems like pollution	4