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ABSTRACT

This document contains the instrument used, results gathered, and discussions of the instrument used to measure students' (grades 10 and 12) understanding of science in its technological and social context. The following sections are included: (1) "Introduction"; (2) "A Comparison of Grade 10 and 12"; (3) "The Grade 10 Students"; (4) "The Grade 12 Students"; (5) "The Bipolar Statements," which contains a comparison of grade 10 and 12, a comparison of males and females, and the demographies of the sample; (6) "The 'Attitude to Science' Clusters"; (7) "Responses by Attitudinal Clusters to the Knowledge Statements"; (8) "Responses by Attitudinal Clusters to the Bipolar Statements"; (9) "The Demographics of the Four 'Attitude to Science' Clusters"; (10) "Discussion" which contains a discussion of the answers to the knowledge statements; and (11) "Conclusions." (ZWH)

Measuring Students' Understanding of Science in its Technological and Social Context

Volume Two: Validating the Instrument

Jeffrey Crelinsten, The Impact Group
Jean de Boerr, Market Facts of Canada
Glen Aikenhead, University of Saskatchewan

Ministry of Education and Training
Ontario

This research project was funded under contract by the Ministry of Education and Training, Ontario. It reflects the views of the authors and not necessarily those of the ministry.

A RESEARCH STUDY COMMISSIONED BY THE ONTARIO MINISTRY OF EDUCATION AND TRAINING

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1.0 INTRODUCTION

The instrument is comprised of two sections. The first contains the set of "knowledge statements" and the second, the set of "attitudinal bipolar".

1.1 The Knowledge Statements

In total, 29 sets of statements were presented. The student respondents were asked, for each set, to "please read all the sentences and then circle the number next to the one that comes closest to your opinion". The statements as presented are to be found in the questionnaires appended to Volumn One of this report. All sets of statements were presented to approximately half of each grade's sample, in order to address the potential fatigue factor. The first two sets, however, those on the definition of science and of technology, were presented to all respondents.

This report on knowledge does not presume to comment on which are the "correct" answers according to the curriculum. It reports merely on the results of the investigation. Section 10 deals with the issue of which answers are "correct" according to established STS scholarship.

In the following sections, the order of the items is the same as the questionnaire.*

2.0 A COMPARISON OF GRADE 10 AND GRADE 12

TABLE 1

SCIENCE IS...

	Total Grade 10	Total Grade 12
Total respondents (100%)	770	652
	%	%
explaining the unknown	34	41
using what we know to make the world a better place to live in	34	37
subjects like chemistry,physics and biology	29	21
a group of people (scientists) and what they believe	4	3
No answer	2	3

* Table 1 refers to item I, Table 2 refers to item 2, and so on.

While in both grades the first statement, "explaining the unknown", is in first place, it is perhaps not surprising that more of those in Grade 12, who have had two extra years of studying science, opt for this statement. It is equally not surprising that the slack is taken up by the Grade 10 response of "subjects like physics, chemistry and biology". In both grades, very few indeed think that science is "scientists and what they believe".

Three per cent and five per cent of Grade 10 and Grade 12 respectively gave more than one answer to this question.

TABLE 2

TECHNOLOGY IS...

	Total Grade 10	Total Grade 12
Total respondents (100%)	770	652
	%	%
- how science is put to use	32	39
- using what we know to make the world a better place to live in	25	27
- machines and inventions	15	9
- machines and inventions as well as designing things	28	25
No answer	2	3

For both grades, "how science is put to use" occupies first place, being mentioned by a third or more. Again for both grades second place is shared, about a quarter mention each, by "using what we know to make the world better" and "machines, inventions and designing things". The stark definition of "machines and inventions" only, received a low response, though somewhat higher among the Grade 10 students than those in the Grade 12.

TABLE 3

WHO SHOULD DECIDE WHAT TYPES OF ENERGY CANADA WILL USE IN THE FUTURE?

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
Scientists and engineers should decide what types of energy (such as nuclear, hydro, solar, etc.) Canada will use in the future, because they know best	19	23
Everybody should be involved in deciding what types of energy Canada will use in the future, because we are all affected by the decision	62	66
People other than scientists and engineers should decide what types of energy Canada will use in the future, because the decision is a social and economic one, not a technical one	16	11
No answer	3	1

There is no doubt about students' opinions on this matter. Two out of three of both grades vote for the second statement. While the remainder of the Grade 10 respondents are equally split on the first and third statements, twice as many Grade 12 students choose the first as choose the third one.

TABLE 4

WHETHER WE HAVE TO ACCEPT BOTH GOOD AND BAD EFFECTS OF TECHNOLOGY

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
We have to accept both the good and the bad effects of technology, because every new development has at least one bad effect, and to enjoy the good ones we have to put up with the bad ones	37	37
We don't have to accept the bad effects of technology, because bad effects can be reduced or removed through careful planning and testing	47	50
We don't have to accept the bad effects of technology, because some new developments have no bad effects and we should use those ones only	13	12
No answer	4	2

There is no difference between the two grades' responses here. Half of each say No - "... bad effects can be reduced or removed". It should be noted that the no:yes ratio overall is 3:2.

TABLE 5

WHETHER SCIENCE AND TECHNOLOGY CAN SOLVE PROBLEMS CAUSED BY POLLUTION

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
Science and technology will not be able to solve problems caused by pollution, because the problems are so bad that it would cost too much	9	8
Science and technology alone cannot solve problems caused by pollution	55	56
Science and technology can solve problems caused by pollution, because science and technology have been successful in solving problems in the past	34	32
No answer	3	4

It appears that the reference to the cost factor in the first statement does not sway more than 10% of either grade. Over half of each grade, however, think that science and technology alone cannot solve pollution problems. A further third believe that they can. There is no difference between the grades in their responses to this question.

TABLE 6

WHETHER WOMEN SCIENTISTS MIGHT MAKE DIFFERENT DISCOVERIES FROM THOSE MADE BY MEN SCIENTISTS

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
Women scientists might make different discoveries from those made by men scientists, because women have different feelings and experiences from men	14	11
Women scientists and men scientists are all scientists, so they make the same kind of discoveries	16	13
Different discoveries made by different scientists have nothing to do with whether the scientists are men or women	70	75
No answer	2	2

Overall, very few of either grade choose the one Yes answer, and again overall we see about three-quarters professing that the gender of a scientist is irrelevant. Answers from respondents of the two genders do show a difference, however. Over 80% of female respondents opt for the third statement compared with 60% of male respondents.

TABLE 7

WHETHER SCIENCE CLASSES HAVE HELPED ME BECOME A BETTER SHOPPER

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
Science classes have helped me become a better shopper, because I can use the scientific method and/or scientific facts to help me decide which products to buy	34	40
Science classes have not helped me become a better shopper. Neither the scientific method nor scientific facts can possibly help me decide which products to buy	27	25
Science classes have not helped me become a better shopper. Even though science teaches the scientific method and valuable facts, people like me tend to buy things they see on television or in advertisements	34	31
No answer	6	4

One third or more of each grade accredit science classes with helping them become better shoppers. A further third, however, claim to respond to television or advertisements. We see half as many more francophone than anglophone students (42% vs. 28%) indicate responsiveness to TV and ads.

TABLE 8

WHETHER THE MASS MEDIA OR SCIENCE CLASSES GIVE A BETTER PICTURE OF SCIENCE

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
The mass media (television, newspapers, magazines, etc.) give you a better picture of what science is really like, than science classes do	17	16
Neither the mass media, nor science classes, give you a good picture of what science is really like	18	14
Science classes give you a better picture of what science is really like, than the mass media do	59	68
No answer	5	5

While somewhat more of the Grade 12 students than the Grade 10 students vote for science classes, 60% or more of both grades accredit science classes with giving a better picture of what science is really like. One in six of both grades, however, opts for the mass media. About a further one in six says neither source gives a good picture of what science is really like.

TABLE 9

MOST SCIENTISTS ARE DOING SCIENCE...

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
to satisfy their own curiosity about the world around them	24	26
to be well-known and/or rich	8	9
because they want to help people by finding new medical cures and solutions to environmental problems and by new inventions	68	66
because they want to be looked up to by other scientists	5	3
No answer	4	2

Very few respondents ascribe selfish motives to scientists, as is seen by the numbers opposite the second and fourth statements. Two-thirds think scientists practise their profession to help people. A quarter think they do so out of curiosity about the world around them. More females than males accredit scientists with the desire to help people (74% to 62%).

TABLE 10

IF CANADA SPENT MORE MONEY ON
RESEARCH IN SCIENCE AND TECHNOLOGY:

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
Canada would become a wealthier country	20	28
Canada might or might not become a wealthier country. It would depend on what science and technology were chosen	55	59
Canada might become poorer, because other ways of making Canada wealthier would suffer	20	10
No answer	5	3

Over half of both grades are sitting on the fence on this subject. Of the remainder we see, from Grade 10 figures, an even split between wealthier and poorer. The remainder of the Grade 12 splits 3 to 1 in favour of wealthier. Overall, twice as many males as females (30% to 16%) think Canada would become a wealthier country, but more females than males (68% to 47%) choose the "it depends" statement.

TABLE 11

THERE ARE MORE MEN SCIENTISTS
THAN WOMEN SCIENTISTS TODAY:

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
because boys are more interested in science than girls are	23	20
because boys are better at science than girls are	7	4
because until recently people used to believe that boys were better at science and that girls were better at other things, so more boys than girls made science their career	67	72
No answer	5	4

Here we see that about 70% of both grades think that times are changing. Very few think that one's ability to do science has anything to do with one's gender. One in five, nevertheless, thinks that boys' greater interest in science is the contributing factor.

There is not as much difference as one might expect between the answers of male and female students. With still small numbers, more males think that boys are better at science than do the female respondents (9% and 2% respectively). On the other hand, more females than males opted for the "people used to believe" answer (74% vis-a-vis 65%). Regardless of the respondent's gender, more francophones (28%) than anglophones (18%) seem to think that boys are just more interested in science.

TABLE 12

SCIENTISTS WHO WORK FOR A PROFIT-MAKING COMPANY:

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
tend to put the company's interests ahead of doing the best science they can	17	22
put doing the best science they can ahead of the company's interests	19	18
some put doing the best science they can first; others put the company's interests first	59	56
No answer	5	4

Nearly 60% of the respondents refrain from opting for the generalizations made in either of the first two statements. Instead they feel the choice between doing the best science and the company interests would vary from scientist to scientist. Of the remaining 40% about half opted for each of the first two sentences. As for differences within the other subgroups, more males than females (24% and 14%) think that the company's interests come first and more females than males are fence sitters (64% vs. 51%).

TABLE 13

WHEN SCIENTISTS ARE DECIDING WHETHER OR NOT TO ACCEPT A THEORY:

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
they look only at the facts. If the theory explains the facts, they accept it. If the theory cannot explain even just one fact, they do not accept the theory	47	50
they look at the facts and the theory. If a theory is simpler and/or more logical than other theories, they may accept it even if all the facts are not explained	32	34
they sometimes accept it for other reasons that have nothing to do with how well it compares with other theories or how well it explains the facts	17	13
No answer	5	3

Half of both grades think scientists look only at the facts, and that if the theory explains the facts, they accept it. A third think they look at both facts and theory, and may accept it if the theory is simpler and/or more logical (than other theories) even if all the facts are not explained. There are no differences on this matter between grade, gender, language or any sub-group within the overall sample.

TABLE 14

WHETHER SCIENTISTS TRAINED IN DIFFERENT COUNTRIES LOOK AT SCIENTIFIC PROBLEMS DIFFERENTLY

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
Scientists trained in one country look at scientific problems in different ways from scientists trained in another country, because their education and way of life are different	19	20
Scientists are taught to look at scientific problems in the same way, no matter what countries the scientists are from, because science is the same all over the world	22	18
Any two scientists may look at scientific problems differently. The country where they come from makes no difference	57	62
No answer	3	2

Sixty per cent think that while scientists themselves may differ in the way they look at problems, the country they come from has no bearing on the matter. This opinion is held by more females (67%) than males (53%).

Overall, twenty per cent think that regardless of where they come from, all scientists are similar in the way they look at scientific problems. A further twenty per cent, however, think that differences in education and way of life do have an effect on how a scientist looks at scientific problems.

TABLE 15

WILL A NEW TECHNOLOGY THAT MAY DO MORE HARM THAN GOOD TO SOCIETY BE USED?

	Total Grade 10	Total Grade 12
Total respondents (100%)	386	331
	%	%
If a new technology will do more harm than good to society, it will not be used	32	29
If a new technology works well, is efficient and doesn't cost much, it will be used even if it does more harm than good to society	22	17
Most new technologies are used, because some people benefit from them, even though others may see the harm they can do	43	50
No answer	4	4

The responses of a majority (i.e. two-thirds of the students) are in the affirmative - whether conditional or otherwise. A half or less of each grade's respondents think that most new technologies are used regardless of the harm they can do, since some people benefit from them. Twenty per cent feel that provided a new technology works well, and is an efficient and low-cost one, it will be used even if the harm it does to society outweighs the good.

Thirty per cent believe that if a new technology will do more harm than good to society, it will not be used.

TABLE 16

A SCIENTIFIC MODEL IS...

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
- a copy of the real thing	18	13
- very much like the real thing	32	31
- not like the real thing, but is useful for explaining the real thing	45	54
No answer	3	4

There is little difference between the two grades in the responses. It appears that more Grade 12 students think a scientific model is used for explanatory purposes and more Grade 10 than Grade 12 students think it to be a copy of the real thing.

TABLE 17

WHEN DOES SCIENTIFIC KNOWLEDGE CHANGE?

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
Scientific knowledge never changes	5	2
Scientific knowledge can change only if new research proves earlier research to be wrong	53	57
Scientific knowledge can change if earlier research is looked at in a different way	40	40
No answer	2	4

That scientific knowledge can change only if earlier research is proven to be wrong is the opinion of over half of each grade. Most of the remainder think it can change if looked at differently. No more than a handful thinks it never changes.

TABLE 18

HOW OFTEN THE BEST SCIENTISTS FOLLOW THE STEPS OF THE SCIENTIFIC METHOD

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
The best scientists always follow the steps of the scientific method	40	44
The best scientists sometimes do and sometimes do not follow the steps of the scientific method	53	48
The best scientists never follow the steps of the scientific method. They are clever enough so they don't need to	6	4
No answer	1	4

Over 90% of students in both grades say that the scientific method is used by the best scientists, although it appears that slightly more think it is used sometimes rather than always. We see a difference between the two language groups. More French-speaking students think the best scientists always - as against sometimes - use it (52% vs. 41 %). The respective percentages in the case of the English-speaking students are 37% and 56%.

TABLE 19

SCIENTISTS WRITE ABOUT THEIR WORK IN AN ORGANIZED WAY AND IN A CERTAIN ORDER:

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
they also do their work in an organized way, and in the same order in which they write about it	65	61
they do their work in an organized way, but not in the same order in which they write about it	23	26
they do not usually do their work in an organized way	10	9
No answer	3	4

Nearly two-thirds of both grades think that scientists follow the same order when they write and when they actually do their work. A quarter, again of both grades, think that scientists follow an order when doing their work, but that this order differs from that of their writing. One in ten thinks that the work itself is not usually done in an organized way, even though the writing is. For this set of statements it appears that the smaller the student's community, the higher the percentage of those who think that both the work and the writing are done in the same organized manner.

TABLE 20

HOW SCIENTIFIC MISTAKES AFFECT THE PROGRESS OF SCIENCE

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
Scientific mistakes only slow down the progress of science	6	2
Scientific mistakes sometimes lead to new discoveries and therefore science progresses	72	72
Finding and correcting scientific mistakes is the only way science progresses	22	25
No answer	1	3

Once again we see virtually no difference between the two grades overall. Over 70% of both groups think that mistakes sometimes lead to new discoveries, and over 20% think that correcting mistakes, once they are unearthed, is the only way that science progresses. Very few in both groups think that mistakes have only a negative effect on the progress. There are no differences among any of the sub-groups studied.

TABLE 21

WHETHER SCIENTISTS AND ENGINEERS CAN TELL WHAT WILL HAPPEN

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
Even with accurate information, scientists and engineers can tell us only what will probably happen, not what will definitely happen	51	59
Scientists and engineers can tell us what will definitely happen if they have enough accurate information	33	29
There's no way scientists and engineers can ever tell us even what will probably happen, no matter how much accurate information they have	16	10
No answer	2	2

16% and 10% think that scientists and engineers although armed with accurate information, are unable to predict even what will probably happen. At the other end of the scale, about 30% of both grades say that such information leads to scientists' and technologists' ability to say what will definitely happen. The middle ground, that they can predict no more than what will probably happen, is the view of 50% or so of students at both levels. More anglophone than francophone students (60% vs. 44%) opt for this middle stance, while more francophones (37%) believe in the ability to say what will definitely happen than do their anglophone counterparts (28%).

TABLE 22

IF SCIENTISTS FIND THAT PEOPLE WORKING WITH A CERTAIN MATERIAL HAVE TWICE AS MUCH CHANCE OF GETTING LUNG CANCER AS DO OTHER PEOPLE:

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
this means that the material causes lung cancer and it should not be used	22	22
this does not necessarily mean that the material causes lung cancer and it could still be used	9	8
this does not necessarily mean that the material causes lung cancer. However, more research should be done before the material is used again	68	67
No answer	2	3

Two-thirds of both student groups take the view that more research is required before using the material again. Nearly a quarter vote for the discontinuance of its use since they believe it is obviously the cause. Only one in ten thinks its use could be continued. There is some indication that more females than males voted for the "more research" approach (74% vs. 64%).

TABLE 23

THE RELATIONSHIP BETWEEN SCIENCE AND TECHNOLOGY

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
Science is needed in order to invent new technology	66	68
New technology can be invented without science	14	10
Science is basically the same thing as technology	18	19
No answer	2	4

That technology could not be invented without science is the opinion of two of every three students in both grades. A small percentage (14 and 10) think the opposite. One in five, however, thinks that science and technology are one and the same thing. More francophones than anglophones are of this last opinion (25% and 16% respectively).

TABLE 24

THE USE OF REFERENCE MATERIALS BY GOOD SCIENTISTS

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
Good scientists rarely use reference materials, as they can almost always remember information when they need it	7	5
Good scientists often use reference materials to look up information when they need it	41	35
Good scientists almost always use reference materials to look up information when they need it	51	59
No answer	1	2

Over half of both groups think that good scientists almost always use reference materials. The vast majority of the remainder think they often use them, with only 5% or so of the total saying they rarely do so, because of their ability to recall information when they need it. This picture of responses is also found among all sub-groups.

TABLE 25

DO MEMBERS OF PARLIAMENT NEED TO KNOW ABOUT SCIENCE AND TECHNOLOGY TO DO THEIR JOB?

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
Members of Parliament do not need to know anything about science and technology to do their job, because science and technology have nothing to do with their work	8	4
Members of Parliament need to know about science and technology in order to make good decisions about Canada's future	76	80
Members of Parliament do not need to know anything about science and technology because they can always rely on scientists and engineers for advice	14	13
No answer	2	3

A strong majority of students in both grades believe that MPs do need to know about science and technology for the benefit of the future of the country. Among the "Nos" more think that scientists and engineers can be relied upon to advise elected officials than think that governing the country is totally divorced from science or technology.

TABLE 26

WHEN YOU SOLVE A PROBLEM IN DAILY LIFE...

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
- you are doing science	17	17
- sometimes you are doing science and sometimes not. It depends on the type of problem	70	74
- you are not doing science because science has nothing to do with everyday life	10	6
No answer	2	3

Three out of four say sometimes yes and sometimes no, dependent on the type of problem. Ten per cent or fewer of students of either grade think that science and one's daily life are totally independent of each other. One in six believes that the solution of any problem in daily life requires the use of science. This is the view of more males than females (21% vs. 12%). On the other hand, more females feel that whether or not one is doing science depends on the type of problem (79% vs. 67% males).

TABLE 27

THE ROLE OF SCIENCE
FOR KNOWING ABOUT THE WORLD

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
The only way of knowing about the world is through science	10	5
Science is one of many good ways of knowing something about the world. Science alone however is not enough to know all about the world	63	65
Science is the best way of knowing about the world, even though there are other ways of knowing about it	26	27
No answer	2	3

No more than 10% think that science is the only way to know about the world. A further 25% or so say that there are other ways, but that science is the best one. The moderate group, comprising over 60% of both grades, agrees that while science is a good way, it is but one of a number of ways of knowing about the world. This is the opinion of more anglophones than francophones (68% and 55%), whereas more francophones (36%) think it is the best, although not the only way, than do the anglophone students (22%).

TABLE 28

SCIENCE AND THE INVENTION OF NEW TECHNOLOGY

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
When new technology is invented, it often leads to new scientific facts and theories	55	58
New technology can be invented only by using known scientific facts and theories	27	28
New technology is often invented without using scientific facts and theories	17	10
No answer	2	5

Over half of each grade thinks that new technology can precede new scientific facts and theories by being the cause of them. A quarter or so thinks that scientific facts or theories are necessary for the invention of new technology. That "new technology is often invented without the use of scientific facts or theories" is the position of one in six of Grade 10 and one in ten of Grade 12.

TABLE 29

THE STEPS OF THE SCIENTIFIC METHODS, SCIENCE AND SOLVING DAILY LIFE PROBLEMS

	Total Grade 10	Total Grade 12
Total respondents (100%)	384	321
	%	%
Learning the steps of the scientific method is good for doing science and for solving problems in daily life	57	64
Learning the steps of the scientific method is good only for doing science and not for solving problems	16	12
Learning the steps of the scientific method is a waste of time as it serves no useful purpose in science or in daily life	10	6
Learning the steps of the scientific method may be good for solving problems in daily life, and may or may not be good for doing science	17	15
No answer	1	5

About 60% of both grades think that learning the steps of the scientific method has two benefits - that of learning science and that of solving daily life's problems. At the other end of the scale are small groups, of 10% or less, who think that such learning is "a waste of time as it serves no useful purpose" in either sphere. That the scientific method is "good for doing science but not for solving problems" is the chosen position of 16% and 12% respectively. Under 20% of both grades are undecided on the benefits of the scientific method.

3.0 THE GRADE 10 STUDENTS

TABLE 1

SCIENCE IS...

	Total	Basic	General	Advanced	English	French
Total respondents (100%)	770	97	210	463	516	254
	%	%	%	%	%	%
Explaining the unknown	34	27	31	37	40	22
Using what we know to make the world a better place to live in	34	42	27	35	32	37
Subjects like chemistry, physics and biology	29	24	40	25	24	39
A group of people (scientists) and what they believe	4	5	3	4	3	5
No answer	2	3	2	2	3	1

Overall, 34% of the students vote for each of the first two statements i.e. explaining the unknown and using what we know to make the world better. There are however, differences among students at the different levels within Grade 10. Among students in the basic level program, nearly half think that science is "using what we know to make the world better" while a quarter each think it is "explaining the unknown" and "subjects like physics, chemistry and biology". This last response i.e. "subjects like physics, chemistry and biology" was the one most opted for by students at the general level (40%). Thirty-one per cent and twenty-seven per cent of them, respectively, feel that science is "explaining the unknown" and "using what we know to make the world better".

The two language groups differ greatly from each other on this subject. Forty percent and 24% of the anglophone group respectively think that science is "explaining the unknown" and "subjects like physics, chemistry and biology". The reverse trend can be seen within the francophone group. Fewer students (22%) in central region schools choose the "physics, chemistry and biology" answer than do those at schools elsewhere in the province (34%). It also appears that the percentage of respondents who feel that science is "explaining the unknown" increases with the size of the community in which the school is located. The percentages of students from large communities, (that is, Toronto, Ottawa and Hamilton combined) who choose each of the first three statements are 41, 35 and 21 respectively. In the smallest population density group - communities of under 30,000 population - the comparable percentages are 28,37 and 32. The sample from medium sized communities shows equal percentages for all three statements. Overall, only 4% think that science is "scientists and what they believe". This low percentage stands among all sub- groups under study.

TABLE 2A

TECHNOLOGY IS...

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	770	97	210	463	389	364
	%	%	%	%	%	%
How science is put to use	32	25	26	36	28	37
Using what we know to make the world a better place to live in	25	25	22	26	29	20
Machines and inventions	15	21	19	12	16	13
Machines and inventions as well as designing things	28	29	32	25	25	30
No answer	2	1	1	2	2	2

There are fewer inter-level differences on the definition of technology than on that of science. One third of the grade as a whole says that technology is "how science is put to use". About a quarter each say that it is "machines, inventions and designing things" and "using what we know to make the world better". The higher the level, the more respondents opt for "how science is put to use" and the fewer do so for "machines and inventions". More females than males think technology is "how science is put to use", while more males than females think it is "using what we know to make the world better". There are no significant differences among the other sub-groups.

One possible answer - using what we know to make the world better - appeared in both the science and the technology question. A comparison of the two sets of results follows.

TABLE 2B

THOSE SAYING "USING WHAT WE KNOW TO MAKE THE WORLD BETTER"

	For science	For technology
	%	%
Grade 10 overall	34	25
Basic level program	42	25
General level program	27	22
Advanced level program	35	26
Male	34	29
Female	34	20
English	32	26
French	37	23

Overall, science more than technology is thought to contribute to making the world better. This is particularly the case in the admittedly small basic level sample, and certainly among the female and francophone segments.

TABLE 3

WHO SHOULD DECIDE WHAT TYPES OF ENERGY CANADA WILL USE IN THE FUTURE?

	Total	Basic	General	Advanced
Total respondents (100%)	386	50*	109	227
	%	%	%	%
Scientists and engineers should decide what types of energy (such as nuclear, hydro,solar, etc.) Canada will use in the future, because they know best	19	18	21	19
Everybody should be involved in deciding what types of energy Canada will use in the future, because we are all affected by the decision	62	46	60	67
People other than scientists and engineers should decide what types of energy Canada will use in the future, because the decision is a social and economic one, not a technical one	16	32	17	12
No answer	3	4	5	2

* Note base size

The modal answer in total, and for each level, is that everyone should decide. There is some indication that this view is held by more as the science program level increases. On the other hand, it appears that respondents who think that people other than scientists should decide decrease in number as the science program level increases.

TABLE 4

WHETHER WE HAVE TO ACCEPT BOTH GOOD AND BAD EFFECTS OF TECHNOLOGY

	Total	Basic	General	Advanced	Public	Separate
Total Respondents (100%)	386	50*	109	227	240	146
	%	%	%	%	%	%
We have to accept both the good and the bad effects of technology, because every new development has at least one bad effect, and to enjoy the good ones we have to put up with the bad ones	37	26	35	40	30	47
We don't have to accept the bad effects of technology, because bad effects can be reduced or removed through careful planning and testing	47	48	50	45	51	39
We don't have to accept the bad effects of technology, because some new developments have no bad effects and we should use those ones only	13	20	11	12	14	11
No answer	4	6	5	3	5	3

* Note base size

Half of the total and of all groups except francophones and those in separate schools (of whom 76% are francophone) think that we should not automatically accept both good and bad effects of technology in that the bad effects can be minimised or removed. Among the separate school students, half believe that we do have to accept all effects, be they good or bad.

TABLES 5

WHETHER SCIENCE AND TECHNOLOGY CAN SOLVE PROBLEMS CAUSED BY POLLUTION

	Total	Basic	General	Advanced
Total respondents (100%)	386	50*	109	227
	%	%	%	%
Science and technology will not be able to solve problems caused by pollution, because the problems are so bad that it would cost too much	9	12	10	7
Science and technology alone cannot solve problems caused by pollution	55	32	52	61
Science and technology can solve problems caused by pollution, because science and technology have been successful in solving problems in the past	34	52	35	30
No answer	3	4	5	3

*Note base size

Two-thirds of the grade 10 sample say "No" to this question, with the majority of them qualifying their "No" by saying that science and technology alone cannot solve pollution problems. One third thinks that science and technology can solve them. This view decreases and the "No - not alone" view increases with level of instruction.

TABLE 6

WHETHER WOMEN SCIENTISTS MIGHT MAKE DIFFERENT DISCOVERIES FROM THOSE MADE BY MEN SCIENTISTS

	Total	Basic	General	Advanced	Male	Female
Total respondents(100%)	386	50*	109	227	193	185
	%	%	%	%	%	%
Women scientists might make different discoveries from those made by men scientists, because women have different feelings and experiences from men	14	32	15	10	20	8
Women scientists and men scientists are all scientists, so they make the same kind of discoveries	16	16	19	14	22	10
Different discoveries made by different scientists have nothing to do with whether the scientists are men or women	70	50	64	77	55	84
No answer	2	2	5	1	4	1

* Note base size

Seventy per cent are of the opinion that the scientist's gender has nothing to do with the type of discoveries made. This view increases with the science course level of the respondent; it is also not surprising that it is held more strongly among female students than among their male counterparts. The lower the level within grade 10, the more respondents seem to believe that women scientists having different feelings and experiences would lead them to make different discoveries.

TABLE 7

WHETHER SCIENCE CLASSES HAVE HELPED ME BECOME A BETTER SHOPPER

	Total	Basic	General	Advanced	English	French
Total respondents (100%)	386	50*	109	227	260	126
	%	%	%	%	%	%
Science classes have helped me become a better shopper, because I can use the scientific method and/or scientific facts to help me decide which products to buy	34	42	28	35	36	30
Science classes have not helped me become a better shopper. Neither the scientific method nor scientific facts can possibly help me decide which products to buy	27	30	29	25	28	23
Science classes have not helped me become a better shopper. Even though science teaches the scientific method and valuable facts, people like me tend to buy things they see on television or in advertisements	34	26	36	36	29	46
No answer	6	2	8	6	7	4

* Note base size

One third overall say that science classes have not helped them to become better shoppers in that they buy what they see on television or in advertisements. This view is held much more by francophones than anglophones. A third holds the view that what they've learned in terms of the scientific method and facts has helped, and a quarter thinks that the scientific method and facts cannot help in this respect. Apart from the one already mentioned, there are no differences among the various sub groups.

TABLE 8

WHETHER THE MASS MEDIA OR SCIENCE CLASSES
GIVE A BETTER PICTURE OF SCIENCE

	Total	Basic	General	Advanced	English	French
Total respondents (100%)	386	50*	109	227	260	126
	%	%	%	%	%	%
The mass media (television, newspapers, magazines, etc.) give you a better picture of what science is really like, than science classes	17	22	21	15	14	25
Neither the mass media, nor science classes, give you a good picture of what science is really like	18	30	21	14	22	10
Science classes give you a better picture of what science is really like, than the mass media do	59	46	51	66	59	60
No answer	5	2	7	5	5	6

* Note base size

Sixty per cent of the grade 10 science students think that science classes give a better picture of science than do the mass media. That this is the case increases with increase in the level of the science course. Fifteen per cent of the advanced level opt for the mass media, with an equal percentage giving credit to neither source. More francophones than anglophones (25% to 14%) think the mass media are better - it may be pertinent to note here that this group also buys what they see on TV and advertisements (see Table 7) to a greater extent.

TABLE 9

MOST SCIENTISTS ARE DOING SCIENCE...

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	386	50*	109	227	193	185
	%	%	%	%	%	%
To satisfy their curiosity about the world around them	24	18	17	29	23	25
To be well-known and/or rich	8	8	7	7	10	5
Because they want to help people by finding new medical cures and solutions to environmental problems and by new inventions	68	56	71	70	61	77
Because they want to be looked up to by other scientists	5	16	5	3	6	4
No answer	4	2	6	3	5	2

* Note base size

Well over half of all students accredit scientists with the honourable motive of helping others. This view is held more by females than by males. Satisfying the scientists' own curiosity about the world is thought to be the reason by one in four. Comparatively small percentages indicate that a desire to be well known and/or rich or to be looked up to by other scientists are motivating factors.

TABLE 10

WHAT WOULD HAPPEN IF CANADA SPENT MORE MONEY ON RESEARCH IN SCIENCE AND TECHNOLOGY

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	386	50*	109	227	193	185
	%	%	%	%	%	%
Canada would become a wealthier country	20	24	25	17	26	13
Canada might/might not become a wealthier country. It would depend on what science and technology were chosen	55	36	52	62	46	66
Canada might become poorer, because other ways of making Canada wealthier would suffer	20	34	18	18	24	16
No answer	5	4	6	4	6	3

* Note base size

A majority of grade 10 students feel that whether or not Canada will become wealthier as a result of increased expenditure on research in science and technology, will depend on the science and technology chosen. This opinion is held by more as science level increases, and by many more females than males, this latter group being of the opinion to a greater extent that the spending of more money on scientific and technological research would result in a wealthier Canada. One in five of all groups thinks that Canada might become poorer,as other wealth-making ways would suffer.

TABLE 11

THERE ARE MORE MEN SCIENTISTS
THAN WOMEN SCIENTISTS TODAY:

	Total	Basic	Gen.	Adv.	Male	Female	Eng.	Fr.
Total respondents (100%)	386	50*	109	227	193	185	260	126
	%	%	%	%	%	%	%	%
Because boys are more interested in science than girls are	23	20	26	22	22	23	17	34
Because boys are better at science than girls are	7	14	11	4	13	2	7	7
Because until recently people used to believe that boys were better at science and that girls were better at other things, so more boys than girls made science their career	67	64	57	72	62	71	72	56
No answer	5	2	7	4	5	5	5	5

* Note base size

Two-thirds of the sample think that what people used to believe is the cause. About a quarter, and twice as many francophones as anglophones, believe simply that boys are more interested in science than are girls. The opinion that boys are better at it is held by 13% of the male and only 2% of the female students.

TABLE 12

SCIENTISTS WHO WORK FOR A PROFIT-MAKING COMPANY:

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	386	50*	109	227	193	185
	%	%	%	%	%	%
Tend to put the company's interests ahead of doing the best science they can	17	20	21	15	23	12
Put doing the best science they can ahead of the company's interests	19	38	20	15	21	18
Put doing the best science they can first; others put the company's interests first	59	38	54	65	51	65
No Answer	5	4	4	5	5	5

* Note base size

All scientists working for a profit-making company cannot be the same as each other in terms of whose interests they put first. So think 59% of the grade 10 students, with this opinion being held more so as the science course level increases, and by more female than male students. Twenty per cent think that "doing the best science they can" is the prime interest of these scientists. That opinion seems to wane with increase in level, but is held by equal numbers of each gender of student. More males than females think that the company's interests are put first.

TABLE 13

WHEN SCIENTISTS ARE DECIDING WHETHER OR NOT TO ACCEPT A THEORY:

	Total	Basic	General	Advanced
Total respondents (100%	386	50*	109	227
	%	%	%	%
They look only at the facts. If the theory explains the facts, they accept it. If the theory cannot explain even just one fact, they do not accept the theory	47	32	37	55
They look at the facts and the theory. If a theory is simpler and/or more logical than other theories,they may accept it even if all the facts are not explained	32	34	38	29
They sometimes accept it for other reasons that have nothing to do with how well it compares with other theories or how well it explains the facts	17	26	23	11
No answer	5	8	4	5

* Note base size

Nearly half the sample think that they look only at the facts, so much so that if the theory cannot explain even just one fact, it is rejected. A third, however, believe that both facts and theory are examined, and that the theory may be accepted if it is simpler or more logical than others. A sixth are of the opinion that sometimes the theory is accepted for reasons other than its comparability with other theories or how well it explains the facts. With an increase in the science program level come more believing that only the facts are examined and fewer believing that it is accepted for other reasons. There are no differences apparent in the other sub- groups.

TABLE 14

WHETHER SCIENTISTS TRAINED IN DIFFERENT COUNTRIES LOOK AT SCIENTIFIC PROBLEMS DIFFERENTLY

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	386	50	109	227	193	185
	%	%	%	%	%	%
Scientists trained in one country look at scientific problems in different ways from scientists trained in another country, because their education and way of life are different	19	26	21	16	24	14
Scientists are taught to look at scientific problems in the same way, no matter what countries the scientists are from, because science is the same all over the world	22	28	34	15	27	16
Any two scientists may look at scientific problems differently. The country where they come from makes no difference	57	40	43	68	46	69
No answer	3	6	3	2	4	2

* Note base size

About 60% overall think that any two scientists may look at scientific problems differently and that the country they come from is irrelevant. This opinion is held much more by those at the advanced science course level than those at the basic and general levels, and much more by female than male students. Twenty per cent believe that, as science is the same all over the world, and that scientists are taught to look at scientific problems in the same way, they will in fact look at them in the same way. This opinion is held more by those at the basic and general levels and by males than by their counterparts, as appears to be the one that the different education and way of life from country to country lead to scientific problems being looked at differently.

TABLE 15

WILL A NEW TECHNOLOGY THAT DOES MORE HARM THAN GOOD TO SOCIETY BE USED?

	Total	Basic	General	Advanced
Total respondents (100%)	386	50*	109	227
	%	%	%	%
If a new technology will do more harm than good to society, it will not be used	32	30	28	33
If a new technology works well, is efficient and doesn't cost much, it will be used even if it does more harm than good to society	22	38	24	18
Most new technologies are used, because some people benefit from them, even though others may see the harm they can do	43	26	45	46
No answer	4	6	4	3

* Note base size

Thirty per cent overall, and of those at all program levels think that the technology will not be used. Over 40% think that most such technologies are used because some people benefit from them. Twenty-two per cent say it will be used for reasons other than those related to humanity, viz., if it works well, is efficient and does not cost much. This last opinion seems to be held less strongly the higher the level of the science program the student is in.

TABLE 16

A SCIENTIFIC MODEL IS...

	Total	Basic	General	Advanced
Total respondents (100%)	384	47*	101	236
	%	%	%	%
A copy of the real thing	18	21	18	18
Very much like the real thing	33	40	34	31
Not like the real thing, but is useful for explaining the real thing	45	32	47	47
No answer	3	6	2	3

* Note base size

That a scientific model can explain the real thing, while not being like it, is what nearly half the Grade 10 sample tell us. It may be that fewer at the basic level think this, but one must be careful interpreting a base number of its size. Overall, a third believes a model to be not the real thing but very much like it, while about a fifth thinks it is a copy of the real thing. The relative percentages of these answers are evident in all sub-groups.

TABLE 17

WHEN DOES SCIENTIFIC KNOWLEDGE CHANGE?

	Total	Basic	General	Advanced
Total respondents (100%)	384	47*	101	236
	%	%	%	%
Scientific knowledge never changes	5	15	7	3
Scientific knowledge can change only if new research proves earlier research to be wrong	53	34	47	60
Scientific knowledge can change if earlier research is looked at in a different way	40	47	45	36
No answer	2	2	3	3

* Note base size

Very few of all groups believe that scientific knowledge never changes. The remainder, who believe that it does change, are split although not equally, between those who think it does so if earlier research proves to be wrong (53% of the total grade) and those who think it can if earlier research is looked at differently (40% of the total). More of those at the advanced level subscribe to the "if earlier research proves to be wrong" theory, and fewer to the "if looked at differently" theory. There are no differences among the other sub-groups.

TABLE 18

HOW OFTEN THE BEST SCIENTISTS FOLLOW THE STEPS OF THE SCIENTIFIC METHOD

	Total	Basic	General	Advanced
Total respondents (100%)	384	47*	101	236
	%	%	%	%
The best scientists always follow the steps of the scientific method	40	40	40	41
The best scientists sometimes do and sometimes do not follow the steps of the scientific method	53	43	49	56
The best scientists never follow the steps of the scientific method. They are clever enough so they don't need to	6	15	11	3
No answer	1	2	1	1

* Note base size

There is almost complete agreement among all levels and all sub-groups that the best scientists follow the steps of the scientific method, although more do it sometimes rather than always. That is particularly the situation as far as the students at the advanced level are concerned.

TABLE 19

SCIENTISTS WRITE ABOUT THEIR WORK IN AN ORGANIZED WAY AND IN A CERTAIN ORDER:

	Total	Basic	General	Advanced
Total respondents (100%)	384	47*	101	236
	%	%	%	%
They also do their work in an organized way, and in the same order in which they write about it	65	70	59	66
They do their work in an organized way, but not in the same order in which they write about it	23	19	28	22
They do not usually do their work in an organized way	10	6	11	11
No answer	3	4	2	3

* Note base size

Two-thirds of the grade 10 students think that scientists' order of doing their work and of writing about it are the same. A quarter accredit scientists with doing each in an organized fashion, but not in the same order. One in ten believes, however, that while the writing is done in an organized way, the work itself is not.

TABLE 20

HOW SCIENTIFIC MISTAKES AFFECT THE PROGRESS OF SCIENCE

	Total	Basic	General	Advanced
Total respondents (100%)	384	47*	101	236
	%	%	%	%
Scientific mistakes only slow down the progress of science	6	17	8	3
Scientific mistakes sometimes lead to new discoveries and therefore science progresses	72	55	65	78
Finding and correcting scientific mistakes is the only way science progresses	22	28	25	19
No answer	1	-	2	**

* Note base size
** Less than 0.5%

Four out of five of the students at the advanced level believe that scientific mistakes sometimes lead to new discoveries. This they believe more so than do those studying at the basic and general levels. Few at all levels think scientific mistakes do nothing but slow down the progress of science, and approximately one in five thinks that science progresses only through the finding and correcting of scientific mistakes.

TABLE 21

WHETHER SCIENTISTS AND ENGINEERS CAN TELL WHAT WILL HAPPEN

	Total	Basic	General	Advanced	English	French
Total respondents (100%)	384	47*	101	236	256	128
	%	%	%	%	%	%
Even with accurate information, scientists and engineers can tell us only what will probably happen, not what will definitely happen	51	40	43	56	55	42
Scientists and engineers can tell us what will definitely happen if they have enough accurate information	33	40	35	30	31	35
There's no way scientists and engineers can ever tell us even what will probably happen, no matter how much accurate information they have	16	17	21	13	13	22
No answer	2	2	2	2	2	2

* Note base size

One third of the Grade 10 students believe that, if they have accurate information, scientists and engineers can tell what will definitely happen. Those believing they can tell no more than what will probably happen, however, constitute half of the sample, with those enroled in the advanced level program believing it to a greater extent than their counterparts at the other two levels. This opinion is also held more by anglophones than by francophones. One in six is of the opinion that, even with accurate information, not even what will probably happen can be predicted.

TABLE 22

IF SCIENTISTS FIND THAT PEOPLE WORKING WITH A CERTAIN MATERIAL HAVE TWICE AS MUCH CHANCE OF GETTING LUNG CANCER AS DO OTHER PEOPLE:

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	384	47*	101	236	196	179
	%	%	%	%	%	%
This means that the material causes lung cancer and it should not be used	22	28	29	18	24	19
This does not necessarily mean that the material causes lung cancer and it could still be used	9	21	12	6	13	5
This does not necessarily mean that the material causes lung cancer. However, more research should be done before the material is used again	68	51	57	77	63	76
No answer	2	-	3	2	2	2

* Note base size

Two-thirds of the sample subscribe to the theory that "this does not necessarily mean that it causes lung cancer, but that more research should be done before the material is used again". This view is held most strongly among those at the advanced level and more strongly by females than males. Of the Grade 10 sample, one in five and one in ten, respectively, feel that this means that it "causes lung cancer so should not be used" and "this does not necessarily mean that it causes lung cancer and could still be used". Among the female students, however, four times as many subscribe to the former as do to the latter of these two statements. Students of the advanced level program do so to the extent of three times as many.

TABLE 23

THE RELATIONSHIP BETWEEN SCIENCE AND TECHNOLOGY

	Total	Basic	General	Advanced
Total respondents (100%)	384	47*	101	236
	%	5	%	%
Science is needed in order to invent new technology	66	57	60	69
New technology can be invented without science	14	17	14	14
Science is basically the same thing as technology	18	23	27	14
No answer	2	2	1	2

* Note base size

Sixty-six per cent of the Grade 10 sample believe that new technology cannot be invented without science. A further 14% believe the opposite. The remainder believe that science and technology are basically the same as each other, although it appears that this position is held least by students at the advanced level. An examination of the other subgroups shows no differences among them.

TABLE 24

THE USE OF REFERENCE MATERIALS BY GOOD SCIENTISTS

	Total	Basic	General	Advanced
Total respondents (100%)	384	47*	101	236
	%	%	%	%
Good scientists rarely use reference materials, as they can almost always remember information when they need it	7	6	15	3
Good scientists often use reference materials to look up information when they need it	41	51	36	42
Good scientists almost always use reference materials to look up information when they need it	51	43	48	55
No answer	1	-	1	2

* Note base size

That good scientists almost always use reference materials is the opinion of about 50% of the sample in total and of all its component groups. Forty per cent think that the word "often" better describes the frequency of so doing. Few ascribe to scientists the ability to almost always remember, resulting in their rare use of reference materials.

TABLE 25

DO MEMBERS OF PARLIAMENT NEED TO KNOW ABOUT SCIENCE AND TECHNOLOGY TO DO THEIR JOB?

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	384	47*	101	236	196	179
	%	%	%	%	%	%
Members of Parliament do not need to know anything about science and technology to do their job, because science and technology have nothing to do with their work	8	17	11	5	13	3
Members of Parliament need to know about science and technology in order to make good decisions about Canada's future	76	66	69	81	68	85
Members of Parliament do not need to know anything about science and technology because they can always rely on scientists and engineers for advice	14	17	16	13	17	10
No answer	2	-	4	1	2	2

* Note base size

Three-quarters of the Grade 10 students vote for the statement that says "Members of Parliament need to know about science and technology in order to make good decisions about Canada's future". More female than male students feel this way. The remaining numbers are split roughly two to one in their reason for same. Fourteen per cent say that M.P.s can always rely on scientists and engineers and 8% think that science and technology have nothing to do with their work.

TABLE 26

WHEN YOU SOLVE A PROBLEM IN DAILY LIFE...

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	384	47*	101	236	196	179
	%	%	%	%	%	%
You are doing science	17	13	22	17	24	11
Sometimes you are doing science and sometimes not. It depends on the type of problem	70	64	58	77	62	79
You are not doing science because science has nothing to do with everyday life	10	19	17	6	11	9
No answer	2	4	3	1	3	1

* Note base size

"When you solve a problem in daily life, you are doing science" is the opinion of one in six overall, and of twice as many males (24%) as females (11%). Depending on the type of problem you sometimes are and sometimes are not doing science is the modal response with a 70% figure overall. This is thought to be the case by more of those at the advanced level than by those at the other two levels; the latter groups subscribe more to the notion that science has nothing to do with everyday life, and therefore solving a problem is not doing science.

TABLE 27

THE ROLE OF SCIENCE FOR KNOWING ABOUT THE WORLD

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	384	47*	101	236	196	179
	%	%	%	%	%	%
The only way of knowing about the world is through science	10	32	9	6	14	6
Science is one of many good ways of knowing something about the world. Science alone however is not enough to know all about the world	63	40	55	70	58	69
Science is the best way of knowing about the world, even though there are other ways of knowing about it	26	26	35	23	28	25
No answer	2	2	3	1	2	2

* Note base size

Over 60% subscribe to the thought that while "science is one of many good ways of knowing something about the world, it is not enough to know all about it". Those in basic and general level classes think this to a lesser degree than do those in the advanced level classes. That it is the best, but not the only way, received a 26% mention, with 10% thinking that it is the only way. It would appear, although one cannot say that this is definitely the case, that students of the basic level program think it is the only way to a greater extent than do their counterparts. It can also be seen that the male students subscribe to this view more than the females do. Perhaps these results are related. In the whole sample (not just the half that answered this question), the male female ratio in the Grade 10 basic level program is 70:30.

TABLE 28

SCIENCE AND THE INVENTION OF NEW TECHNOLOGY

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	384	47*	101	236	196	179
	%	%	%	%	%	%
When new technology is invented, it often leads to new scientific facts and theories	55	53	52	56	47	62
New technology can be invented only by using known scientific facts and theories	27	28	24	29	31	24
New technology is often invented without using scientific facts and theories	17	17	19	16	20	12
No answer	2	2	5	1	2	2

* Note base size

Over 50% (and more females than males) tell us that the invention of new technology often leads to new scientific facts and theories. Twenty-seven per cent say that new technology stems from scientific facts and theories. That "new technology is often invented without using scientific facts and theories" is in third place, with a 17% mention.

TABLE 29

THE STEPS OF THE SCIENTIFIC METHOD, SCIENCE AND SOLVING DAILY LIFE PROBLEMS

	Total	Basic	General	Advanced
Total respondents(100%)	384	47*	101	236
	%	%	%	%
Learning the steps of the scientific method is good for doing science and for solving problems in daily life	57	51	50	61
Learning the steps of the scientific method is good only for doing science and not for solving problems in daily life	16	17	13	17
Learning the steps of the scientific method is a waste of time as it serves no useful purpose in science or in daily life	10	19	12	7
Learning the steps of the scientific method may be good for solving problems in daily life, and may or may not be good for doing science	17	13	24	15
No answer	1	-	3	1

* Note base size

Half or more of all Grade 10 students and of all subgroups believe that learning the steps of the scientific method is "good for doing science and for solving problems in daily life". Sixteen per cent think it is good for the former, but not the latter. Only 10% consider it to be a waste of time as it is good for neither. Seventeen per cent are really fence-sitters, they say it may be good for solving problems and it may or may not be good for doing science. Fewer of the students at the advanced than the other levels subscribe to the "no useful purpose" position.

4.0 THE GRADE 12 STUDENTS

TABLE 1A

SCIENCE IS...

	Total	Basic	General	Advanced	English	French
Total respondents (100%)	652	69	176	407	440	212
	%	%	%	%	%	%
Explaining the unknown	41	23	30	49	43	36
Using what we know to make the world a better place to live in	37	36	40	35	37	35
Subjects like chemistry, physics and biology	21	28	24	18	18	27
A group of people (scientists) and what they believe	3	7	4	2	4	2
No answer	3	6	5	2	4	2

TABLE 1B

SCIENCE IS...

		REGION		POPULATION		
	Total	Central	Other	Large	Medium	Small
Total respondents (100%)	652	284	368	222	243	187
	%	%	%	%	%	%
Explaining the unknown	41	45	38	48	37	37
Using what we know to make the world a better place to live in	37	40	33	39	36	34
Subjects like chemistry, physics and biology	21	15	26	14	21	28
A group of people (scientists) and what they believe	3	3	4	4	5	1
No answer	3	5	2	6	2	1

Overall we see about 40% of the grade 12 students saying that each of "explaining the unknown" and "using what we know to make the world better" is the definition of science. Twenty per cent subscribe to the definition being "subjects like physics, chemistry and biology". Only 3% say that science is "scientists and what they believe".

A look at the various sub-groups' responses reveals some differences. As the level of science studied increases the number of those telling us that science is "explaining the unknown" increases, with a decrease in those defining science as "subjects like physics, chemistry and biology". More anglophones than francophones opt for the "explaining the unknown" answer, while the reverse is the case for the "subjects like" answer. This is also the case among the central region vis-a-vis the "other" region students, and with decrease in community size also comes increase in those saying that science is "subjects like physics, chemistry and biology".

TABLE 2A

TECHNOLOGY IS...

	Total	Basic	General	Advanced
Total respondents (100%)	652	69	176	407
	%	%	%	%
How science is put to use	39	17	27	47
Using what we know to make the world a better place to live in	27	25	29	27
Machines and inventions	9	14	7	9
Machines and inventions as well as designing things	25	38	35	18
No answer	3	6	2	3

Overall, 40% of the Grade 12 science students tell us that technology is "how science is put to use". About 25% each is the vote for "using what we know to make the world better" and "machines, inventions and designing things". No more than 10% think technology is just machines and inventions. The only subgroups that show differences amongst them are those of the level of science studied, and here we see two considerable differences. Nearly half of the advanced level classes say that technology is "how science is put to use" - those at the basic and general levels do so to a much lesser extent. The reverse is the case as far as "machines, inventions and designing things" is concerned, for which the Grade 12 students at the advanced level vote to only half the degree (18%) of those at the other two levels (36%).

In the lists provided for the first two questions appears the phrase using what we know to make the world better. Below is a comparison of the results for science and for technology.

TABLE 2B

THOSE SAYING "USING WHAT WE KNOW TO MAKE THE WORLD BETTER" AS A DEFINITION

	For science	For technology
	%	%
Total Grade 12	37	27
Basic level	36	25
General level	40	29
Advanced level	35	27

In total, and at each level, there is approximately a ten percentage point difference in science's favour.

TABLE 3

WHO SHOULD DECIDE WHAT TYPES OF ENERGY CANADA WILL USE IN THE FUTURE?

	Total	Basic	General	Advanced	English	French
Total respondents (100%)	331	36*	92	203	223	108
	%	%	%	%	%	%
Scientists and engineers should decide what types of energy (such as nuclear, hydro, solar, etc.) Canada will use in the future, because they know best	23	19	20	26	21	29
Everybody should be involved in deciding what types of energy Canada will use in the future, because we are all affected by the decision	66	61	64	68	71	57
People other than scientists and engineers should decide what types of energy Canada will use in the future, because the decision is a social and economic one, not a technical one	11	22	17	5	10	11
No answer	1	-	1	1	**	3

* Note base size
Less than 0.5%

Two-thirds of the sample think, that because we are all affected by the decision, everybody should have a say in the matter. The remaining third is split 2 to 1 for and against scientists and engineers being the decision makers. There is some indication that more English- than French-speaking students think everybody should be involved, and that this view is held to a greater extent the greater the community size.

TABLE 4

WHETHER WE HAVE TO ACCEPT BOTH GOOD AND BAD EFFECTS OF TECHNOLOGY

	Total	Basic	Gen.	Adv.	Male	Female	Eng.	Fr.
Total respondents (100%)	331	36*	92	203	180	147	223	108
	%	%	%	%	%	%	%	%
We have to accept both the good and the bad effects of technology, because every new development has at least one bad effect, and to enjoy the good ones we have to put up with the bad ones	37	44	38	34	33	41	33	44
We don't have to accept the bad effects of technology, because bad effects can be reduced or removed through careful planning and testing	50	39	47	54	56	43	55	41
We don't have to accept the bad effects of technology, because some new developments have no bad effects and we should use those ones only	12	17	12	11	9	14	12	11
No answer	2	-	3	2	3	2	1	5

* Note base size

Fifty per cent of the grade 12 students think that we do not have to accept both kinds of effects in that the bad ones can be removed or at least reduced. A further 12% agree on the non-acceptance, but more strongly so. This leaves nearly 40% saying that we have to accept the bad effects in order to enjoy the good ones. Within grade 12 there are differences of opinion. More of those at the advanced level than of those at the other levels, opt for the "bad effects can be reduced or removed" answer, as do more males than females and more anglophones than francophones; more of the last-mentioned group say that we do have to accept both good and bad effects.

TABLE 5

WHETHER SCIENCE AND TECHNOLOGY CAN SOLVE PROBLEMS CAUSED BY POLLUTION

	Total	Basic	Gen.	Adv.	Male	Female	Public	Separate
Total respondents (100%)	331	36*	92	203	180	147	201	130
	%	%	%	%	%	%	%	%
Science and technology will not be able to solve problems caused by pollution, because the problems are so bad that it would cost too much	8	14	12	5	8	8	8	8
Science and technology alone cannot solve problems caused by pollution	56	36	38	68	51	63	60	52
Science and technology can solve problems caused by pollution, because science and technology have been successful in solving problems in the past	32	47	42	24	36	27	28	38
No answer	4	3	8	1	6	2	4	4

* Note base size

Over fifty per cent say that science and technology alone cannot solve pollution problems. Students at the advanced level voice this opinion to a much greater extent than do those in the basic and general levels; females more than males feel this way, as do more public- than separate school students - more separate school students believing in the ability to solve problems caused by pollution. More of those in medium-sized communities than in large-sized communities hold this last opinion (38% vs. 26%).

TABLE 6

WHETHER WOMEN SCIENTISTS MIGHT MAKE DIFFERENT DISCOVERIES FROM THOSE MADE BY MEN SCIENTISTS

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	331	36*	92	203	180	147
	%	%	%	%	%	%
Women scientists might make different discoveries from those made by men scientists, because women have different feelings and experiences from men	11	6	13	11	14	6
Women scientists and men scientists are all scientists, so they make the same kind of discoveries	13	28	16	9	17	9
Different discoveries made by different scientists have nothing to do with whether the scientists are men or women	75	67	66	80	67	84
No answer	2	-	4	**	2	1

* Note base size
Less than 0.5%

On any subject that has anything to do with gender we know we are going to have to examine the results from students of both sexes, as we know there will be differences. The above table runs true to that form.

Overall, 75% say that the differences in discoveries made by scientists of different sexes are not gender-related in any way. More students at the advanced level than those at the other two levels feel this way as do more females than their male counterparts. The response for this statement dwarfs that for each of the other two statements offered.

TABLE 7

WHETHER SCIENCE CLASSES HAVE HELPED ME BECOME A BETTER SHOPPER

	Total	Basic	Gen.	Adv.	Eng.	Fr.	Large	Med.	Small
Total respondents (100%)	331	36*	92	203	223	108	113	123	95
	%	%	%	%	%	%	%	%	%
Science classes have helped me become a better shopper, because I can use the scientific method and/or scientific facts to help me decide which products to buy	40	44	32	43	43	34	42	44	33
Science classes have not helped me become a better shopper. Neither the scientific method nor scientific facts can possibly help me decide which products to buy	25	19	32	24	27	22	23	23	32
Science classes have not helped me become a better shopper. Even though science teaches the scientific method and valuable facts, people like me tend to buy things they see on television or in advertisements	31	36	29	30	27	37	27	31	35
No answer	4	-	8	3	3	6	9	2	1

* Note base size

Forty per cent of students say that science classes have helped them become a better shopper. This means that about sixty per cent register the opposite opinion, though they are almost evenly split as to the reason for the same. One half of those who replied in the negative say that neither the scientific method nor scientific facts can possibly help them decide which products to buy. The other half admits to a tendency to buy things seen on television or in advertisements. There is no significant difference in the answers from students at each level. We do see, however, more francophones than anglophones accrediting TV and ads with having more effect than science classes. It appears that those living in small communities reply in the negative to a greater extent than do those in the largest communities.

TABLE 8

WHETHER THE MASS MEDIA OR SCIENCE CLASSES
GIVE A BETTER PICTURE OF SCIENCE

	Total	Basic	Gen.	Adv.	Male	Female	Eng.	Fr.
Total respondents (100%)	331	36*	92	203	180	147	223	108
	%	%	%	%	%	%	%	%
The mass media (television, newspapers, magazines, etc.) give you a better picture of what science is really like, than science classes do	16	22	16	14	17	14	15	17
Neither the mass media, nor science classes, give you a good picture of what science is really like	14	11	14	14	10	18	17	6
Science classes give you a better picture of what science is really like, than the mass media do	68	72	66	68	68	67	66	71
No answer	5	-	3	6	6	4	4	7

* Note base size

The science classes to mass media ratio in the table above is over 4 to 1 overall. More females than males think that neither the mass media nor science classes have the ability to give a good picture of what science is really like, as do more English-than French-speaking and more "central region" students (22%) than those in the rest of the province (7%).

TABLE 9

MOST SCIENTISTS ARE DOING SCIENCE...

	Total	Basic	General	Advanced
Total respondents (100%)	331	36*	92	203
	%	%	%	%
To satisfy their curiosity about the world around them	26	14	17	32
To be well-known and/or rich	9	19	11	7
Because they want to help people by finding new medical cures and solutions to environmental problems and by new inventions	66	67	68	65
Because they want to be looked up to by other scientists	3	3	3	2
No answer	2	-	7	1

* Note base size

Two-thirds of the grade 12 sample, and of every subgroup therein, think that most scientists are in their profession to help people in ways such as finding new medical cures, inventions and solving environmental problems. More in the advanced level program, at a 32% mention, think that curiosity about the world around them is the motivating factor than do students at the basic and general levels combined.

TABLE 10

WHAT WOULD HAPPEN IF CANADA SPENT MORE MONEY ON RESEARCH IN SCIENCE AND TECHNOLOGY

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	331	36*	92	203	180	147
	%	%	%	%	%	%
Canada would become a wealthier country	28	33	23	29	34	20
Canada might/might not become a wealthier country. It would depend on what science and technology were chosen	59	50	57	61	49	69
Canada might become poorer, because other ways of making Canada wealthier would suffer	10	17	14	7	12	9
No answer	3	-	7	2	5	1

* Note base size

The modal answer is that Canada might or might not become wealthier, dependent on what science and technology were chosen. This is the opinion of 60% overall; twenty per cent more female students subscribe to this option than male students. On the other hand, more males think that Canada would become wealthier (34%:20%), resulting in an overall percentage of 28. No more than 10% think that the result would be a poorer Canada in that other ways of increasing the wealth of the country would suffer.

TABLE 11

THERE ARE MORE MEN SCIENTISTS
THAN WOMEN SCIENTISTS TODAY:

	Total	Basic	Gen.	Adv.	Male	Fe-male	Public	Se-parate
Total respondents (100%)	331	36*	92	203	180	147	201	130
	%	%	%	%	%	%	%	%
- because boys are more interested in science than girls are	20	17	25	18	23	16	16	26
- because boys are better at science than girls are	4	11	3	3	4	3	5	2
- because until recently people used to believe that boys were better at science and that girls were better at other things, so more boys than girls made science their career	72	72	64	76	68	78	74	69
No answer	4	-	8	3	5	3	5	2

* Note base size

A mere handful believes the reason to be that boys are better at science than girls are - and there is no difference between the sexes on this. That boys are more interested in science is thought to be the cause by 20% overall, by more males than females and by more separate school than public school students. Around 70% overall think that the reason is history, viz., that people used to believe that boys were better at science than girls were. More of those at the advanced than at the general level subscribe to this opinion, as do more females than males.

TABLE 12

SCIENTISTS WHO WORK FOR A PROFIT-MAKING COMPANY:

	Total	Basic	General	Advanced	Male	Female
Total Respondents (100%)	331	36*	92	203	180	147
	%	%	%	%	%	%
- tend to put the company interests ahead of doing the best science they can	22	36	20	21	26	16
- put doing the best science they can ahead of the company's interests	18	19	25	15	19	18
- put doing the best science they can first; others put the company's interests first	56	44	53	59	51	63
No answer	4	-	2	5	4	3

* Note base size

The modal answer in total and all subgroups is that some put doing their best science first while others put the company's interests first, at a 56% mention overall. Those at the advanced level appear to feel this way more than the others in Grade 12 science. More females than males think this to be the case. The remainder of the sample is split 50:50 between doing the best science and putting the company's interests first; however, more males than females think the latter.

TABLE 13

WHEN SCIENTISTS ARE DECIDING WHETHER
OR NOT TO ACCEPT A THEORY...

	Total	Basic	Gen.	Adv.	Public	Sep.	Large	Med.	Small
Total respondents (100%)	331	36*	92	203	201	130	113	123	95
	%	%	%	%	%	%	%	%	%
- they look only at the facts, they accept it. If the theory cannot explain even just one fact, they do not accept the theory	50	25	43	57	45	57	54	54	38
- they look at the facts and the theory. If a theory is simpler and/or more logical than other theories, they may accept it even if all the facts are not explained	34	47	37	31	37	31	32	29	44
- they sometimes accept it for other reasons that have nothing to do with how well it compares with other theories or how well it explains the facts	13	25	16	10	16	9	12	13	15
No answer	3	3	4	3	3	4	4	3	3

* Note base size

That the facts and the facts only will help them in their decision is the opinion of 50% of the sample. We see, however, that the advanced level class believes this to be the case more so than do the other classes, as do separate school (and French) students more than their grade-mates. Fewer of those in small than in the two larger-sized communities give this answer. One third overall, with this time **more** in the small communities than elsewhere, think that the facts **and** the theory are looked at, and that the theory may be accepted if it is simpler and/or more logical than other theories even if all the facts are not explained.

TABLE 14

WHETHER SCIENTISTS TRAINED IN DIFFERENT COUNTRIES LOOK AT SCIENTIFIC PROBLEMS DIFFERENTLY

	Total	Basic	General	Advanced
Total Respondents (100%)	331	36*	92	203
	%	%	%	%
Scientists trained in one country look at scientific problems in different ways from scientists trained in another country, because their education and way of life are different	20	25	22	18
Scientists are taught to look at scientific problems in the same way, no matter what countries the scientists are from, because science is the same all over the world	18	28	25	13
Any two scientists may look at scientific problems differently. The country where they come from makes no difference	62	53	51	68
No answer	2	3	2	2

* Note base size

Over 60% agree that any two scientists may look at scientific problems differently and that the country they come from has no bearing on the matter. Those studying in the advanced program give this answer to a higher degree than those studying in the general or basic programs. About 20% of the total and every subgroup think that, because their education and way of life are different, scientists from different countries do look at scientific problems in different ways. A further 20% (although fewer of students at the advanced level) say that scientists, regardless of their country, are taught to look at scientific problems in the same way, because science is the same all over the world.

TABLE 15

WILL A NEW TECHNOLOGY THAT DOES MORE HARM THAN GOOD TO SOCIETY BE USED?

	Total	Basic	General	Advanced	English	French
Total respondents (100%)	331	36*	92	203	223	108
	%	%	%	%	%	%
If a new technology will do more harm than good to society, it will not be used	29	28	32	29	27	34
If a new technology works well, is efficient and doesn't cost much, it will be used even if it does more harm than good to society	17	14	17	18	16	20
Most new technologies are used, because some people benefit from them, even though others may see the harm they can do	50	56	47	51	54	43
No answer	4	3	4	4	4	4

* Note base size

That most new technologies are used, because some people benefit from them, even though others may see resultant harm, is the opinion of 50% of the grade 12 sample and all levels therein. This is believed more by anglophones than francophones. About thirty per cent, in total and of all component groups, say that it will not be used. In total and in all subgroups, under 20% say it will be used for reasons of efficiency and low cost, even if it does more harm than good.

TABLE 16

A SCIENTIFIC MODEL IS...

	Total	Basic	General	Advanced	English	French
Total Respondents (100%)	321	33*	84	204	217	104
	%	%	%	%	%	%
- a copy of the real thing	13	15	15	12	10	19
- very much like the real thing	31	30	33	29	29	34
- nothing like the real thing, but is useful for explaining the real thing	54	45	45	58	59	43
No answer	4	9	6	2	3	5

* Note base size

A scientific model is not like the real thing, but is useful for explaining the real thing, say 54% of the Grade 12 science students. More of those in the advanced science course than of those in the other two science course levels believe this to be the case, as do more English than French speaking students. About 30% of all groups under study say a model is very much like the real thing, with 13% overall (and more francophones than anglophones) saying it is a copy of the real thing.

TABLE 17

WHEN DOES SCIENTIFIC KNOWLEDGE CHANGE?

	Total	Basic	Gen.	Adv.	Male	Fe-male	Eng.	Fr.
Total respondents (100%)	321	33*	84	204	172	142	217	104
	%	%	%	%	%	%	%	%
Scientific knowledge never changes	2	3	1	2	3	1	3	1
Scientific knowledge can change only if new research proves earlier research to be wrong	57	36	63	57	63	51	53	65
Scientific knowledge can change if earlier research is looked at in a different way	40	55	32	41	34	46	44	31
No answer	4	9	6	2	3	5	4	4

* Note base size

Only 2% believe that scientific knowledge never changes. Those who do believe it can change are, overall, split into two camps - those who say it "can change only if new research proves earlier research to be wrong" (57% of total), and those who say it "can change if earlier research is looked at in a different way" (40% of total). Within the sample from the general level program, twice as many subscribe to "... if earlier research is wrong" as do to "... if looked at in a different way". The advanced level figures mirror those of the total grade. We do see differences between males and females, in that more males say it can change because of wrong earlier research, with more females saying it can change if the earlier research is looked at differently. As is often the case, the public/separate school percentages are very close to those of anglophone/francophone students. This is not surprising given that 68% of the separate school students are French-speaking.

TABLE 18

HOW OFTEN THE BEST SCIENTISTS FOLLOW
THE STEPS OF THE SCIENTIFIC METHOD

	Total	Basic	General	Advanced	English	French
Total respondents (100%)	331	33*	84	204	217	104
	%	%	%	%	%	%
The best scientists always follow the steps of the scientific method	44	42	50	42	37	59
The best scientists sometimes do and sometimes do not follow the steps of the scientific method	48	39	39	53	56	33
The best scientists never follow the steps of the scientific method. They are clever enough so they won't need to	4	9	5	2	4	4
No answer	4	9	5	2	3	5

* Note base size

Only 4% think that the best scientists never follow the steps of the scientific method. The remainder are evenly split overall as to the frequency of following them. Those at the advanced level favour sometimes rather than always, and there is an indication that students in the general level science course do the opposite. We do see large differences between the two language groups - more francophones say "always" and more Anglophones say "sometimes".

TABLE 19

SCIENTISTS **WRITE** ABOUT THEIR WORK IN AN ORGANIZED WAY. THEY **DO** THEIR WORK...

				REGION		POPULATION		
	Total	Eng.	Fr.	Central	Other	Large	Med.	Small
Total respondents (100%)	321	217	104	141	180	109	120	92
	%	%	%	%	%	%	%	%
- they also do their work in an organized way, and in the same order in which they write about it	61	58	69	53	68	55	62	68
- they do their work in an organized way, but not in the same order in which they write about it	26	29	18	32	21	30	24	22
- they do not usually do their work in an organized way	9	10	8	10	8	9	10	8
No answer	4	4	5	6	3	6	3	2

* Note base size

The above table omits the figures from the three levels. They are comparable with each other, and therefore with the total. This omission allows for space to show subgroups in which there are differences. Sixty per cent of the grade 12 science students ascribe scientists with also working in an organized way, and doing their work **in the same order** as that in which they write about it. A further quarter agree that the work is done in an organized fashion, but **not in the same order** as they write about it. Only one in ten think the order of doing work is not organized. Looking at the two language groups, more French think the work and the writing **are** done in the same order, and more English think that they, while both organized, are **not** done in the same order. For both groups - and in fact for every subgroup under study - the modal answer is "both organized, both in same order". With increase in population density there is a decrease in those subscribing to this answer and an increase in the "both organized, but in different orders" percentage. This obviously is reflected in the different figures from the two provincial regions.

TABLE 20

HOW SCIENTIFIC MISTAKES AFFECT THE PROGRESS OF SCIENCE

	Total	Basic	Gen.	Adv.	Eng.	Fr.	Large	Med.	Small
Total respondents (100%)	321	33*	84	204	217	104	109	120	92
	%	%	%	%	%	%	%	%	%
Scientific mistakes only slow down the progress of science	2	3	2	2	2	3	3	2	3
Scientific mistakes sometimes lead to new discoveries and therefore science progresses	72	67	69	74	75	65	78	72	65
Finding and correcting scientific mistakes is the only way science progresses	25	24	26	24	23	28	21	24	29
No answer	3	9	5	1	2	6	3	4	2

* Note base size

That scientific mistakes sometimes lead to new discoveries is the answer from the vast majority overall and of all subgroups. A quarter say that the only way science progresses is through finding and correcting these mistakes. Virtually nobody says that such mistakes only slow down the progress of science. No major differences are apparent among the subgroups.

TABLE 21

WHETHER SCIENTISTS AND ENGINEERS CAN TELL WHAT WILL HAPPEN

	Total	Basic	Gen.	Adv.	Male	Fe-male	Eng.	Fr.
Total respondents (100%)	321	33*	84	204	172	142	217	104
	%	%	%	%	%	%	%	%
Even with accurate information, scientists and engineers can tell us only what will probably happen, not what will definitely happen	59	48	49	65	55	64	65	45
Scientists and engineers can tell us what will definitely happen if they have enough accurate information	29	36	32	27	33	25	24	39
There's no way scientists and engineers can ever tell us even what will probably happen, no matter how much accurate information they have	10	12	15	7	10	9	9	12
No answer	2	3	5	1	2	3	2	4

* Note base size

Sixty per cent of the grade 12 students say that, even with accurate information, scientists and engineers can predict only what will **probably**, not definitely happen. More at the advanced level (65%) say this than do those at the other two levels (49%), as do more anglophones than francophones and more females than males. The thirty per cent of those who say that what will definitely happen can be predicted include disproportionately more French- than English-speaking students. One in ten students thinks that telling even what will probably happen is not within the capabilities of accurately informed scientists and engineers.

TABLE 22

IF SCIENTISTS FIND THAT PEOPLE WORKING WITH A CERTAIN MATERIAL HAVE TWICE AS MUCH CHANCE OF GETTING LUNG CANCER AS DO OTHER PEOPLE:

	Total	Basic	General	Advanced	Male	Female
Total respondents (100%)	321	33*	84	204	172	142
	%	%	%	%	%	%
- this means that the material causes lung cancer and it should not be used	22	24	25	21	26	17
- this does not necessarily mean that the material causes lung cancer and it could still be used	8	18	13	5	8	9
- this does not necessarily mean that the material causes lung cancer. However, more research should be done before the material is used again	67	48	60	74	65	71
No answer	3	9	4	2	2	4

* Note base size

Three-quarters of the sample is of the opinion that the material and the lung cancer are not necessarily related. To most of them this means doing more research before the material is used again. More of students at the advanced level subscribe to this than do students at the other level courses. About a quarter at each level say the material and the lung cancer are related, so discontinuance of use of the material should be effected. There is an indication that more males than females think this way. That the material could still be used is the choice of 8% overall, with fewer advanced than other program level students making this choice.

All other subgroups demonstrate a pattern comparable to that of the total grade 12 sample.

TABLE 23

THE RELATIONSHIP BETWEEN SCIENCE AND TECHNOLOGY

	Total	Basic	General	Advanced
Total respondents (100%)	321	33*	84	204
	%	%	%	%
Science is needed in order to invent new technology	68	58	56	74
New technology can be invented without science	10	15	14	7
Science is basically the same thing as technology	19	21	23	17
No answer	4	6	7	2

* Note base size

Technology cannot be invented without science is what nearly 70% tell us. Only 10% disagree with that, and a further 20% say that science and technology are in essence the same thing. Perhaps we notice that advanced level program students subscribe to the first theory to a greater extent than do students in the basic and general level programs.

There are no differences in the gender and language subgroups.

TABLE 24

THE USE OF REFERENCE MATERIALS BY GOOD SCIENTISTS

	Total	Basic	General	Advanced	Large	Medium	Small
Total respondents (100%)	321	33*	84	204	109	120	92
	%	%	%	%	%	%	%
Good scientists rarely use reference materials, as they can almost always remember information when they need it	5	18	8	2	5	6	5
Good scientists often use reference materials to look up information when they need it	35	39	40	32	36	40	27
Good scientists almost always use reference materials to look up information when they need it	59	39	52	65	60	52	67
No answer	2	6	1	2	4	3	-

* Note base size

As the level of science studied increases, so do those telling us that good scientists **almost always** use reference materials. With 59% overall being of this opinion, this leaves 40% who think otherwise. Nearly all of these students say that good scientists often rather than rarely use reference materials. While in centres of different sizes the **almost always** answer wins, the ratio of those saying almost always to **often** varies.

TABLE 25

DO MEMBERS OF PARLIAMENT NEED TO KNOW ABOUT SCIENCE AND TECHNOLOGY TO DO THEIR JOB?

	Total	Basic	General	Advanced	English	French
Total respondents (100%)	321	33*	84	204	217	104
	%	%	%	%	%	%
Members of Parliament do not need to know anything about science and technology to do their job, because science and technology have nothing to do with their work	4	9	5	2	5	2
Members of Parliament need to know about science and technology in order to make good decisions about Canada's future	80	82	70	84	83	73
Members of Parliament do not need to know anything about science and technology because they can always rely on scientists and engineers for advice	13	6	19	12	10	20
No answer	3	3	6	2	3	5

Note base size

There is little doubt in the minds of 80% of the grade 12 students that M.P.s **do** need to know about science and technology for the future benefit of Canada. This is the choice of more English- than French-speaking students. The remaining think that M.P.s do **not** need to know about these disciplines. Three-fourths of this group says that scientists' and engineers' advice can be relied on by them and one fourth says that science and technology have nothing to do with an M.P.'s job. More francophones than anglophones opt for the "rely on scientists and engineers" choice.

TABLE 26

WHEN YOU SOLVE A PROBLEM IN DAILY LIFE...

	Total	Basic	General	Advanced	Large	Medium	Small
Total respondents (100%)	321	33*	84	204	109	120	92
	%	%	%	%	%	%	%
- you are doing science	17	18	26	13	20	23	5
- sometimes you are doing science and sometimes not. It depends on the type of problem	74	64	64	79	72	67	84
- you are not doing science because science has nothing to do with everyday life	6	12	6	5	3	7	10
No answer	3	6	4	2	5	3	1

* Note base size

Seventy-four per cent of the grade 12 students choose the answer that says that the type of problem being solved dictates whether or not one is doing science. Seventy- nine per cent of students at the advanced level are of this opinion compared with 64% of those at the other two levels; all but 16% of those students in small centres also share this view. That one is doing science whenever one solves a problem in daily life is the opinion of 17%, but fewer among the students at the advanced level than among the others, and certainly fewer among those in the smallest centres. A mere handful thinks that solving these problems is not doing science because it (science) has nothing to do with everyday life.

TABLE 27

THE ROLE OF SCIENCE
FOR KNOWING ABOUT THE WORLD

	Total	Basic	General	Advanced	English	French
Total respondents (100%)	321	33*	84	204	217	104
	%	%	%	%	%	%
The only way of knowing about the world is through science	5	3	11	3	4	8
Science is one of many good ways of knowing something about the world. Science alone however is not enough to know all about the world	65	61	58	69	73	49
Science is the best way of knowing about the world, even though there are other ways of knowing about it	27	30	27	26	21	39
No answer	3	6	5	2	3	4

* Note base size

Only 5% think that the **only** way of knowing about the world is through science. That it is not the only way, but the **best** way, is the answer given by 27%; by more francophones than anglophones, and by more living outside the central region of the province than by their counterparts within this region (31% and 21% respectively).

Sixty-five per cent, with more anglophones than francophones doing so, take the stance that while, alone, science is not enough to know all about the world, it is one of many good ways of knowing something about it.

TABLE 28

SCIENCE AND THE INVENTION OF NEW TECHNOLOGY

	Total	Basic	General	Advanced
Total respondents (100%)	321	33*	84	204
	%	%	%	%
When new technology is invented, it often leads to new scientific facts and theories	58	61	62	56
New technology can be invented only by using known scientific facts and theories	28	15	18	35
New technology is often invented without using scientific facts and theories	10	12	12	9
No answer	5	12	6	3

* Note base size

About 60% of the grade as a whole and of all component subgroups are of the opinion that the invention of new technology often leads to new scientific facts and theories. About 30% disagree with that and think that **only** by using the latter can the former take place. The final 10% say that new technology is often invented without the benefit of scientific facts and theories. The picture for the students at the advanced level differs from that for those at the other levels. Note that four times as many of the former opt for the second statement as do for the third one.

TABLE 29

THE STEPS OF THE SCIENTIFIC METHOD, SCIENCE AND SOLVING DAILY LIFE PROBLEMS

	Total	Basic	General	Advanced
Total respondents (100%)	321	33*	84	204
	%	%	%	%
Learning the steps of the scientific method is good for doing and for solving problems in daily life	64	55	54	69
Learning the steps of the scientific method is good only for doing science and not for solving problems in daily life	12	6	15	12
Learning the steps of the scientific method is a waste of time as it serves no useful purpose in science or in daily life	6	6	7	5
Learning the steps of the scientific method may be good for solving problems in daily life, and may or may not be good for doing science	15	24	17	12
No answer	5	9	6	3

* Note base size

About two-thirds of the grade 12 students choose the statement **learning the steps of the scientific method is good for doing science and for solving problems in daily life**, with more in advanced level classes than the others, doing so. Only 6% took the completely opposite position, viz., that **learning the steps serves no useful purpose in science or in daily life**. The remainder are almost evenly split between **it's good for science, but not for solving life's problems** and **it may be good for the problem solving and may or may not be good for doing science**. The advanced level program students, not surprisingly, accredited learning the steps of the scientific method with being good in both respects to a greater extent than did students of the basic and general level programs.

5.0 THE BIPOLAR STATEMENTS

Over 40 pairs of bipolar statements were presented and a 7-point scale was used for students to give their opinions on each pair. Circling the number "1" meant total agreement with the first of the two statements; circling the "7" meant total agreement with the second. The closer the number circled to a "1" or "7", the more agreement with the respective statement. The full distribution for each pair has been produced in computer print-out and is available within the Ministry. For ease of reading, the results are presented here in the form of mean scores.

The arrows point towards which statement the mean tends. Means of 3.8 to 4.2 inclusive have not been "arrowed" as they are very close to the centre position of 4.0.

5.1 A Comparison of Grade 10 and Grade 12

This statement was weighted by 1	Total Grade 10	Total Grade 12	This statement was weighted by 7
Studying science has made me more interested in issues such as pollution	← 3.0	← 2.7	Studying science has not made me more interested in issues such as pollution
Women scientists tend to be too aggressive	5.0 →	5.1 →	Women scientists are no more aggressive than other women
I'm more interested in people than in technology	← 3.0	← 3.2	I'm more interested in technology than in people
Other people look up to scientists more than businesspeople	4.0	3.9	Other people look up to businesspeople more than to scientists
I'm glad I've had to learn at least some science	← 2.1	← 1.7	I wish I had never to learn any science
To improve our quality of living, Canada should spend more on technological and scientific research than on education and welfare	4.3 →	4.4 →	To improve our quality of living, Canada should spend more on education and welfare than on technological and scientific research
More scientists seem to be absent-minded professors	4.6 →	4.7 →	Most scientists are just like other people
I do not like all the detail that goes into learning science	← 3.6	4.1	I love all the detail that goes into learning science
Government agencies should be the ones to tell scientists what to do research on	4.8 →	4.9 →	Scientists themselves should be the ones to decide what to do research on
After high school I would like to study technology at a university	4.7 →	4.1	After high school I would not like to study technology at a university
Knowing about science will help me live a better life	← 3.0	← 2.7	Knowing about science will not help me live a better life
New technology has had a great effect on my family's way of living	← 3.4	← 3.0	New technology has had little or no effect on my family's way of living
To be a good scientist you have to be a "workaholic"	4.3 →	4.0	To be a good scientist you don't need to be a "workaholic"

This statement was weighted by 1	Total Grade 10	Total Grade 12	This statement was weighted by 7
A technologist usually gets paid more than a scientist	3.8	3.9	A scientist usually gets paid more than a technologist
To do a good science you have to remember a whole bunch of facts	3.9 ←	3.7	To do good science you only have to know where to go for the information
An engineer usually gets paid more than a scientist	3.9 ←	3.4	A scientist usually gets paid more than an engineer
Science has made life more complicated for everyone	4.7 →	4.8 →	Science has made life simpler for everyone
A science course should concentrate on making the students more concerned about the environment ←	2.6 ←	2.5	A science course should not concentrate on making the students more concerned about the environment
I love working with technology	3.8 ←	3.2	I hate working with technology
After high school, I would like to study engineering	5.0 →	4.6 →	After high school, I would not like to study engineering
It is hard for a scientist to believe in religion	5.3 →	5.3 →	Being a scientist has nothing to do with believing in religion
Knowing science does not help one in everyday life	4.9 →	5.1 →	Knowing science does help one in everyday life
The environment cannot be cleaned up without the help of science ←	3.2 ←	2.6	The environment can be cleaned up without the help of science
All scientists, no matter from what country, should share their knowledge with one another ←	2.2 ←	1.9	Scientists should share their knowledge only with other scientists from their own country
If you don't know computers, you won't be able to get a good job ←	3.6 ←	3.7	If you don't know computers, you will be able to get a good job
Science is very easy to learn	4.1	3.9	Science is very hard to learn
I would love to be a scientist	4.3 →	← 3.7	I would hate to be a scientist
I like to solve problems with other people's help	3.8	3.9	I like to solve problems by myself

This statement was weighted by 1	Total Grade 10	Total Grade 12	This statement was weighted by 7
There's too much high-tech stuff already	4.3 →	4.5 →	There's not enough high-tech stuff yet
I would rather be a technologist than a scientist	4.0	4.2	I would rather be a scientist than a technologist
You need to learn science only if you are going to be a scientist or a science teacher	5.2 →	5.5 →	You need to learn science no matter what you are going to be
Learning science helps people think for themselves	3.8 ←	3.3	Being able to think for yourself has nothing to do with having learned science
Science has done much more good than harm ←	3.0 ←	2.9	Science has done much more harm than good
More technology means fewer jobs for people	4.5 →	4.6 →	More technology means different but not fewer jobs for people
I'd much rather work with animals and nature than in an office or lab ←	3.3 ←	3.3	I'd much rather work in an office of lab than with animals or nature
Being a scientist means you'll make a lot of money	4.0	3.9	Being a scientist means you might not make a lot of money
I love to read books that make me think ←	3.1 ←	2.9	I love to read books that don't make me think
After high school I would like to study technology at a community college	4.8 →	4.3 →	After high school I would not like to study technology at a community college
I love to find out how things work ←	2.7 ←	2.4	As long as things work, I don't care how they do it
Science is important for everything in daily life ←	2.9 ←	2.7	Science has nothing to do with anything in daily life
People who choose jobs in technology are smarter than people who choose jobs in science	4.2	4.2	People who choose jobs in science are smarter than people who choose jobs in technology
You have to be a genius to be a scientist	4.8 →	5.0 →	You don't have to be a genius to be a scientist

This statement was weighted by 1	Total Grade 10	Total Grade 12	This statement was weighted by 7
Scientists have feelings	← 2.0	← 1.9	Scientists have no feelings
Being an engineer means you might not make a lot of money	4.6	→ 4.8	→ Being an engineer means you'll make a lot of money
Canada needs to have more scientists and engineers	← 3.2	← 2.7	Canada already has too many scientists and engineers
You have to have learned science to get a good job	4.0	4.0	You don't have to have learned science to get a good job
Science is a very personal thing	5.0	→ 5.0	→ Science is not a very personal thing
Scientists are just as creative as artists	← 3.2	← 3.0	Artists are creative, scientists aren't
Community colleges are not as good as universities for someone who wants a good job	← 3.0	← 3.3	Universities are not as good as communities colleges for someone who wants a good job

5.2. A COMPARISON OF MALES AND FEMALES

This statement was weighted by 1	Males	Females	This statement was weighted by 7
Studying science has made me more interested in issues such as pollution	← 2.8	← 2.8	Studying science has not made me more interested in issues such as pollution
Women scientists tend to be too aggressive	4.6	→ 5.5	→ Women scientists are no more aggressive than other women
I'm more interested in people than in technology	← 3.5	← 2.6	I'm more interested in technology than in people
Other people look up to scientists more than businesspeople	3.9	4.0	Other people look up to businesspeople more than to scientists
I'm glad I've had to learn at least some science	← 2.0	← 1.8	I wish I had never to learn any science

This statement was weighted by 1	Males	Females	This statement was weighted by 7
To improve our quality of living, Canada should spend more on technological and scientific research than on education and welfare	4.1	4.5	To improve our quality of living, Canada should spend more on education and welfare than on technological and scientific research
More scientists seem to be absent-minded professors	4.6 →	4.7 →	Most scientists are just like other people
I do not like all the detail that goes into learning science	3.8	3.9	I love all the detail that goes into learning science
Government agencies should be the ones to tell scientists what to do research on	4.7 →	5.0 →	Scientists themselves should be the ones to decide what to do research on
After high school I would like to study technology at a university	4.0	4.8 →	After high school I would not like to study technology at a university
Knowing about science will help me live a better life ←	2.8 ←	2.9	Knowing about science will not help me live a better life
New technology has had a great effect on my family's way of living ←	2.9 ←	3.5	New technology has had little or no effect on my family's way of living
To be a good scientist you have to be a "workaholic"	3.9	4.4 →	To be a good scientist you don't need to be a "workaholic"
A technologist usually gets paid more than a scientist	3.8	3.9	A scientist usually gets paid more than a technologist
To do a good science you have to remember a whole bunch of facts ←	3.7	3.9	To do good science you only have to know where to go for the information
An engineer usually gets paid more than a scientist ←	3.5	3.8	A scientist usually gets paid more than an engineer
Science has made life more complicated for everyone	4.7 →	4.9 →	Science has made life simpler for everyone
A science course should concentrate on making the students more concerned about the environment ←	2.8 ←	2.4	A science course should not concentrate on making the students more concerned about the environment
I love working with technology ←	3.0	4.2	I hate working with technology

This statement was weighted by 1	Males	Females	This statement was weighted by 7
After high school, I would like to study engineering	4.3 →	5.4 →	After high school, I would not like to study engineering
It is hard for a scientist to believe in religion	5.1 →	5.5 →	Being a scientist has nothing to do with believing in religion
Knowing science does not help one in everyday life	4.8 →	5.2 →	Knowing science does help one in everyday life
The environment cannot be cleaned up without the help of science	← 2.9	← 2.9	The environment can be cleaned up without the help of science
All scientists, no matter from what country, should share their knowledge with one another	← 2.2	← 1.9	Scientists should share their knowledge only with other scientists from their own country
If you don't know computers, you won't be able to get a good job	← 3.7	← 3.5	If you don't know computers, you will be able to get a good job
Science is very easy to learn	3.8	4.2	Science is very hard to learn
I would love to be a scientist	3.9	4.2	I would hate to be a scientist
I like to solve problems with other people's help	4.1	← 3.6	I like to solve problems by myself
There's too much high-tech stuff already	4.6 →	4.1	There's not enough high-tech stuff yet
I would rather be a technologist than a scientist	3.8	4.4 →	I would rather be a scientist than a technologist
You need to learn science only if you are going to be a scientist or a science teacher	5.3 →	5.4 →	You need to learn science no matter what you are going to be
Learning science helps people think for themselves	← 3.5	3.8	Being able to think for yourself has nothing to do with having learned science
Science has done much more good than harm	← 3.1	2.8	Science has done much more harm than good
More technology means fewer jobs for people	4.5 →	4.6 →	More technology means different but not fewer jobs for people

This statement was weighted by 1	Males	Females	This statement was weighted by 7
I'd much rather work with animals and nature than in an office or lab	← 3.3	← 3.3	I'd much rather work in an office of lab than with animals or nature
Being a scientist means you'll make a lot of money	4.0	3.9	Being a scientist means you might not make a lot of money
I love to read books that make me think	← 3.1	← 2.9	I love to read books that don't make me think
After high school I would like to study technology at a community college	4.2	5.0 →	After high school I would not like to study technology at a community college
I love to find out how things work	← 2.2	← 2.9	As long as things work, I don't care how they do it
Science is important for everything in daily life	← 2.9	← 2.8	Science has nothing to do with anything in daily life
People who choose jobs in technology are smarter than people who choose jobs in science	4.2	4.2	People who choose jobs in science are smarter than people who choose jobs in technology
You have to be a genius to be a scientist	4.9	→ 4.8 →	You don't have to be a genius to be a scientist
Scientists have feelings	← 2.1	← 1.8	Scientists have no feelings
Being an engineer means you might not make a lot of money	4.7	→ 4.6 →	Being an engineer means you'll make a lot of money
Canada needs to have more scientists and engineers	← 2.9	← 3.0	Canada already has too many scientists and engineers
You have to have learned science to get a good job	3.9	4.0	You don't have to have learned science to get a good job
Science is a very personal thing	4.9	→ 5.0 →	Science is not a very personal thing
Scientists are just as creative as artists	← 3.0	← 3.2	Artists are creative, scientists aren't
Community colleges are not as good as universities for someone who wants a good job	← 3.2	← 3.1	Universities are not as good as communities colleges for someone who wants a good job

5.3. The Demographics of the Sample

TABLE 1

SEX OF STUDENT

	Total	Grade 10	Grade 12
Total respondents (100%)	1422	770	652
	%	%	%
Male	52	51	54
Female	46	47	44
Not stated	2	2	2

TABLE 2

LANGUAGE OF STUDENT'S EDUCATION

	Total	Grade 10	Grade 12
Total respondents (100%)	1422	770	652
	%	%	%
English	67	67	67
French	33	33	33

TABLE 3

AGE OF STUDENT

	Total	Grade 10	Grade 12
Total respondents (100%)	1422	770	652
	%	%	%
15 or less	32	57	2
16	24	31	16
17	25	7	45
18	13	2	27
19 or more	4	*	8
Not stated			
Mean age	16	15	17

* Less than 0.5%

TABLE 4

SCIENCE LEVEL OF STUDENT

	Total	Grade 10	Grade 12
Total respondents (100%)	1422	770	652
	%	%	%
Basic	12	13	11
General	27	27	27
Advanced	61	60	62

* Less than 0.5%

TABLE 5

TYPE OF SCHOOL ATTENDED

	Total	Grade 10	Grade 12
Total respondents (100%)	1422	770	652
	%	%	%
Public	61	62	61
Separate	39	38	39

TABLE 6

DENSITY OF POPULATION

	Total	Grade 10	Grade 12
Total respondents (100%)	1422	770	652
	%	%	%
1,000,000 plus (Toronto)	15	15	14
500,000 - 999,999	18	17	20
100,000 - 499,999	25	26	23
30,000 - 99,000	14	14	14
10,000 - 29,999	3	3	2
Under 10,000	18	17	19
Rural	8	8	7

TABLE 7

ONTARIO REGION OF SCHOOL

	Total	Grade 10	Grade 12
Total respondents (100%)	1422	770	652
	%	%	%
Central	43	43	43
Eastern	19	19	19
Mid-northern	6	6	6
North-eastern	12	12	12
North-western	3	3	3
Western	17	17	17

6.0 THE "ATTITUDE TO SCIENCE" CLUSTERS

To investigate whether there is any relationship between science students' attitudes towards science, as expressed in their responses to the bipolar statements, and science students' knowledge, a sophisticated multivariate analysis was undertaken. This resulted in there being four distinct groups of students, to which have been ascribed the names below:

Science enthusiasts. This group constitutes **20%** of the students and three out of five are male. Its members love everything about science.

In general terms, they:

- are more interested in technology than in people.
- are very glad to have had to learn science.
- love all the detail that goes into learning science.
- would like to study technology at a university.
- think science has made life easier for everyone.
- love working with technology.
- would like to study engineering.
- think knowing science helps one in everyday life.
- think science is very easy to learn.
- would love to be a scientist.
- would rather be a scientist than a technologist.
- think that learning science helps one to be able to think for oneself.
- love to read books that make them think.
- love to find out how things work.
- think science is important for everything in daily life.
- think Canada needs to have more scientists and engineers.
  believe knowing science does help one in everyday life
- feel that science has made life simpler for everyone

Disinterested in science. These account for **13%** of the sample, with two-thirds being male. In direct contrast to the science enthusiasts, they dislike almost everything about science, as can be seen by the following. Again in general terms, they:

- think most scientists to be absent-minded professors.
- do not like all the detail that goes into learning science.
- think government agencies should decide on what scientists do research.
- think that knowing science does not help one in everyday life.
- find science hard to learn.
- think science has done more harm than good.
- are less interested in finding out how things work.
- think (more than do the other groups) that science has nothing to do with anything is daily life.
- (more) think scientists have no feelings.
- (more) think Canada already has too many scientists and engineers.

Science appreciators, who have a distinct love-hate relationship with science, make up **21%** of the sample, and females outnumber males by more than two to one. This group dislikes studying science intensely, but is most favourably disposed towards what science has achieved, as is evidenced below. They:

- are more interested in people than technology.
- think scientists themselves should decide on what to do research.
- would not like to study technology at a university.
- hate working with technology.
- would not like to study engineering after high school.
- would hate to be a scientist.
- think science has done much more good than harm.
- would not like to study technology at a community college.
- think science is not a very personal thing.
- (more) think community colleges are not as good as universities for someone who wants a good job.

Middle of the road is the name given to the largest group which comprises **47%** of the sample. This is the group that has fewest strong opinions, and the two sexes are almost evenly represented in it.

This group's opinions, partially because of its size, reflect those of the total sample and therefore it does not seem to have as much of a personality as do the other three.

7.0 RESPONSES BY ATTITUDINAL CLUSTERS TO THE KNOWLEDGE STATEMENTS

TABLE 1

SCIENCE IS...

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	1335	623	169	275	268
	%	%	%	%	%
- explaining the unknown	38	38	32	39	39
- using what we know to make the world a better place to live in	35	36	31	32	37
- subjects like chemistry, physics and biology	25	23	30	30	21
- a group of people (scientists) and what they believe	4	3	7	3	4
No answer	3	2	4	1	4

Thirty per cent of the disinterested group as well as the appreciators consider science to be no more than subjects like physics, chemistry and biology, compared with just over 20% of the other two groups. The only other difference among the groups that is worthy of mention is that of fewer of those disinterested telling us that science is explaining the unknown.

TABLE 2A

TECHNOLOGY IS...

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	1335	623	169	275	268
	%	%	%	%	%
- how science is put to use	36	37	24	35	40
- using what we know to make the world a better place to live in	26	27	33	23	25
- machines and inventions	11	11	14	13	9
- machines and inventions as well as designing things	26	25	28	30	24
No answer	2	2	4	1	3

Of all groups except the disinterested one, more told us that technology is how science is put to use than said that it is using what we know to make the world better.

TABLE 2B

THOSE SAYING "USING WHAT WE KNOW TO MAKE THE WORLD BETTER" AS A DEFINITION

	For science	For technology
	%	%
Amongst:		
The middle of the road group	36	27
The disinterested in science group	31	33
The science appreciator group	32	23
The science enthusiast group	37	25

Again we see the disinterested cluster out of step with their fellow students. One in three of them thinks each subject is defined by the words in the table heading. The three other groups, however, mention technology to a lesser extent than they do science in this respect.

TABLE 3

WHO SHOULD DECIDE WHAT TYPES OF ENERGY CANADA WILL USE IN THE FUTURE?

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analysed (100%)	670	304	92	148	126
	%	%	%	%	%
Scientists and engineers should decide what types of energy (such as nuclear, hydro, solar, etc.) Canada will use in the future, because they know best	21	20	25	20	25
Everybody should be involved in deciding what types of energy Canada will use in the future, because we are all affected by the decision	64	66	58	64	64
People other than scientists and engineers should decide what types of energy Canada will use in the future, because the decision is a social and economic one, not a technical one	14	13	20	16	9
No answer	1	1	1	1	2

There are two indications here, viz., that science enthusiasts, who are keen to continue in the scientific field, do not want to be left out of the energy picture, and that more of those disinterested in science want people other than scientific types to be in the picture. To a lesser extent this is also true of science appreciators who dislike studying science even though they (as is evident from the name given to this group) appreciate its achievements.

TABLE 4

WHETHER WE HAVE TO ACCEPT BOTH GOOD AND BAD EFFECTS OF TECHNOLOGY

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
We have to accept both the good and the bad effects of technology, because every new development has at least one bad effect, and to enjoy the good ones we have to put up with the bad ones	37	36	39	38	37
We don't have to accept the bad effects of technology, because bad effects can be reduced or removed through careful planning and testing	49	53	42	47	46
We don't have to accept the bad effects of technology, because some new developments have no bad effects and we should use those ones only	12	10	14	14	14
No answer	2	1	4	2	2

The only difference apparent here is that more of the middle of the road group than of those disinterested in science think that bad effects can be reduced or removed, and that therefore we do not have to accept both good and bad.

TABLE 5

WHETHER SCIENCE AND TECHNOLOGY CAN SOLVE PROBLEMS CAUSED BY POLLUTION

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
Science and technology will not be able to solve problems caused by pollution, because the problems are so bad that it would cost too much	8	6	12	11	9
Science and technology alone cannot solve problems caused by pollution	56	54	55	60	53
Science and technology can solve problems caused by pollution, because science and technology have been successful in solving problems in the past	34	37	32	28	37
No answer	3	4	2	1	2

It would appear that fewer in the science appreciator than in the enthusiast and the middle of the road groups accredit science and technology with the ability to solve problems caused by pollution.

TABLE 6

WHETHER WOMEN SCIENTISTS MIGHT MAKE DIFFERENT DISCOVERIES FROM THOSE MADE BY MEN SCIENTISTS

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
Women scientists might make different discoveries from those made by men scientists, because women have different feelings and experiences from men	13	14	23	8	8
Women scientists and men scientists and men scientists are all scientists, so they make the same kind of discoveries	14	16	21	11	10
Different discoveries made by different scientists have nothing to do with whether the scientists are men or women	73	70	59	80	81
No answer	1	1	1	2	2

Although we see, for the appreciator and enthusiast groups, 80% saying that different discoveries have nothing to do with the sex of the scientists, we suspect that the reasons for that are different. The appreciator group is predominantly female, and perhaps, for the enthusiast group, the aura of science and its purity in their minds are determining factors. Whatever the reasons be, these two groups match each other perfectly in terms of the distribution of their answers. Look now at the group that is **disinterested** in science. We still see the majority of them agreeing with the above-mentioned 80%s, but a quarter of them do think that discoveries made by scientists of different sexes will be different.

TABLE 7

WHETHER SCIENCE CLASSES HAVE HELPED ME BECOME A BETTER SHOPPER

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
Science classes have helped me become a better shopper, because I can use the scientific method and/or scientific facts to help me decide which products to buy	37	38	26	35	48
Science classes have not helped me become a better shopper. Neither the scientific method nor scientific facts can possibly help me decide which products to buy	26	26	33	24	23
Science classes have not helped me become a better shopper. Even though science teaches the scientific method and valuable facts, people like me tend to buy things they see on television or in advertisements	33	32	38	37	26
No answer	4	5	4	4	3

Half of the science enthusiast group, but only a quarter of the disinterested in science group say that science classes **have** helped them become better shoppers. The latter and the appreciators - or nearly 40% of them - do not give any credit to science classes, but rely on things seen in ads or on T.V.. One third of the disinterested group says that scientific methods and facts cannot help in terms of becoming a better shopper.

TABLE 8

WHETHER THE MASS MEDIA OR SCIENCE CLASSES
GIVE A BETTER PICTURE OF SCIENCE

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
The mass media (television, newspapers, magazines, etc.) give you a better picture of what science is really like, than science classes do	17	14	24	17	21
Neither the mass media, nor science classes give you a good picture of what science is really like	16	16	28	16	6
Science classes give you a better picture of what science is really like, than the mass media do	64	68	48	63	67
No answer	4	3	4	4	6

Two-thirds of all groups but the disinterested one vote for science classes, those in the latter group doing so to the extent of one in two. Only 6% of the enthusiasts say that neither science classes nor mass media give a better picture of science, compared with 28% of those disinterested in science.

TABLE 9

MOST SCIENTISTS ARE DOING SCIENCE...

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
- to satisfy their curiosity about the world around them	25	24	23	26	26
- to be well-known and/or rich	8	10	11	7	5
- because they want to help people by finding new medical cures and solutions to environmental problems and by new inventions	68	68	59	72	70
- because they want to be looked up to by other scientists	4	4	8	4	2
No answer	3	4	3	1	2

It is fascinating to see on which subject matters the appreciator group aligns itself, as it were, with the enthusiast group, and on which ones it joins the disinterested one. Here we see evidence of the former situation. More of the last named group, especially when compared with the enthusiast group (19% to 7%) think that the reasons for most scientists to be doing science include the motives of being well known and/or rich, or admired by other scientists.

TABLE 10

WHAT WOULD HAPPEN IF CANADA SPENT MORE MONEY ON RESEARCH IN SCIENCE AND TECHNOLOGY

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
Canada would become a wealthier country	24	19	26	18	40
Canada might/might not become a wealthier country. It would depend on what science and technology were chosen	58	64	50	59	46
Canada might become poorer, because other ways of making Canada wealthier would suffer	15	13	23	18	11
No answer	3	4	2	4	3

Forty per cent of the science enthusiasts think that more research money would lead to a wealthier country. In the other three groups, however, only between 20% to 25% agree with this statement. That Canada might become poorer is the opinion of more of those disinterested in science, and, to some extent, appreciators than of the enthusiasts.

TABLE 11

THERE ARE MORE MEN SCIENTISTS
THAN WOMEN SCIENTISTS TODAY:

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
- because boys are more interested in science than girls are	21	18	23	26	21
- because boys are better at science than girls are	6	6	15	-	6
- because until recently people used to believe that boys were better at science and that girls were better at other things, so more boys than girls made science their career	70	73	57	72	71
No answer	4	4	5	4	5

More in the disinterested group say that the reason is that boys are better than girls at science. It is interesting to note that **none** of the appreciators think that this is so. (The fact that boys constitute about two-thirds of the enthusiasts group and girls in turn constitute two-thirds of the appreciator group may have some bearing on these results.)

TABLE 12

SCIENTISTS WHO WORK FOR A PROFIT-MAKING COMPANY:

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
- tend to put the company's interests ahead of doing the best science they can	20	17	33	18	19
- put doing the best science they can ahead of the company's interests	18	18	22	18	15
- put doing the best science they can first; others put the company's interests first	58	61	42	60	62
No answer	4	4	4	3	4

Sixty per cent of all groups except the disinterested in science one, can be thought to be sitting on the fence on this subject - only 40% of those in the disinterested group are there with them. The remainder of this group is split 3 to 2 in favour of putting the company's interests first (as against doing the best science). The other three groups' remainders are virtually evenly split between the company's interests and doing their best science.

TABLE 13

WHEN SCIENTISTS ARE DECIDING WHETHER OR NOT TO ACCEPT A THEORY:

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
- they look only at the facts. If the theory explains the facts, they accept it. If the theory cannot explain even just one fact, they do not accept the theory	49	49	46	48	52
- they look at the facts and the theory. If a theory is simpler and/or more logical than other theories, they may accept it even if all the facts are not explained	33	33	39	36	28
- they sometimes accept it for other reasons that have nothing to do with how well it compares with other theories or how well it explains the facts	15	15	14	11	18
No answer	3	3	2	6	2

Nearly all groups are in agreement on this subject. The enthusiast group appears to differ, but only modestly, from the other three groups.

TABLE 14

WHETHER SCIENTISTS TRAINED IN DIFFERENT COUNTRIES LOOK AT SCIENTIFIC PROBLEMS DIFFERENTLY

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
Scientists trained in one country look at scientific problems in different ways from scientists trained in another country, because their education and way of life are different	19	21	28	14	15
Scientists are taught to look at scientific problems in the same way, no matter what countries the scientists are from, because science is the same all over the world	20	19	22	22	17
Any two scientists may look at scientific problems differently. The country where they come from makes no difference.	60	59	50	64	67
No answer	2	2	2	1	2

The majority of each group says that any two scientists may look at scientific problems differently and that the country in which they were trained has no bearing on the matter. While half of the disinterested group voices this opinion, two-thirds of the science enthusiasts do so. Twice as many of the former as appreciators or enthusiasts think that one country's scientists do look at problems differently, due to their different education and way of life.

TABLE 15

WILL A NEW TECHNOLOGY THAT MAY DO MORE HARM THAN GOOD TO SOCIETY BE USED?

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	670	304	92	148	126
	%	%	%	%	%
If a new technology will do more harm than good to society, it will not be used	31	29	28	36	29
If a new technology works well, is efficient and doesn't cost much, it will be used even if it does more harm than good to society	20	21	22	18	21
Most new technologies are used, because some people benefit from them, even though others may see the harm they can do	46	47	47	45	46
No answer	3	3	5	2	3

There are no differences worth noting among the four groups on this subject.

TABLE 16

SCIENTIFIC MODEL IS...

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
- a copy of the real thing	16	18	19	12	16
- very much like the real thing	32	33	35	37	23
- not like the real thing, but is useful for explaining the real thing	49	49	42	49	55
No answer	3	2	4	3	6

A third or so of all groups except the science enthusiasts say that a scientific model is very much like the real thing. Less than a quarter of this particular group however do so. They, to a greater extent than, particularly, the disinterested in science group, say that a model can explain the real thing while not being like it.

TABLE 17

WHEN DOES SCIENTIFIC KNOWLEDGE CHANGE?

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
Scientific knowledge never changes	4	2	13	5	2
Scientific knowledge can change only if new research proves earlier research to be wrong	55	60	36	53	56
Scientific knowledge can change if earlier research is looked at in a different way	40	39	44	39	44
No answer	3	1	8	5	1

The disinterested group is "the odd group out" in this table. Far fewer of them think that scientific knowledge changes only if earlier research is proven to be wrong and more of them, while still few, think that it never changes.

TABLE 18

HOW OFTEN THE BEST SCIENTISTS FOLLOW
THE STEPS OF THE SCIENTIFIC METHOD

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
The best scientists always follow the steps of the scientific method	42	46	32	37	43
The best scientists sometimes do and sometimes do not follow the steps of the scientific method	51	49	49	59	51
The best scientists never follow the steps of the scientific method. They are clever enough so they don't need to	5	3	14	3	4
No answer	2	2	4	2	2

This table shows one of the occasions where the views of the disinterested group differ substantially from those of the middle of the road group. Fewer of the former are of the opinion that the best scientists **always** follow the steps of the scientific method, and it would appear that more of them than of any other group think that the cleverness of the best scientists means that they never have to resort to the scientific method.

TABLE 19

SCIENTISTS **WRITE** ABOUT THEIR WORK IN AN ORGANIZED WAY AND IN A CERTAIN ORDER:

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
- they also do their work in an organized way, and in the same order in which they write about it	63	67	45	62	65
- they do their work in an organized way, but not in the same order in which they write about it	24	21	34	22	27
- they do not usually do their work in an organized way	10	10	17	13	4
No answer	3	3	6	4	3

About two-thirds of all groups except those disinterested in science have the impression that scientists follow the same order when writing about their work as when doing the work itself. About half of the disinterested group is in agreement; however more of them think that the order of scientists' work, while being organised in its conduct, is not followed in the writing. More of them, certainly than of the enthusiasts, think that scientists do not do their work in an organized fashion.

TABLE 20

HOW SCIENTIFIC MISTAKES AFFECT THE PROGRESS OF SCIENCE

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
Scientific mistakes only slow down the progress of science	4	2	13	6	2
Scientific mistakes sometimes lead to new discoveries and therefore science progresses	73	78	60	72	72
Finding and correcting scientific mistakes is the only way science progresses	23	21	27	20	26
No answer	1	-	3	2	1

The majority of every group tells us that scientific mistakes sometimes lead to new discoveries. There is an indication, however, that more of the group that is disinterested in science than of the rest think they only slow down science's progress.

TABLE 21

WHETHER SCIENCE AND ENGINEERS CAN TELL WHAT WILL HAPPEN

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
Even with accurate information, scientists and engineers can tell us only what will probably happen, not what will definitely happen	55	59	39	60	51
Scientists and engineers can tell us what will definitely happen if they have enough accurate information	31	26	40	28	39
There's no way scientists and engineers can ever tell us even what will probably happen, no matter how much accurate information they have	13	15	19	12	6
No answer	2	1	1	1	5

About 40% of each of the enthusiastic and disinterested groups have confidence that, with accurate information, scientists and engineers can forecast what will **definitely** happen. Among appreciators and the middle of the road segments, twice as many (60%) vote for what will **probably** happen as do for what will **definitely** happen. Only 5% of the enthusiasts do **not** believe that what will happen can be probably or definitely predicted.

TABLE 22

IF SCIENTISTS FIND THAT PEOPLE WORKING WITH A CERTAIN MATERIAL HAVE TWICE AS MUCH CHANCE OF GETTING LUNG CANCER AS DO OTHER PEOPLE:

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
- this means that the material causes lung cancer and it should not be used	22	21	29	21	22
- this does not necessarily mean that the material causes lung cancer and it could still be used	8	7	18	8	7
- this does not necessarily mean that the material causes lung cancer. However, more research should be done before the material is used again	68	72	48	69	69
No answer	2	1	5	2	3

Once more, those disinterested in science differ from their fellow students. While there is virtually no difference among the groups as far as the discontinuation of use of the material is concerned, more of the first named segment say the material could be used and therefore fewer of them see the need for more research before that occurs.

TABLE 23

THE RELATIONSHIP BETWEEN SCIENCE AND TECHNOLOGY

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
Science is needed in order to invent new technology	68	71	45	65	74
New technology can be invented without science	12	11	22	17	6
Science is basically the same thing as technology	18	17	30	16	16
No answer	2	2	4	2	4

Two-thirds or more of all groups, except the disinterested cluster, say that science is needed in order to invent new technology; fewer than half of this particular group say so. More of them than of the others seem to think that science and technology are basically the same thing. Few of the science enthusiasts think that technology can be invented without science. Somewhat more of the middle of the road group do, but around 20% of each of those who are disinterested and appreciative say that this is the case.

TABLE 24

THE USE OF REFERENCE MATERIALS BY GOOD SCIENTISTS

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
Good scientists rarely use reference materials, as they can almost always remember information when they need it	6	4	19	4	4
Good scientists often use reference materials to look up information when they need it	38	35	40	46	37
Good scientists almost always use reference materials to look up information when they need it	55	61	36	48	59
No answer	2	1	4	1	2

Like most of the others, this table also indicates that those disinterested in science differ from the rest. That they think scientists are cleverer than do the other groups was evident in their response to the earlier question about following the steps of the scientific method. Here we see about 20% of them saying that good scientists rarely need to use reference materials as they can remember the required information when needed. Only 4% of each of the other groups concur. Fifty to sixty per cent of these other groups say that good scientists almost always use reference materials; fewer that 40% of the disinterested group says so.

TABLE 25

DO MEMBERS OF PARLIAMENT NEED TO KNOW ABOUT SCIENCE AND TECHNOLOGY TO DO THEIR JOB?

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
Members of Parliament do not need to know anything about science and technology to do their job, because science and technology have nothing to do with their work	6	4	18	6	5
Members of Parliament need to know about science and technology in order to make good decisions about Canada's future	79	83	58	76	83
Members of Parliament do not need to know anything about science and technology because they can always rely on scientists and engineers for advice	14	12	19	18	10
No answer	2	2	4	2	2

While 80% or so of all other groups think that M.P.s do need to know about science to do their job properly, 40% or so of those in the disinterested group think, for one reason or the other, that they do not.

TABLE 26

WHEN YOU SOLVE A PROBLEM IN DAILY LIFE...

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
- you are doing science	17	16	17	13	24
- sometimes you are doing science and sometimes not. It depends on the type of problem	72	75	57	79	68
- you are not doing science because science has nothing to do with everyday life	8	6	25	9	4
No answer	2	2	1	-	4

Earlier we mentioned that the appreciators do not like studying or being personally involved with science even though they acknowledge - and appreciate - the good done by science. That seems to manifest itself above, at least when they are compared with the science enthusiasts. A quarter of those disinterested in science - the ones who want nothing to do with science - say that because science has nothing to do with daily life, solving problems therein is not doing science. This is not agreed with by nearly all of the other groups.

TABLE 27

THE ROLE OF SCIENCE FOR KNOWING ABOUT THE WORLD

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
The only way of knowing about the world is through science	8	6	19	8	5
Science is one of many good ways of knowing something about the world. Science alone however is not enough to know all about the world	65	67	55	70	58
Science is the best way of knowing about the world, even though there are other ways of knowing about it	26	24	27	20	36
No answer	2	2	1	2	1

While hardly any science enthusiasts think that science is the **only** way to know about the world, a third of them think it is the best one. The appreciator and middle of the road groups' pictures are similar, with about 70% of each saying that science is one of many good ways, but not enough alone. Note the comparatively higher percentage of those disinterested in science who say that science is the only way.

TABLE 28

SCIENCE AND THE INVENTION OF NEW TECHNOLOGY

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
When new technology is invented, it often leads to new scientific facts and theories	57	59	39	61	56
New technology can be invented only by using known scientific facts and theories	27	26	35	19	33
New technology is often invented without using scientific facts and theories	14	14	22	15	9
No answer	3	2	5	5	3

About 60% of all groups, again except the disinterested one (at 40%), are of the opinion that new technology often **leads** to scientific facts and theories. About a third of each of the latter group and of the enthusiasts tell us that new technology is invented **only** by using the facts and theories. Few of the enthusiast but more of the disinterested group think that new technology can be invented without resorting to the facts and theories.

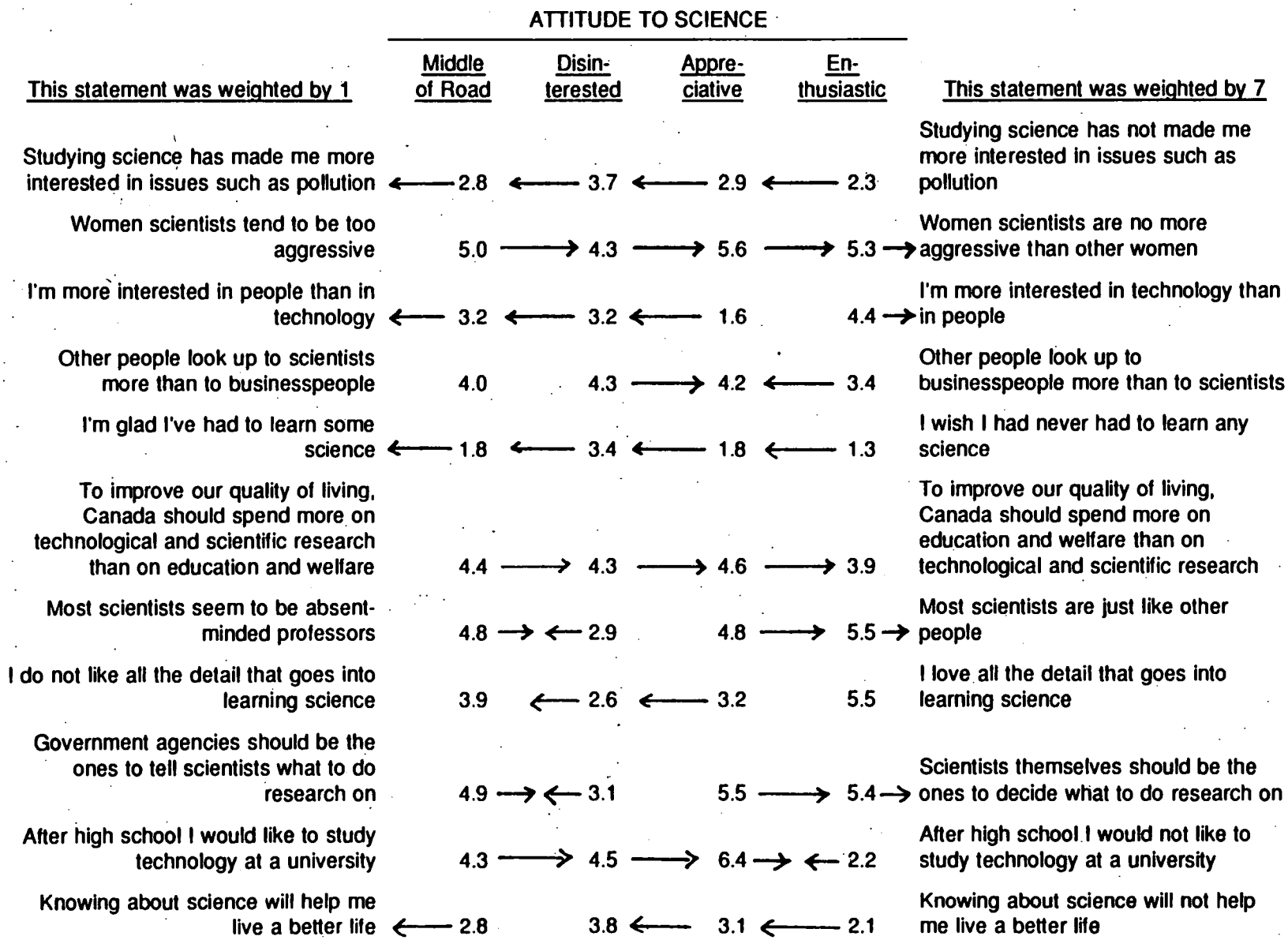
TABLE 29

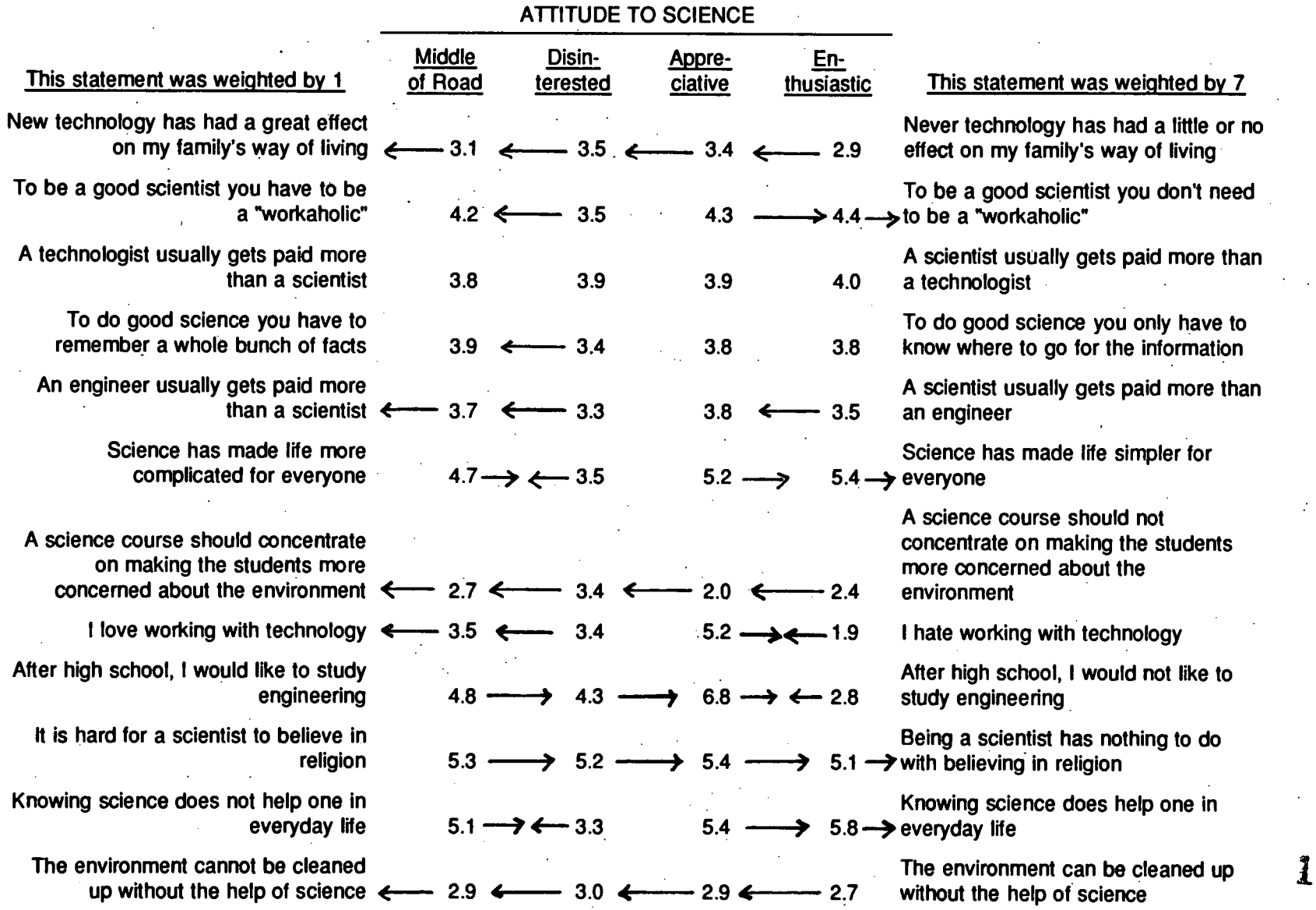
THE STEPS OF THE SCIENTIFIC METHOD, SCIENCE AND SOLVING DAILY LIFE PROBLEMS

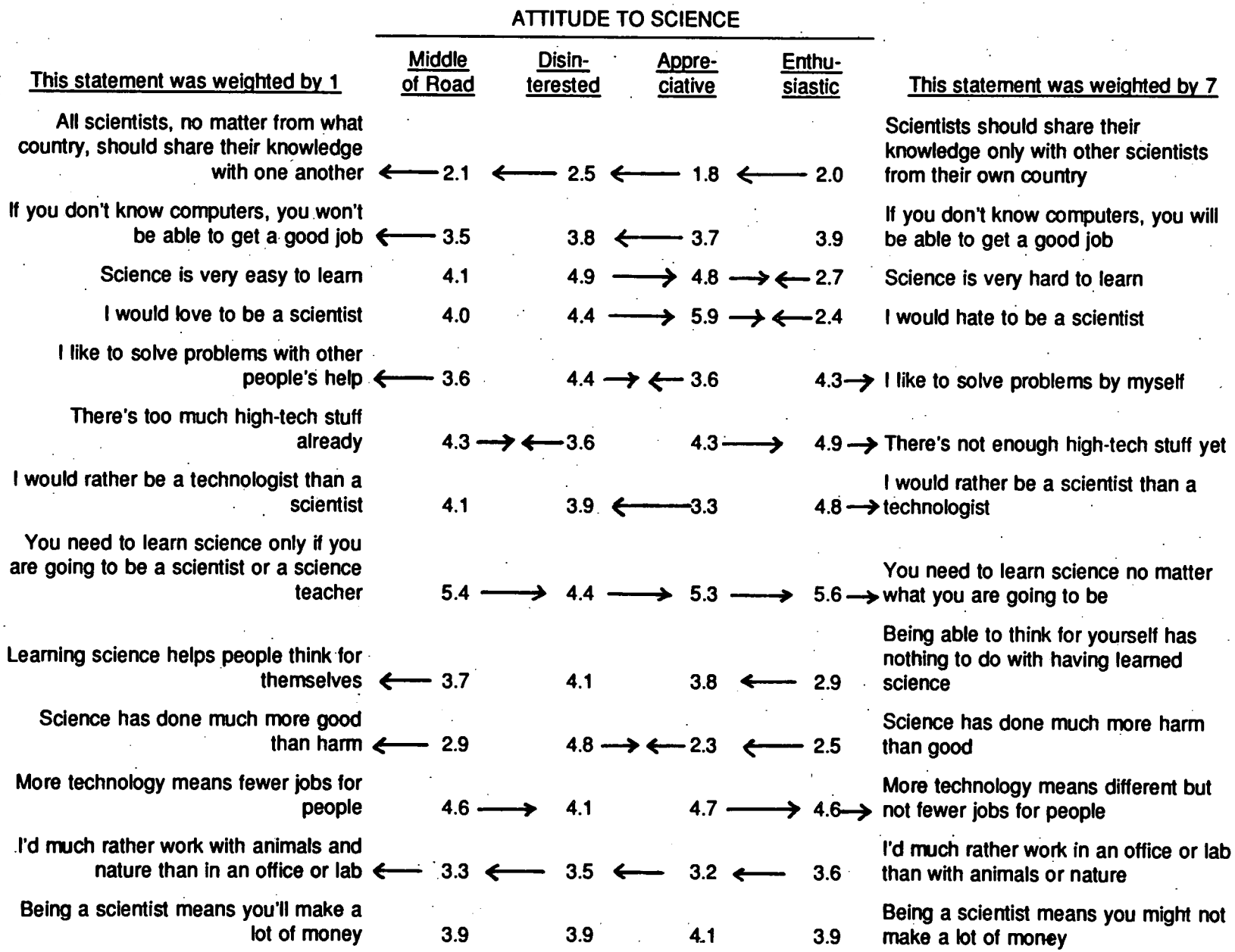
		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total analyzed (100%)	665	319	77	127	142
	%	%	%	%	%
Learning the steps of the scientific method is good for doing science and for solving problems in daily life	61	62	39	58	70
Learning the steps of the scientific method is good only for doing science and not for solving problems in daily life	15	17	14	17	8
Learning the steps of the scientific method is a waste of time as it serves no useful purpose in science or in daily life	10	10	17	13	4
Learning the steps of the scientific method may be good for solving problems in daily life, and may or may not be good for doing science	15	16	21	13	14
No answer	3	1	4	3	6

Twenty-five per cent of the disinterested in science group say that learning the steps of the scientific method is a waste of time and serves no useful purpose. All the others, however, viz, the large middle of the road group, the appreciator, or love/hate group and the science enthusiasts say, to the extent of 60% or more, that such learning is good both for doing science and for solving one's daily problems in life.

8.0 RESPONSES BY ATTITUDINAL CLUSTERS TO THE BIPOLAR STATEMENTS




ATTITUDE TO SCIENCE
This statement was weighted by 1
Middle of Road
Disin-terested
Appre-ciative
En-thusiastic
This statement was weighted by 7
New technology has had a great effect on my family's way of living
3.1
3.5
3.4
2.9
Never technology has had a little or no effect on my family's way of living
To be a good scientist you have to be a "workaholic"
4.2
3.5
4.3
4.4
To be a good scientist you don't need to be a "workaholic"
A technologist usually gets paid more than a scientist
3.8
3.9
3.9
4.0
A scientist usually gets paid more than a technologist
To do good science you have to remember a whole bunch of facts
3.9
3.4
3.8
3.8
To do good science you only have to know where to go for the information
An engineer usually gets paid more than a scientist
3.7
3.3
3.8
3.5
A scientist usually gets paid more than an engineer
Science has made life more complicated for everyone
4.7
3.5
5.2
5.4
Science has made life simpler for everyone
A science course should concentrate on making the students more concerned about the environment
2.7
3.4
2.0
2.4
A science course should not concentrate on making the students more concerned about the environment
I love working with technology
3.5
3.4
5.2
1.9
I hate working with technology
After high school, I would like to study engineering
4.8
4.3
6.8
2.8
After high school, I would not like to study engineering
It is hard for a scientist to believe in religion
5.3
5.2
5.4
5.1
Being a scientist has nothing to do with believing in religion
Knowing science does not help one in everyday life
5.1
3.3
5.4
5.8
Knowing science does help one in everyday life
The environment cannot be cleaned up without the help of science
2.9
3.0
2.9
2.7
The environment can be cleaned up without the help of science


ATTITUDE TO SCIENCE
Middle of Road
Disin-terested
Appre-ciative
Enthu-siastic
This statement was weighted by 1
This statement was weighted by 7
All scientists, no matter from what country, should share their knowledge with one another
2.1
2.5
1.8
2.0
Scientists should share their knowledge only with other scientists from their own country
If you don't know computers, you won't be able to get a good job
3.5
3.8
3.7
3.9
If you don't know computers, you will be able to get a good job
Science is very easy to learn
4.1
4.9
4.8
2.7
Science is very hard to learn
I would love to be a scientist
4.0
4.4
5.9
2.4
I would hate to be a scientist
I like to solve problems with other people's help
3.6
4.4
3.6
4.3
I like to solve problems by myself
There's too much high-tech stuff already
4.3
3.6
4.3
4.9
There's not enough high-tech stuff yet
I would rather be a technologist than a scientist
4.1
3.9
3.3
4.8
I would rather be a scientist than a technologist
You need to learn science only if you are going to be a scientist or a science teacher
5.4
4.4
5.3
5.6
You need to learn science no matter what you are going to be
Learning science helps people think for themselves
3.7
4.1
3.8
2.9
Being able to think for yourself has nothing to do with having learned science
Science has done much more good than harm
2.9
4.8
2.3
2.5
Science has done much more harm than good
More technology means fewer jobs for people
4.6
4.1
4.7
4.6
More technology means different but not fewer jobs for people
I'd much rather work with animals and nature than in an office or lab
3.3
3.5
3.2
3.6
I'd much rather work in an office or lab than with animals or nature
Being a scientist means you'll make a lot of money
3.9
3.9
4.1
3.9
Being a scientist means you might not make a lot of money

ATTITUDE TO SCIENCE

This statement was weighted by 1	Middle of Road	Disinterested	Appreciative	Enthusiastic	This statement was weighted by 7
I love to read books that make me think	← 3.0	4.0	4.2	← 1.6	I love to read books that don't make me think
After high school I would like to study technology at a community college	4.4 →	4.6 →	5.7 →	3.8	After high school I would not like to study technology at a community college
I love to find out how things work	← 2.3	4.3 →←	3.3	← 1.4	As long as things work, I don't care how they do it
Science is important for everything in daily life	← 2.7	4.4 →←	3.1	← 1.9	Science has nothing to do with anything in daily life
People who choose jobs in technology are smarter than people who choose jobs in science	4.2	4.5 →	4.1	4.2	People who choose jobs in science are smarter than people who choose jobs in technology
You have to be a genius to be a scientist	4.9 →	4.4 →	4.9 →	5.1 →	You don't have to be a genius to be a scientist
Scientists have feelings	← 1.7	4.8 →←	1.6	← 1.4	Scientists have no feelings
Being an engineer means you might not make a lot of money	4.7 →	4.1	4.9 →	4.8 →	Being an engineer means you'll make a lot of money
Canada needs to have more scientists and engineers	← 3.0	4.4 →←	2.9	← 2.1	Canada already has too many scientists and engineers
You have to have learned science to get a good job	3.9	4.2	4.5	3.6	You don't have to have learned science to get a good job
Science is a very personal thing	4.9 →	4.1	5.8 →	4.9 →	Science is not a very personal thing
Scientists are just as creative as artists	← 3.0	3.9 ←	3.6	← 2.4	Artists are creative, scientists aren't
Community colleges are not as good as universities for someone who wants a good job	← 3.3	3.8 ←	2.5	← 3.2	Universities are not as good as community colleges for someone who wants a good job

9.0 THE DEMOGRAPHICS OF THE FOUR "ATTITUDE TO SCIENCE" CLUSTERS

TABLE 1

SEX OF STUDENT

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total clustered (100%)	1335	623	169	275	268
	%	%	%	%	%
Male	52	54	65	30	59
Female	47	45	33	67	39
Not stated	2	1	2	3	2

Overall in the sample the male : female ratio is 53 : 47. The middle of the road group matches this ratio. When we look at the other groups, however, we see the disinterested in science being 66 : 34 and the science enthusiasts being 60 : 40, both in favour of males. The science appreciators, those who dislike having any "hands on" dealings with science but appreciate what science has achieved, comprise 69% female and 31% male. (The percentages have been recalculated on those answering this question).

TABLE 2

LANGUAGE OF STUDENT'S EDUCATION

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total clustered (100%)	1335	623	169	275	268
	%	%	%	%	%
English	68	70	67	68	66
French	32	30	33	32	34

The language of instruction shows little influence on the students' attitudes towards science.

TABLE 3

AGE OF STUDENT

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total clustered (100%)	1335	623	169	275	268
	%	%	%	%	%
15 or less	32	31	28	37	31
16	24	25	25	26	19
17	25	25	22	23	27
18	14	14	14	11	16
19 or more	4	4	6	2	5
Not stated	2	2	4	1	2
Mean age	16	16	16	16	16

The age distribution of each attitudinal group shows no appreciable difference from the other groups nor, therefore, from the distribution of the total sample.

TABLE 4

GRADE AND SCIENCE LEVEL OF STUDENT

	ATTITUDE TO SCIENCE				
	Total	Middle of Road	Disin-terested	Appre-ciative	Enthu-siastic
Total clustered (100%)	1335	623	169	275	268
	%	%	%	%	%
Grade 10					
- basic	7	6	11	6	5
	21	18	39	24	12
- general	14	12	28	18	7
- advanced	33	33	21	38	33
Grade 12					
- basic	5	4	5	5	6
- general	12	13	15	10	10
- advanced	30	31	18	23	39

Again we see the middle of the road group mirroring the total sample. Among the disinterested group there is a disproportionately higher number of grade 10 general students, and it is not surprising that we see disproportionately lower numbers at both advanced levels. The appreciators do not differ greatly from the total in their grade/level distribution. In the enthusiast group however we find - again this will not surprise the reader - a lower than overall representation in the basic and general grade 10 programs combined, and a higher than overall representation in the advanced grade 12 program.

TABLE 5

TYPE OF SCHOOL ATTENDED

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total clustered (100%)	1335	623	169	275	268
	%	%	%	%	%
Public	62	61	69	59	59
Separate	38	39	31	39	41

The type of school attended has little bearing on the students' attitudes towards science.

TABLE 6

DENSITY OF POPULATION

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total clustered (100%)	1335	623	169	275	268
	%	%	%	%	%
1,000,000 plus (Toronto)	18	19	18	13	23
500,000 - 999,999	15	14	15	18	10
100,000 - 499,999	24	19	32	30	25
30,000 - 99,999	14	14	15	15	11
10,000 - 29,999	3	3	2	1	3
Under 10,000	19	24	12	12	19
Rural	8	7	5	11	9

The four groups do not deviate to any extent from the total sample, so it is safe to say that the size of town in which the school is located also has little or no bearing on the students' attitudes towards science.

TABLE 7

ONTARIO REGION OF SCHOOL

		ATTITUDE TO SCIENCE			
	Total	Middle of road	Disin-terested	Appre-ciative	En-thusiastic
Total clustered (100%)	1335	623	169	275	268
	%	%	%	%	%
Central	43	44	49	43	40
Eastern	19	18	15	21	21
Mid-northern	5	4	7	7	6
North-eastern	12	13	7	10	13
North-western	5	6	5	4	4
Western	15	15	17	15	15

The region in which the student is educated and, presumably therefore, lives, appears not to shape students attitudes towards science.

10.0 DISCUSSION

In order to use the questionnaire effectively, a discussion of the answers to the "knowledge statements" is useful. The following discussion is presented as a guide for those who will be using, or adapting, the questionnaire in the future.

10.1 The Knowledge Statements

The 29 "knowledge statements" in the questionnaire were adapted from VOSTS items. Just as the VOSTS items themselves do not have "correct" answers, but measure different beliefs about STS issues, so these questions have various "correct" answers. In the following analysis, a "correct" answer means the one that is closest to the accepted views within the STS literature. In some cases, there are more than one answer that reflect, at least in part, the established wisdom in STS scholarship. In these cases, the answers may be ranked as "more correct" and "correct".

The item numbering corresponds to the numbering used in sections 5 and 6.

Item 1. "Science is a group of people (scientists) and what they believe."

This answer reflects the view of sociologists of science, who maintain that science is defined by community goals rather than by an absolute measure of what is true. The fact that very few students (<5%) chose this option reflects the fact that this view of science is relatively new, and is probably not taught in the classroom. In the STS context, this is the most "correct" answer.

The answer "explaining the unknown" reflects an understanding of science as a process of discovery. It is a notion of science that is prevalent in the teaching of science and in the history of science. Science is often presented as a succession of discoveries" (hence explaining the unknown), and the scientific method is presented as a way of arriving at discoveries. The fact that the percentage of students choosing this option increases from grade 10 to grade 12 (34% and 41%) suggests that students are being taught this view of science in school.

The answer "using what we know to make the world a better place to live in" reflects an understanding of science as "applied", without acknowledging the fact that science is often carried out simply as an activity unto itself, as a satisfying career. About one third of the students chose this option. This suggests a number of possible interpretations: that teachers are presenting science as useful to society, that students are receiving the message from policy makers and the scientific community via the media that science is useful to society, that students believe that science is useful to society.

A small percentage of students in both grades (3% in grade 10; 5% in grade 12) chose more than one option for this item. This is understandable, since more than one response can be considered applicable.

Item 2. Technology is machines and inventions as well as designing things.

This answer reflects the "correct" view that technology is also a process, a way of dealing with the world, rather than simply hardware. It is reflected in management of organizations, people and information, just as it is reflected in the design of tools. About a quarter of the students tested chose this option.

The answer "using what we know to make the world a better place to live in" reflects the progressive viewpoint that technology is the engine of progress. About a quarter of the students chose this option. It would be useful to compare this response with other questions which reflect an understanding of technology as a positive force in society, without negative influences.

The answer "how science is put to use" reflects the simple notion that technology is applied science. This view is taught by many people, and shows up as the most common response in the test. However, STS practitioners prefer not to present technology as applied science. Technology sometimes precedes science (as in the case of the steam engine and the laws of thermodynamics). Technology is also a domain unto itself, with its own pervasive influence on society, not necessarily related to science at all.

The original VOSTS item (#10211-see Appendix C, Vol I) from which this was adapted contained many more subtleties. It may be useful to add one other element that was not included in the simplified version. This is the definition of technology that includes organizing people. The following is a revision of this item that includes this element. It also separates the "machines and inventions" option from the designing things option.

Technology is
- how science is put to use
- using what we know to make the world a better place to live in
- machines and inventions
- ways of designing and manufacturing things, and of organizing people

Item 3. "Who should decide what types of energy Canada will use in the future?

"Everybody should be involved..."

This answer is the "correct" answer, and was chosen by 60% or more of the students. It reflects the understanding that there are many stakeholders involved in social decision-making. Scientists and engineers are technical experts, and should be involved in the decision-making process. However, there are social costs and benefits that go beyond the technical issues, and so the technical experts must not be relied upon solely in the decision-making process.

The answer that "scientists and engineers should decide" reflects a complete reliance of technical experts for advice and decisions. In both grades, a third of the students chose either this option or the one that people other than scientists or engineers should decide. It is interesting that twice as many grade 12 students chose the "scientists and engineers should decide" option than the option that excludes the technical experts. In grade 10, the percentages were roughly equal. This suggests that as science students progress through the school system, an increasing minority of them believe that technical scientific and engineering expertise has a primacy over other kinds of expertise for deciding certain issues in society - presumably ones that include a technical component, such as energy options.

Item 4. "We have to accept both the good and the bad effects of technology, because every new development has at least one bad effect, and to enjoy the good ones we have to put up with the bad ones."

This is the "correct" answer. It reflects an understanding that there are costs and benefits associated with technology. In deciding whether or not to use technology, the costs and the benefits must be weighed against each other. 37% of the students tested chose this option.

The answer, 'we don't have to accept the bad effects of technology, because bad effects can be reduced or removed through careful planning and testing" reflects the technological optimism associated with the term technological fix. This philosophy is criticized in the STS literature, in that it assumes that there is always a technological solution to technologically induced societal problems. The fact that half the students in both grade levels opted for this option suggests that technological optimism is prevalent among these students. Whether it comes via television and the general culture, or via the school system, cannot be determined. Correlations with other items related to this issue would be interesting.[1]

The answer, "we don't have to accept the bad effects of technology, because some new developments have no bad effects and we should use those ones only" presents the "incorrect" position that some technology can be used in society with no tradeoffs. This view was chosen by less than 15% of the students.

More francophone students than anglophone believe that we have to accept trade-offs, whereas more anglophone students than francophone students believe that technological solutions can be found to alleviate the bad effects of technology.

The original VOSTS item did not deal with the issue of whether or not we have to accept trade-offs, only whether or not (and why) trade-offs exist. Teachers may want to separate these two issues into different items. The trade-off item could be phrased as follows:

- Technology always has good and bad effects, because every new development, no matter how many good effects it has, also has at least one bad effect that cannot be reduced or removed.

- Technology always has good and bad effects, but bad effects can be reduced or removed through careful planning and testing.

- Technology can have good effects and no bad effects, because some new developments have no bad effects.

The issue of acceptance or non-acceptance of trade-offs can be handled as follows:

- We have to accept both good and bad effects of technology, because all developments have both, and the only way we can enjoy the good effects is to accept the bad ones.

- We do not have to accept bad effects of technology, because enough careful planning and testing can reduce or remove bad effects of technology.

- We do not have to accept bad effects of technology, because not all technology has bad effects, and we need choose only technology that has no bad effects.

Item 5. This item is related to item 4, but attacks the issue using a specific issue - pollution. The "correct" answer is "Science and technology alone cannot solve problems caused by pollution".

The third option ("Science and technology can solve problems caused by pollution, because science and technology have been successful in solving problems in the past") is the "technological optimism" answer.

It is interesting that in the specific case of pollution, more than half the students in both grades chose the "correct" option that admits the limitations of science and technology, while about one third chose the "technological optimism" answer. For the general case in item 4 the situation is reversed, with about half picking the technological optimism response, and slightly over a third choosing the option that accepts the cost/benefit equation for technology.

This variation between general and specific cases is important. Students will often have different views when faced with a concrete example, as opposed to a generalization.[2] The results for items 4 and 5 suggest that students have more faith in technology generally, but are less sanguine about technological solutions to pollution problems.

However, there are slight differences between the way the "technological optimism" option is phrased in items 4 and 5. In item 4, the statement is that "bad effects reduced". In item 5, it is that "science and technology have been successful in solving problems in the past". A student who believes in principle that bad effects can be reduced may not believe that pollution problems have been solved in the past. This may be the reason for the difference in responses we found in the pilot. In order to make correlations between these two items more meaningful, teachers may try using either of the two forms in a parallel way. These forms would be:

Item 4. we don't have to accept the bad effects of technology, because bad effects can be reduced or removed through careful planning and testing

Item 5. Science and technology can solve problems caused by pollution, because science and technology can reduce or remove problems through careful planning and testing

and

Item 4. we don't have to accept the bad effects of technology, because science and technology have been successful in solving problems in the past

Item 5. Science and technology can solve problems caused by pollution, because science and technology have been successful in solving problems in the past

In future applications of this questionnaire, teachers may want to revise these items in this way.

Item 6. "Women scientists might make different discoveries from those made by men scientists, because women have different feelings and experiences from men."

This is the "correct" answer, according to most STS scholars who have studied the professional scientific research community, especially in the behavioural sciences. For example, theories of animal behaviour developed during the 1950s by male researchers observing primates in the field focussed on aggression in males. A decade later, female researchers like Jane Goodall and others observed cooperative behaviour among male primates. Other examples have been found by historians of science that suggest there can be differences in observational emphasis and related theory construction among male and female scientific researchers.

This issue is particularly sensitive, because it might suggest to some students that if male and female scientists are different, then one's science might be better than the other's. The issue, however, has more to do with the relative nature of scientific knowledge, than sex equity. Nonetheless, students predominantly answered that gender makes no difference in what scientists find in the natural world.

That the issue is perceived by students as a sex equity issue is reinforced by the comparison between male and female student responses. While the aggregate response in favour of no gender difference was 70%, 60% of male students chose this option compared with 80% of the female students.

Item 7. There is really no "correct" answer to this one, since it asks students about how they may or may not use science when they shop. This question monitors several issues at once- influence of scientific reasoning, scientific facts and the media on consumer habits.

The ratio of students answering in favour of science to those favouring the media increases from grade 10 to grade 12. It would be interesting to verify in a future study, whether students rely less on the media as they learn more science.

Item 8. This question attempts to measure student perception of the influence of the media on their understanding of science. There is no "correct" answer here. Presumably, if there existed a cornucopia of excellent sit-coms, soap operas, other dramas and documentaries on television, and films and videos that portrayed the lives of working scientists, then students might perceive the media as giving them a better picture of science than did their science classes. An

interesting variation of this item would be to pose the possibility of good media productions on the world of science and scientists, and ask students to compare their imagined media with what they learn in science classes.

Item 9. "Most scientists are doing science because they want to be looked up to by other scientists." (Option 4)

This is the "correct" answer, though phrased in a very simplified way. According to sociologists of science, the scientific community has its own internal norms of behaviour, and scientists are primarily motivated by peer approval. Peer recognition is the highest achievement. This social definition of what motivates individual scientists is difficult to express simply. Therefore, a large number of students will probably not select this option. However, if the teaching of STS issues, especially the dynamics of the scientific community, continues to develop, one might expect the percentage of responses for this option to increase over the years.

The response (option 3) "because they want to help people by finding new medical cures and solutions to environmental problems and by new inventions" is a combination of the applied science view and the technological optimist view. It also reflects a commonly heard justification for funding of scientific research on the basis of economic benefit and social progress. It is not surprising to see the majority of students (two thirds in both grades) selecting this response.

Option 1 ("to satisfy their own curiosity about the world around them") presents the picture of a scientist as the seeker of fundamental truths, and the pure research ethic. One might expect that students, as they grow older and learn more about the economic benefits of science, might choose option 3 more than option 1. It would be particularly interesting to try this item on younger students, to see if the ratio is significantly different from grades 10 and 12.

Item 10. This question deals with the importance of research and development for the economy. The first option (If Canada spent more money on research in science and technology Canada would become a wealthier country") might be considered "correct" in that it maintains that R&D are important for the economy.

However, the second "it depends" option is "more correct". (...Canada might or might not become a wealthier country. It would depend on what science and technology were chosen.") It reflects the fact that some research will not lead to wealth, whereas other research might. Spending money on research may lead to other benefits for a country than mere wealth. It leads to jobs, indigenous expertise and so on.

The fact that the ratio of students choosing option 1 to those choosing option 2 increases with grade level is interesting. It suggests that more of the older students believe that research is important for the economy than their younger counterparts.

Twice as many males as females chose the "Canada would become wealthier" option, while more females than males chose the "it depends" statement.

Item 11. "There are more men scientists than women scientists today because until recently people used to believe that boys were better at science and that girls were better at other things, so more boys than girls made science their career."

This is the correct answer, and most of the students chose it. Nonetheless, the 20% who believe that boys are more interested in science than girls represents a rather large fraction of the test population. More francophones than anglophones chose this option.

Item 12. "Scientists who work for a profit-making company: some put doing the best science they can first; others put the company's interests first."

This is the "correct" answer, although in the context of this question item it may be serving as a "fence-sitting" option. In the STS context, the important point is that motivations for doing science are complex. Peer recognition is paramount, and scientists in industry will place this first if they can. However, there is an inherent tension between the scientist's desire to publish results immediately and the company's need to patent discoveries first before making the results widely available - if at all. Some scientists in industry are primarily motivated to help the company, and do not seek rewards from the larger scientific community. In certain situations, for example when company scientists are asked to present evidence regarding controversial issues (such as pollution levels generated at a plant), they may put the company's interests first. This reality is apparent when, for example, chemists hired by a company and an environmental group give opposing evidence, based on the same education in chemistry. In these instances, option 1 ("tend to put the company's interests ahead of doing the best science they can") is "correct".

Forty percent of the students opted for either the option that scientists in industry put their company first, or that scientists in industry put science first. Interestingly, while the overall breakdown was fifty-fifty, more males than females opted for the first option (put company's interests ahead of doing best science). More females chose the "it depends" option.

More males than females also thought that Canada would become wealthier if more money were invested in research in science and technology (question 10). More females than males chose the "it depends" statement in question 10 as well.

Item 13. "When scientists are deciding whether or not to accept a theory, they sometimes accept it for other reasons that have nothing to do with how well it compares with other theories or how well it explains the facts." (Option 3)

This is the "most correct" answer. Case studies in the history of science show that protagonists in scientific debates about the validity of theories have a wide range of motivations for their positions. Some are carving a name for themselves, others are trying to preserve their own value within the discipline, some are motivated by personal hostilities, and so on. During war time, debates are often carried out on ideological lines, having little to do with scientific considerations at all.

Option 2 ("they look at the facts and the theory. If a theory is simpler and/or more logical than other theories, they may accept it even if all the facts are not explained") is also a "correct" response.

It addresses the fact that scientists strive to find theories that are simple, elegant and explain many phenomena with a small number of principles. While scientists use experiments to test theories, historians of science have found many cases where scientists reject results of one experiment (claiming that some experimental error has been made) simply because the theory is too satisfying to reject prematurely on the basis of one experimental result. However, this is a contentious issue within the scientific community, and the source of many of the debates that

rage about whether or not to accept a theory. Experimental scientists tend to rely heavily on test results.

Theoreticians look at the larger picture, and often suspend judgment even in the face of apparently definitive experimental results. It is in this context that the complex range of motivations that spur on scientific debates arise, and hence the "more correct" status of the third option. Scientific reputations, and the related support (both institutionally and financially) are often at stake, and personal motivations take hold.

About half of both student populations (grades 10 and 12) chose the first option ("they look only at the facts. If the theory explains the facts, they accept it. If the theory cannot explain even just one fact, they do not accept the theory.") This suggests that students are being taught that scientific knowledge is solely based upon fact, and that experimental results determine whether or not theories are accepted. This empirical basis for scientific knowledge is an important characteristic of the science research enterprise. However, it becomes too simplistic when one looks at the way the scientific community truly operates. A more sophisticated view of scientists and how they function as a community includes not only the importance of empirical observation and experiment, but also includes the nature of scientific theories, the personal motivations of individual scientists, and the institutional context in which they work.

In both grades, the percentage of students choosing option 1 ("scientists only look at the facts") was highest in the advanced level science programs. In grade 12, a larger percentage of students in separate schools chose this option than in public schools.

Item 14. This question looks at the relationship between national cultures and scientific knowledge. It is similar to question 6, which looks at the relationship between gender and scientific knowledge.

The ideological stance or "party line" within established science is option 2: "Scientists are taught to look at scientific problems in the same way, no matter what countries the scientists are from, because science is the same all over the world." The view expressed here is that science is universal, international and objective. In fact, science is influenced by societal contexts, just as is any human enterprise.

The first option, "Scientists trained in one country look at scientific problems in different ways from scientists trained in another country, because their education and way of life are different", is "correct" to the extent that it recognizes cultural influences on the conduct of science. The scholarly literature on acceptance of theories within different cultures, and the use of science and technology education and research as tools for cultural and economic imperialism, explore some of these issues.

The third option, "Any two scientists may look at scientific problems differently. The country where they come from makes no difference" recognizes personal (hence psychological) differences among scientists, but does not acknowledge cultural influences on individual psychology. In both grades, most students chose this option, with a larger percentage of students in the advanced level programs choosing it than in the basic and general programs.

The fact that most students chose this option suggests that students believe that the country a scientist comes from has no bearing on the way he or she practices science. Another possible interpretation, however, is that students were expressing their belief in cultural equality, or the fact

that no matter where people come from, they are equal within society. This would explain their choice of the option that maintains that individuals have equally valid ways of looking at a scientific problem. The fact that in both grades more females chose this option than males also suggests the possibility that the "equity" issue was foremost in students' minds.

Since option 3 is shorter and more succinct than the first two options, students may have understood it more clearly. The following simplification of the options in this item is therefore recommended:

Two scientists from different countries may look at scientific problems differently, because their education and way of life are different.

Two scientists from different countries may look at scientific problems differently, because any two people are different, but the country where they come from makes no difference.

Two scientists from different countries will look at scientific problems in the same way, because science is the same all over the world.

Item 15. "If a new technology will do more harm than good to society, it will not be used." This is the idealist view of technology use, and the closest to being "incorrect". However, in specific cases, and in some communities, it is a principle that is strongly adhered to in practice. Therefore, it is interesting to monitor how many students choose this option. In both grades, roughly 30% chose it, and this percentage is roughly consistent in all subgroups.

The other two options state that the technology will be used even if it does harm to society. Option 2 presents an economic argument (efficiency and low-cost), while option 3 presents a social argument (people will benefit). The largest number of students in both grades opted for #3. In grade 10, twice as many students selected #3 as did #2, while in grade 12 this ratio increased to three times as many. In grade 12, more anglophones than francophones chose this option.

Item 16. This item tries to determine student understanding of scientific models and their relationship to reality. The current thinking about scientific models is that they are analogies that help scientists understand the way nature works. So, for example, the wave theory of light, or the particle theory of light, or the wave-particle model of light, use waves and particles to understand the behaviour of light. It does not mean, however, that light is necessarily a wave or a particle.

Some scientists do, nevertheless, present their models as if they are real. For instance, scientists in the 19th century presented light as a wave undulating in the ether. The ether, to them, was real and many scientific papers were written describing the properties of this ether. The ether concept was rejected in the 20th century, but some physicists had difficulty letting go of the concept.

"A scientific model is not like the real thing, but is useful for explaining the real thing" is the "correct" answer. (Option 3)

"A scientific model is a copy of the real thing" is the "incorrect" answer. (Option 1)

About half the students choose option 3. More grade 12 students chose option 3 than did students in grade 10. The percentage differences are not large enough for the number of students tested to conclude this difference definitively.

In grade 12, a higher percentage of students in the advanced level programs chose option 3. Also in grade 12, a higher percentage of anglophone students chose this option than did francophone students.

Item 17. This item looks at how scientific knowledge changes. It relates to item #13, which examines what makes scientists decide whether or not to accept a theory.

Option 2 ("Scientific knowledge can change only if new research proves earlier research to be wrong") presents the view that science is built on a solid empirical foundation, and only new experimental evidence can cause scientists to change a theory.

Option 3 ("Scientific knowledge can change if earlier research is looked at in a different way") presents the more sophisticated view presented by scholars such as Thomas Kuhn. Kuhn maintains that scientists work within a paradigm that defines the larger conceptual framework in which to interpret experimental evidence. If the paradigm changes, old evidence can be interpreted differently.

Within the scientific community itself, there are often debates as to whether or not scientific knowledge can change without new experimental evidence. The common "ideology" is the empirical one, that states the primacy of experimental evidence. However, history of science is full of examples where theories have changed on the basis of larger, theoretical issues.

More than half the students chose option 2, which suggests that the empirical view of science is dominant in their science education. In grade 10, a larger percentage of students in the advanced level program chose this option. There are indications that in grade 12, a higher percentage of students in the general level programs than in the advanced level programs chose this option. However, the population size at the general level is too small to be definitive. In grade 12, more males chose this option than did females, as did more francophones than anglophones.

Item 18. "The best scientists always follow the steps of the scientific method" is the answer that one might expect most students to choose, since they are taught the steps of the scientific method very thoroughly. Less than half did in fact choose this option. This suggests that students are beginning to appreciate that doing real science does not always mean following a rigid procedure, even though reporting of results may follow a standard presentation.

More francophone students chose this option than did anglophone students. This result is consistent with the larger percentage of grade 12 francophone students choosing option 1 in question 13, options 1 and 2 in question 16, and option 2 in question 17, all of which reflect the more empirical view of scientific knowledge.

The answer "The best scientists sometimes do and sometimes do not follow the steps of the scientific method" received about half of the student responses. This answer is "more correct", since it presents the view that scientists do not always follow the standard recipe we call the 'scientific method' in performing their research.

The answer "The best scientists never follow the steps of the scientific method. They are clever enough so they don't need to" received the least number of responses. In fact, the great scientists have not followed the classic steps of the scientific method at all, even though their scientific publications are presented in the standard format. The word "never" may have steered students away from this option; but the fact that more than half chose the second option (sometimes do, sometimes don't) rather than the first (always) is a significant result.[3]

NOTE: In this option, the word "clever" could be replaced with the word "creative", which would be more consistent with the original VOSTS item. This option would then read: "The best scientists never follow the steps of the scientific method. They are creative enough so they don't need to". Teachers may want to try it separately with both words, to see if there is a difference.

Item 19. This item relates to the previous item. The "scientific method" is often taught to students in the context of how they write about the results of an experiment they have performed. In the real world of science research, scientists often do not perform their work in the same way that they report it.

The "correct" answer is "they do their work in an organized way, but not in the same order in which they write about it". While the statement does not carry all the nuances that accurately describe the situation, it is considered close enough to be useful.

Scientists often do not do their work in a very organized way, sometimes groping blindly in the dark, trying this and then that, before any clear picture emerges of where they are going. The third option tries to reflect this situation, and is "more correct" in the STS context. However, the word "usually" is perhaps too strong.

The following revision to this item might be useful:

"they also do their work in an organized way, and in the same order in which they write about it"

"they do their work in an organized way, but quite often not in the same order in which they write about it"

"they quite often do not do their work in an organized way at all, even though they write about it in an organized way"

Another recommended change to this item is to replace the word "organized" with "logical". This more closely relates to the original VOSTS item, but "logical" was changed to a word that younger students would definitely understand. Teachers might want to try the item with the word "logical" if they think their students are sufficiently familiar with its meaning.

It is significant that over 60% of the students chose the first response (the simplistic view of scientific method). This suggests that they understand the conduct of scientific research very narrowly in terms of the classic steps of the scientific method. Exposure to some examples from the history of science about how actual scientists carried out their research, and debated the results, would be a useful part of their science education. Contact with practicing scientists willing to discuss the nature of their research also would be useful.

The fact that a higher percentage of francophone students chose option 1 than did anglophone students is consistent with the results in other items pertaining to the nature of science and scientific research. It is also interesting that the simplistic view of scientific method was chosen by a higher percentage of students in areas of smaller population density. Students living within larger population densities may have more contact with working scientists, or teachers who have had this contact.

Item 20. This item concerns a) the importance of serendipity in scientific research, and b) the way that scientific knowledge progresses.

Option 2 ("Scientific mistakes sometimes lead to new discoveries and therefore science progresses") is the "correct" answer. The vast majority of students chose this option. Most probably they chose it because they understand that mistakes sometimes lead to new discoveries. Implicit in this option is also the notion that science does not progress incrementally by building on previous work, that flashes of insight and accidental discoveries occur regularly.

Option 3 ("Finding and correcting scientific mistakes is the only way science progresses") presents the incremental view of science. It is a view that is held by some practicing scientists and philosophers of science, but one that is increasingly becoming marginal. It is consistent with the belief that science progresses only through experimental confirmation of empirical facts, rather than also building up theories from principle.

About a quarter of students chose this response. This is consistent with an emphasis on the laboratory and empirical side of science. The percentage of students selecting this option seems to decrease in the advanced level programs.

Item 21. "Even with accurate information, scientists and engineers can tell us only what will probably happen, not what will definitely happen." This is the "correct" response. It highlights the fact that predictions are never 100% certain. Over half of the students in both grades chose this option, with a larger percentage of students in the advanced level choosing it.

"Scientists and engineers can tell us what will definitely happen if they have enough accurate information."

This option was chosen by about a third of the students. At both grade levels, more males than females believe in the ability of science and engineering to predict events definitely, given sufficient information. More francophone students than anglophones exhibit greater faith in scientists and engineers to predict events with certainty, especially at the grade 12 level.

Item 22. "If scientists find that people working with a certain material have twice as much chance of getting lung cancer as do other people: this does not necessarily mean that the material causes lung cancer. However, more research should be done before the material is used again."

This is the "correct" response to this item. This item deals with two issues at the same time, a) whether the scientific evidence definitely proves a link between the material and lung cancer, and b) whether or not the material should stop being used, in face of the evidence. The "correct" answer recognizes that the causal relationship is not certain, but also that the evidence is strong enough to warrant action to protect the safety of workers. Most students (over 65% in both

grades) chose this option, with more students in the advanced level program than in the other levels making this choice. More females made this choice in both grades.

The answer "this does not necessarily mean that the material causes lung cancer and it could still be used" received less than 10% of the responses. Among grade 10 students, however, 1 in 10 of the males made this choice, compared with only 1 in 20 of the females.

The answer "this means that the material causes lung cancer and it should not be used" was chosen by almost one quarter of the students in both grades. More males chose this option than did females in both grades.

Item 23. This item relates to item #2, and produced similar responses.

Over two thirds of the students in both grades chose the response "Science is needed in order to invent new technology." In item #2, the most common response was "technology is how science is put to use". These responses suggest that students believe that technology is equivalent to applied science, a view that is commonly taught in schools and in post-secondary institutions.

The "correct" response for this item is "New technology can be invented without science". Only about 1 in 10 students chose this option in both grades.

Item 24. "Good scientists almost always use reference materials to look up information when they need it." This is the "correct" response to this item. It presents the picture of scientists using resource materials to look up factual information, rather than memorizing it. More than half the students chose this option, with most of the rest choosing the "fence-sitter" option "often". Less than 10% of all students chose the "rarely" option.

Item 25. "Members of Parliament need to know about science and technology in order to make good decisions about Canada's future." A strong majority of students chose this "correct" option. In both grades, a larger percentaje of females than males did so.

Roughly 20% of the students chose one of two options stating that members of Parliament do <u>not</u> need to know anything about science and technology. One reason was that the politicians could rely on scientists and engineers, and the other choice was that science and technology has nothing to do with politicians' work. Interestingly, 2 to 3 times as many of these students felt that the reason was that politicians could rely on scientists and engineers" option.

Item 26. This item is quite different from the original VOSTS item (#40421). The VOSTS item tried to measure students' views about weather or not knowledge about science and technology helps them in solving problems in daily life. The phrasing for this simplified item explores whether or not students make any connection between everyday problem-solving, and doing science.

Option 2 ("When you solve a problem in daily life sometimes you are doing science and sometimes not. It depends on the type of problem") received the majority of responses. In grade 10, more females (79%) than males (62%) chose this option. In both grades, a higher percentage of students in advanced level programs chose this option. In grade 12, the highest proportion of students choosing this option were from regions with a small population density.

One in six of the students in both grades believes that "when you solve a problem in daily life you are doing science". Twice as many males as females in the grade 10 sample chose this option.

Ten per cent or fewer of students in either grade chose option 3 that states science has nothing to do with everyday life. We recommend that for future uses of this item, option 3 be changed to read: "When you solve a problem in daily life, you are not doing science because science has nothing to do with solving problems in daily life."

Item 27. "Science is one of many good ways of knowing something about the world. Science alone however is not enough to know all about the world."

Over 60% of both grades chose this "correct" option, with more students in the advanced level programs choosing it.

More anglophones than francophones believe that science is one of many good ways of knowing about the world. The francophones opted more for the statement that "Science is the best way of knowing about the world, even though there are other ways of knowing about it."

More females believe science is one of many good ways, while more males believe that science is the best way, or the only way.

Overall, 1 in 10 grade 10 students believe that science is the only way, while 1 in 20 grade 12 students chose this option.

Item 28. This item deals with two issues at the same time: how technology affects science and how science affects technology. It is related to items #2 and #23. The responses to these two items suggest that the majority of students believe that technology is essentially applied science - that science leads to technology.

In item #28, more than a quarter of the students chose a similar statement, option 2: "New technology can be invented only by using known scientific facts and theories." According to the STS literature on the relationship between science and technology, this statement is "incorrect", or more precisely, simplistic.

The "correct" answer in item #28 is option 3: "New technology is often invented without using scientific facts and theories." One in six of the grade 10 students chose this option, while only one in ten of the grade 12 students selected it. This suggests that as students take more science courses, they learn that science leads to technology, or that technology is essentially applied science.

There are indications in the results of item #28 that this is more the case for students in advanced level programs. In grade 10, the ratio of students selecting option 2 to those choosing option 3 remains the same for the different program levels. In grade 12, the ratio is vastly different for students in the advanced level programs. Four times as many of these students chose the "incorrect" option (2) as chose the "correct" one (3).

Another "correct" statement is option 1: "When new technology is invented, it often leads to new scientific facts and theories." This statement was selected by more than 50% of the students in both grades.

This item might more usefully be broken into two separate items, one dealing with the influence of science on technology and the other dealing with the reverse. The reason for this becomes clear when one compares the results for items 23 and 28. In #23, over two thirds of the students population chose "science is needed in order to invent new technology". Yet in #28, only somewhat more than one quarter of the student population chose "new technology can be invented only by using known scientific facts and theories". The reason for the drop in percentage was that option #1 in item 28 is also "correct", namely "when new technology is invented, it often leads to new scientific facts and theories". Over half (57%) the student population chose this option. Of those who did not choose this option, about two thirds chose the option that the invention of technology requires science, which agrees with the results for item 23.[4] These two issues should be tested separately, by building a separate item out of option 1, and a separate item out of options 2 and 3.

Suggested revised items are:

28a.
When new technology is invented, it often leads to new scientific facts and theories.

When new technology is invented, it never leads to new scientific facts and theories, because technology is the application of known scientific facts and theories.

When new technology is invented, it never leads to new scientific facts and theories, because technology and science are not related in that way.

28b.
New technology can be invented only by using known scientific facts and theories.

New technology is often invented without using scientific facts and theories.

New technology is invented by inventors, without ever using scientific facts and theories.

Item 29. "Learning the steps of the scientific method is a waste of time as it serves no useful purpose in science or in daily life."

This is the "correct" statement, although expressed in very strong terms. It reflects the reality that the steps of the scientific method as presented in school science classes has very little to do with the conduct of real scientific research. The formulaic procedure of observation, hypothesis, prediction, experimentation, conclusion rarely occurs in real scientific practice. Theoreticians often work independently from experimental scientists. Many scientists begin their work with theoretical concepts, and try to find observable effects that emerge from them. A great number of scientists are concerned with increasing scientific accuracy of measurement, with little interest in theory at all. The steps of the scientific method are a useful pedagogical tool, but a good science education moves beyond this first approximation of what science is, and explores real-world science, scientific debates and different kinds of scientific research practice. As for daily life, the steps of the scientific method are not useful. Rather the knowledge derived from a study of science can be useful, as well as the nature of scientific reasoning (cause and effect, separation of variables, experimental controls, etc.).

Ten per cent or less of students tested chose this response. About 10-15% of students in both grade are undecided ("...may be good for solving problems in daily life, and may or may not be

good for doing science"). This result reflects the fact that learning the steps of the scientific method has traditionally been a large part of science education. The utility of the steps of the scientific method has been equated to the utility of science itself, without necessarily separating the two. As STS education increases, and more real-life science is discussed, this may change.

The majority of students chose option 1: "Learning the steps of the scientific method is good for doing science and for solving problems in daily life." The percentage of students choosing this option goes up with grade level, and within each grade, a higher percentage of students in advanced level programs chose this option. This suggests that students with more advanced science education believe in the utility of the learning the steps of the scientific method for doing science and for daily life.

Roughly the same percentage of students in the various grades and program levels believe that "learning the steps of the scientific method is good only for doing science and not for solving problems in daily life."[5]

10.2 The Bipolar "Attitudinal" Statements

These statements were intended to give a measure of students' attitudes toward science and technology, and related issues. A cluster analysis was performed, and four distinct groups emerged. An analysis of these groups responses to the questionnaire is provide in section 10.3.

Correlations can be made between the attitudinal statements and the knowledge statements. For example, consider the sixth bipolar item: "To improve our quality of living, Canada should spend more on..." In both grades, the mean response is close to the middle, with a slight leaning toward favouring spending on education and welfare over science and technology. This item relates to knowledge statement #10. Here, the majority of students chose the middle option ("it depends" on what science and technology are chosen (to spend money on) whether or not Canada will become wealthier or poorer).

In the knowledge statement, twice as many males than females chose the "Canada would become wealthier" option, while more females than males chose the "it depends" option. In the bipolar item, females leaned more toward the "education and welfare" option than did males.

There are several bipolar items that measure students' attitudes towards science as they relate to daily life. More students felt that "Knowing about science will help me live a better life" than the opposite, and the same result was obtained for the more impersonal phrasing "Knowing science does help one in everyday life." This agrees with the results obtained with the more specific form used in knowledge statement #29, where the majority of students selected "Learning the steps of the scientific method is good for doing science and for solving problems in daily life."

The mean responses to the bipolar statements for grade 10 and grade 12 students were compared, to see if there were any major differences between the two grades. No differences greater then 0.6 were found. The following is a list of all differences of 0.5 or more in median response between grade 10 and grade 12.

- Grade 12 students were less inclined to dislike the detail involved in learning science than their grade 10 counterparts (0.5).

- Grade 12 students were more inclined to think that an engineer gets paid more than a scientist (0.5).

- Both student groups were more inclined to "love working with technology" than to "hate" it, but grade 12 students were more favourably inclined than grade 10 students (0.6).

- While students in both grades believed to a greater extent than not that the environment cannot be cleaned up without the help of science, grade 12 students believed this more strongly than grade 10 students (0.6).

- The mean response of all students to the question whether they would "love to" or "hate to" be a scientist was exactly in the middle. But the mean response in grade 10 leans toward "hating" while the response for grade 12 leans equally toward "loving". This suggests an increased appreciation of science at the higher grade level. (Spread was 0.6).

- Grade 12 students were more inclined to believe that learning science helps people think for themselves than were grade 10 students (0.5).

- Grade 12 students were less strongly against the idea of studying technology at a community college after high school than were grade 10 students (0.5).

- Both students groups believed that Canada needs to have more scientists and engineers, but grade 12 students believed so more strongly (0.5).

Most of the differences indicate that the older students are slightly more favorably inclined toward science and technology than are the younger group.

Much greater differences emerged when comparing male and female responses.

- Male and female students were more inclined to believe that women scientists are no more aggressive than other women, but female students believed this much more strongly (0.9).

- Both male and female students were more likely to be interested in people than technology, but females much more so than males (0.9).

- Male students' mean response whether or not they would like to study technology at a university after high school was right in the middle. Female students definitely tended not to want to do so (0.8).

- Male students felt more strongly that new technology has had a great effect on their family's way of living than did female students (0.6).

- Female students were more inclined than were male students to believe that to be a good scientist you don't need to be a "workaholic" (0.5)

- A dramatic difference appeared regarding technology. Male students were inclined to love working with technology, while female students edged into saying they hate doing so (1.2).

- Both male and female students tended not to want to study engineering after high school, but female students very much more so than male students (1.1).

- Female students were more inclined to enjoy solving problems with other people's help, while male students tended to be neutral or like solving problems by themselves (0.5).

- Male students tended to believe there is not enough high-tech stuff yet, but female students were neutral (0.5).

- Female students were more likely to prefer being a scientist to being a technologist, while male students were neutral or even the opposite (0.6).

- Neither male nor female students were inclined to want to study technology at a community college after high school, but female students were much more definite about this (0.8).

- Both male and female students tended to say they love to find out how things work, but males selected this option more strongly than did females (0.7).

The clearest message coming from these differences is that females do not like technology as much as do males (or they dislike it more than do males).

10.3. "Attitude to Science" Cluster Responses to Knowledge Statements

Only the mean responses to the bipolar "attitudes to science" questions were analyzed in section 10.2, without indicating the standard deviations. Thus a mean response of 4.1, for example, could mean that most responses were grouped around the middle; or it might mean that there was one group on one side and another roughly equal group on the other side of the issue (bi-normal distribution). The mean response alone does not indicate to what extent the more extreme positions were present.

In order to find such variations, a multivariate analysis of the responses was performed. Four distinct groups of students emerged:

- Science enthusiasts (20% of sample, 3 out of 5 male)

- Disinterested in science (13% of sample, two-thirds male)

- Science appreciators (21% of sample, more than two-thirds female)

- Middle of the road (47% of sample, equal male-female)

The "science enthusiasts" group probably represents the students who are enrolled in science because they intend to go on to pursue careers in science, technology or engineering.

The "science appreciator" group is mostly female, which correlates with the analysis of the major male-female differences in mean response to the bipolar statements. There we found that the female students disliked technology much more than did the male students. Interestingly, this

group seems to enjoy the fruits of science and technology, while not wanting anything to do with actually working in science and technology.

The existence of a "disinterested in science" group is significant when one realizes that the sample population was drawn from science students. These are senior high school students who are taking science as an option - yet they strongly dislike science. This fact suggests that these students are in science class for reasons other than an interest in science - perhaps because science is perceived to be a prerequisite for other things.

The following discussion outlines some of the differences among the groups that emerged from their answers to the knowledge statements. The discussion is based on the results presented in section 7.

Only one quarter of the "disinterested" group defined technology as "how science is put to use", compared with a third or more of the other groups. The "disinterested" group tended more toward defining technology as "using what we know to make the world a better place to live in". It is interesting that taken together, both responses define technology as applied knowledge, with the first focusing on science and the second using the generic term "knowledge" without reference to science. Over 50% of the students chose either of these two definitions, but the "disinterested" group favoured the generic form. This view of technology as applied knowledge rather than applied science is in keeping with the disinterested group's negative view of science.

Table 2B in Section 7 compares the percentage of students in each group that chose "using what we know to make the world better" as a definition for science and technology. More students in all groups, except the "disinterested in science" group, chose this definition for science than for technology. The "disinterested" group, by contrast, chose this definition equally for both science and technology.

The two items that have to do with the relationship between science and technology (items 23 and 28)[6] also relate to these findings. The "disinterested" group tended more than did the other groups to see technology as independent from science. In item 23, fewer than half the "disinterested" group said that "science is needed in order to invent new technology", while two-thirds or more of the other three groups chose this option. Similarly, in the same item, almost four times as many of the "disinterested" group than of the "enthusiastic" group, and twice as many of the "disinterested" than of the "middle of the road" said that "new technology can be invented without science". In item 28, a very similar profile of responses was obtained for the option "new technology is often invented without using scientific facts and theories".

The "enthusiastic" group was least likely to say that technology can be invented without science, and most likely to say that science is required to invent new technology.

In deciding what types of energy Canada will use in the future (Table 3 in section 7), a similar percentage (25%) of students in the "disinterested" group and the "enthusiastic" group believed that scientists and engineers should decide. Yet twice as many of the former group than the latter believed that people other than scientists and engineers should decide. Slightly fewer of the "appreciative" group (20%) opted for scientists and engineers deciding, while more of them than the "enthusiastic" group felt that scientists and engineers should be excluded from deciding. The majority of all groups believed that everybody should be involved in deciding, although the majority was smaller in the "disinterested" group.

More than half of all groups believed that "science and technology alone cannot solve problems caused by pollution" (Table 5), but the "appreciative" group believed this more strongly than did all other groups. A third or more of the other three groups believed that science and technology can solve problems caused by pollution, while less than one third of the "appreciative" group believed so. This result is particularly interesting, since the "appreciative" group is the one that seemed to appreciate the effects of science and technology, while at the same time wanting nothing or little to do with science or technology themselves. They looked to science and technology the least, compared with their fellow students, for help in solving pollution problems.

Interestingly, a greater percentage of students had faith in technology when the question was asked without specific reference to pollution (Table 4). About one half of all groups believed that "we don't have to accept the bad effects of technology, because bad effects can be reduced or removed through careful planning and testing". Contrast this with the previous item, where 60% or more of all groups felt either that "science and technology alone cannot solve problems caused by pollution" or that "science and technology will not be able to solve problems caused by pollution, because the problems are so bad that it would cost too much". In Table 4, less than 40% of all groups felt that "we have to accept both the good and the bad effects of technology, because every new development has at least one bad effect, and to enjoy the good ones we have to put up with the bad ones." The only differences among groups was that slightly more of the "middle of the road" group than of the "disinterested" group thought that bad effects can be reduced or removed through careful planning and testing. The groups responded in a similar fashion otherwise.

There was also little difference among the different groups in their responses to item 15, which asked whether a new technology will be used even if it may do more harm than good. Almost half of all groups believed that "most new technologies are used, because some people benefit from them, even though others may see the harm they can do." Almost one third of the students felt that "if a new technology will do more harm than good to society, it will not be used." The only difference among groups was an indication that perhaps more of the "appreciative" group than the other three believed this to be the case (36% vs. 28% or 29%). However, this result would have to be tested further.

When it comes to investing more money in science and technology (item 10), the "enthusiastic" group clearly felt more strongly in favour, than did the other three groups (40% compared to 19%, 26% and 18%). This makes sense, since these students probably plan to make careers in science and technology. About 1 in 10 of the "middle of the road" and the "enthusiastic" groups believed that "Canada might become poorer" if more money were spent on research in science and technology, while about 1 in 5 of the "disinterested" and "appreciative" groups felt this to be the case. Both the latter groups share an apparent lack of interest in doing science or technology, although the "appreciative" group seems to appreciate their beneficial effects.

Many of the items deal with the nature of science and scientific knowledge. Item 8 asked whether the mass media or science classes give a better picture of science. On average, over 60% of all the students felt that science classes give a better picture. Two-thirds of all groups, except the "disinterested" group felt this way, while only about a half of the "disinterested" group did so. Over a quarter of the "disinterested" felt that neither science classes nor the media give a good picture. Significantly fewer of the "enthusiastic" group (6%) chose this option than among the other three groups. About 1 in 6 of the students as a whole chose the media, with the "disinterested' and "enthusiastic" groups choosing this option slightly more than the average.

Eighty percent of both the "appreciative" and the "enthusiastic" groups said that "different discoveries made by different scientists have nothing to do with whether the scientists are men or women" (Table 6). The "enthusiast" group is in all likelihood motivated by its belief in the neutrality and objectivity of science, whereas the "appreciative" group is largely female, and probably motivated by sex equality issues. A smaller percentage, although still more than half, of the "disinterested" group agreed with the 80% of the other two groups. A quarter of this group believed that women and men scientists might make different discoveries (compared with only 8% of the "enthusiastic" and "appreciative" groups, and 14% of the "middle of the road" group).

Item 11 asked students to explain why there are more men scientists than women scientists today. While the majority of all groups believed the reason is that "until recently people used to believe that boys were better at science and that girls were better at other things, so more boys than girls made science their career", the majority among the "disinterested" group was much smaller than for the other three groups (57% compared with over 70%). More than twice the percentage of students in the "disinterested" group as in the "middle of the road" and the "enthusiastic" groups believed that "boys are better at science than girls are." None of the "appreciative" group, which were primarily female students, chose this option at all.

Item 14 is similar to item 6, and deals with the effect of national cultures on scientists' approach to scientific problems. Here one sees the "disinterested" group differing from the others again, just as they did in item 6 about men and women scientists. The "appreciative" and "enthusiastic" groups had similarly high responses (about two-thirds) in favour of the fact that "the country where [scientists] come from makes no difference"; whereas only half of the "disinterested" group believed this to be the case. About twice as many of the "disinterested" group as of the other two groups said that the country where a scientist is trained can make a difference in the way scientists look at scientific problems.

Both items 6 and 14 relate to societal influences on the nature of scientific practice (gender and national context of training). In both cases more of the "disinterested" group than of any of the other groups, especially the "appreciative" and "enthusiastic" groups, chose the "correct" STS answer. This suggests the possibility that a positive attitude toward the practice of science and its effects may be accompanied by a homogeneous view of what constitutes scientific knowledge.

A number of other items deal with the nature of scientific knowledge. The "enthusiastic" group mostly strongly believed that scientists use only the facts to decide the merits of a theory. More of the students in the other three groups than in the "enthusiastic" group believed that scientists also consider the simplicity and logic of the theory. (Item 13)

More of the students in the "enthusiastic" group than in the other three groups also believed that science is the best way of knowing about the world. More than half of the students in all groups believed that science alone is not enough to know all about the world; but significantly more of the "appreciative" and "middle of the road" groups believed so. Interestingly, while the smallest percentage of students in all four groups believed that science is the way of knowing about the world, the largest percentage was in the "disinterested" group. (Item 27)

In item 20, the "disinterested" group differed from the rest in that more of them believed that mistakes in science are a hindrance to science. More of these students believed that either scientific mistakes slow down the progress of science, or that finding and correcting mistakes is the only way science progresses. Sixty percent of these students believed that scientific mistakes sometimes lead to progress in science, compared with over 70% for the other three groups. In

this case, the "disinterested" group had a less "correct" view of science than their peers in other groups.

In item 17, the "disinterested" group was the only group in which more students believed that "scientific knowledge can change if earlier research is looked at in a different way" than that "scientific knowledge can change only if new research proves earlier research to be wrong". All other groups had the reverse pattern, with the "middle of the road" group the most dramatic (60% favour if earlier research wrong vs. 39% favour if earlier research looked at differently). In this case, the "disinterested" group had the "more correct" view of the way science is.

Fewer of the "disinterested" group than the other three groups believed that the best scientists always follow the steps of the scientific method, and about four times as many of these students than the others believed that the best scientists never follow them, because they are clever. (Item 18)

When it comes to the practice of science, students in the "disinterested" group tended more than did students in the other groups to believe that scientists write about their work differently from the way they do their work. While a relatively small percentage of all groups believed that scientists do not usually do their work in an organized way, a much smaller percentage of the "enthusiastic" group chose this option than of the other groups. (Item 19)

The "disinterested" group was also more likely to think that good scientists remember information when needed and therefore rarely use reference materials. While the majority of students in all groups believed that scientists either use reference materials "often" or "almost always", there was a difference among groups where they put their emphasis. The "appreciative" group was divided roughly equally, whereas more of the "enthusiastic" and the"middle of the road" groups chose the "almost always" option over "often". Slightly fewer of the "disinterested" group believed in the "almost always" than in the "often".

There are interesting comparisons between the "appreciative" and the "enthusiastic" groups' answers to the items about scientific knowledge and practice. Both groups tended to agree in general, but the "enthusiastic" group had a slightly more idealistic picture of science than the "appreciative" group. For example, while more students in both groups believed that scientists select theories more on the basis of facts than on the attributes of the theory, the "enthusiastic" group exhibited this difference much more strongly. Fewer students in both groups believed that the best scientists always follow the steps of the scientific method than the "sometimes do, sometimes do not" option, but the difference was less marked in the "enthusiastic" group. More than 60% of both groups believed that scientists do and write about their work in the same way, but a larger minority of the "appreciative" group believed that scientists do not usually do their work in an organized way. Finally, while more than half of both groups acknowledged that science is one of many good ways of knowing about the world, and that science alone is not enough to know all about the world, many more of the "appreciative" group believed this to be the case. In addition, more than one-third of the "enthusiastic" group believed that science is the best way of knowing about the world, while only 20% of the "appreciative" group said so.

When it comes to the predictive capability of science (item 21), there was an interesting agreement between the "enthusiastic" group and the "disinterested" group, with the "appreciative" group giving a very different response pattern. About 40% of both the former groups believed that with enough information, scientists and engineers can predict the future definitely. Three

times as many of the "disinterested" group than of the "enthusiastic" group, however, believed that scientists and engineers cannot predict even what probably will happen (19% and 6%).

The "appreciative" group differed significantly from both the other groups. Sixty percent of this group (compared with 50% for the "enthusiastic" and 40% for the "disinterested") believed that scientists and engineers can only predict probabilities. Less than 30% of this group believed that they can predict the future with certainty, and twice as many of this group as in the "enthusiastic" group believed there is no way to predict even probabilities. The "middle of the road" group exhibited the same pattern as the "appreciative" group. This finding suggests that the "appreciative" group is more aware of the limitations of science than both the "enthusiastic" group and the "disinterested" group.

When the predictive power of science was applied to a real-life issue, however, the pattern changed dramatically. Only the "disinterested" group differed from the other three on whether or not a certain material should continue to be used if scientists show that people working with it have twice as much chance of getting lung cancer as do other people (item 22). The pattern for the other three groups was identical, with 90% or more saying the material should not be used. Of these, slightly more than 3 to 1 were in favour of more research being conducted, compared with those who believed no further research is needed.

On the other hand, about 80% of the "disinterested" group believed the material should not be used, with about 2 to 1 in favour of more research, compared with no further research required. A larger minority of the "disinterested" group than of the other three groups felt that the material could still be used, because the causal link between use of the material and lung cancer was not proven. Here we see that all groups were inclined to give science the benefit of the doubt when people's lives are at stake, with the "disinterested" group more divided on the issue than the other three.

The "enthusiastic" and the "appreciative" groups tended to agree about scientists' motives for doing science. Seventy percent or more of these groups believed that scientists do science "because they want to help people by finding new medical cures and solutions to environmental problems and by new inventions." Only 59% of the "disinterested" group chose this option, while more of them than any other group chose the two options "to be well-known and/or rich" and "because they want to be looked up to by other scientists". The agreement between the "appreciative" and the "enthusiastic" groups on this issue reflects both groups' positive attitude toward the effects of science and technology on their lives. Their tendency to disagree more on the nature of science is a reflection of their differences in attitude toward practicing science itself.

The "enthusiastic" and "appreciative" groups also agreed on the motives of scientists working for a profit-making company, whereas the "disinterested" group exhibited a different pattern. One-third of the "disinterested" group believed that these scientists put the interests of their company ahead of "doing the best science they can", whereas less than 20% of the other groups believed this to be the case. Slightly more of the "disinterested" group than of the other groups also believed that these scientists put "doing the best science they can ahead of the company's interests". While 60% or more of the other three groups believed that some of them put science first while others put the company first, only about 40% of the "disinterested" group chose this option.

Finally, there were several items that treated the relationship of science to everyday life. The characteristics of the different groups came out clearly in these items. As might be expected, the

greatest proportion of the "enthusiastic" group (about half) felt that science classes have helped them become better shoppers (item 8). About a third of the "middle of the road" and the "appreciative" group felt the same. Only about a quarter of the "disinterested" group felt this way.

In the same item (8), the highest proportion of the "disinterested" group (a third) felt that science classes have not helped because "neither the scientific method nor scientific facts can possibly help me decide which products to buy". About a quarter of the other three groups felt this way. Only about a quarter of the "enthusiastic" group felt that science classes have not helped because the media influences them more, while more than a third of the "disinterested" and the "appreciative" groups feel this way. A third of the "middle of the road" group felt this way.

This item reflects the four groups rather well. The "enthusiastic" group relies more on science in everyday life than do the others, and less on the media. The "disinterested" group relies least on science and most on the media. The "appreciative" group relies more on science than the "disinterested" group and less than the "enthusiastic" group, but relies on the media about equally with the "disinterested" group. The "middle of the road" group response mirrors the average of all the student responses.

Item 29 deals with the same issue, only in relation to solving daily life problems rather than specifically to wise shopping. Here we see a similar pattern among the four groups. The "middle of the road" group mirrors the average response. So does the "appreciative" group. The major differences are among the "disinterested" group and the "enthusiastic" group. The "disinterested" group is the only one in which a minority of students (about 40%) felt that "learning the steps of the scientific method is good for doing science and for solving problems in daily life". A quarter of the "disinterested" students felt that "learning the steps of the scientific method is a waste of time as it serves no useful purpose in science or in daily life", compared with less than 10% for the other three groups. The only option in which about the same proportion of these students agreed with a similar proportion of students in the "middle of the road" and "appreciative" groups was that the scientific method is good for science but not for daily problem solving. Significantly fewer of the "enthusiastic" group chose this response (8% compared with 14% and 17%). And the largest percentage of the "enthusiastic" group chose the first option, that the scientific method is good for science and for daily problem solving. Clearly, students' interest in science correlates with their belief in its utility for daily living.

In item 26, students were asked whether or not they equate daily problem-solving with doing science. A quarter of the "enthusiastic" group felt they are doing science when they solve a problem in daily life, whereas half as many of the "appreciative" group felt this way. About 80% of the "appreciative" group acknowledged that sometimes you are doing science and sometimes not, depending on the problem. Almost as many of the "middle of the road" group felt this way, whereas about two-thirds of the "enthusiastic" group and less than 60% of the "disinterested" group did. A quarter of the "disinterested" group felt that science has nothing to do with everyday life, exactly the same percentage that chose the similarly extreme position in the previous item ("learning the steps of the scientific method is a waste of time as it serves no useful purpose in science or in daily life").

The majority of all groups felt that members of Parliament need to know about science and technology in order to make good decisions about Canada's future (item 25). It was a slim majority (58%), however, in the "disinterested" group, and a very comfortable majority (over 75%) in the other groups. Interestingly, among those students who felt that parliamentarians do not need to know anything about science and technology themselves because they can rely on

scientists and engineers for advice, twice as many of the "disinterested" and the "appreciative" groups as of the "enthusiastic" group felt this way. We saw from previous items that a significant minority of the "disinterested" group believed that scientists and engineers are particularly clever, and hence presumably they believe scientists and engineers could be relied upon for advice. The "appreciative" students, who appreciate the work of scientists and engineers, while not wanting to know anything about science and technology themselves, are also likely to recommend seeking advice from scientists and engineers. The "enthusiastic" group is presumably more concerned that social decision-makers are aware of science and technology than those students who are not very interested in science. Significantly, three times as many of the "disinterested" group as of the other groups (18% compared with 6% or less) chose the third option (that parliamentarians need to know anything about science and technology, because science and technology have nothing to do with parliamentarians' work).

10.4. Relevant Uses of the Questionnaire

Since the STS focus of the secondary science curriculum is relatively new, there is a wide variety of needs that can be addressed by the questionnaire that has been developed. The original motivation for this project was to address the need for an evaluation instrument for STS topics. It was decided early in the project, however, that a multiple-choice format is not an appropriate tool for evaluation purposes in this field.[7] Rather, it can be a powerful tool for monitoring student understanding. The questionnaire can also be used to stimulate discussion in a number of settings, including the classroom, in-service workshops, teacher training and learning materials design.

The following is an inventory of some useful and interesting ways to use the questionnaire.

10.4.1. Grade Comparisons of Student Knowledge and Attitudes

Within a school, a board, or the entire province, the questionnaire can be administered to students in various grades to investigate more thoroughly any differences among students in different grades. Especially interesting would be a simultaneous test including grades 9, 10, 11 and 12, using the same questionnaire. This would provide a "snapshot" of the views of students at different grades, at one specific time.

10.4.2. Longitudinal Monitoring of Student Knowledge and Attitudes

A province-wide test can be repeated at the same time each year for a number of years. Results can be compared from year to year to monitor if and how students' attitudes and knowledge are changing. For example, will the four "attitude to science" groups that were found in this study be apparent five years from now? If so, will their relative sizes remain the same?

10.4.3. Classroom Discussion

The questionnaire is particularly useful as a way to stimulate discussion with students. All or some of the questions can be handed out in class. Students' answers are collected and organized, and the various answers can be discussed. Students can formulate their own versions of the questions, or even develop different questions that explore other issues.

10.4.4. In-service Workshops

During the focus group with teachers, and during meetings of the Advisory Group, the project team was advised that the questionnaire could serve as an invaluable tool for teacher in-service. 'Workshops can be organized at the Board level and within the school setting, either during professional development days or during special sessions. The questionnaire (or parts of it) can be administered within the context of the workshop, to stimulate discussion of the issues. Teachers can explore different ways of using the questionnaire, or developing the topics covered in the various items.

10.4.5. Monitoring Teacher Attitudes

Teachers can answer the questionnaire themselves, and see how their answers compare with their students' responses. In this way, especially over time, teachers can assess the impact of their teaching on their students.

Teachers can also compare their own answers with those of other teachers, to assess the extent to which agreement has been reached among their peers.

10.4.6. Student Projects

Projects can be developed that more thoroughly explore the issues raised in a particular question. Examples include analysis of scientific periodicals, historical research, interviews with scientists and engineers (within the school and/or the local community), interviews with other stakeholders, essays, oral presentations, debates, simulations (eg. an environmental assessment hearing or a scientific meeting), audio-visual presentations, field visits to relevant institutions (media, research, government, industry, associations).

10.4.7. Learning Materials Development

In the same vein, Boards of Education can use the various items presented in the questionnaire as a starting point for the development of STS learning materials. Fact sheets, bibliographies, videographies, lesson plans, kits, field trip suggestions, contact names of people and institutions are among the different kinds of support materials that might be developed around the issues covered in the questionnaire. The format of the questionnaire might be adapted to provide a tool for evaluation within the context of particular materials or topics.

10.4.8. Pre-service Training

The questionnaire can be used by Faculties of Education in a fashion similar to how it would be used for in-service. It could be incorporated into discussions of science teaching, evaluation, cross-curricular teaching, or the science-technology-society field itself. Student teachers can practise using part of the questionnaire with students to discuss STS issues. Education students can design their own items, and test them as a research project.

10.4.9. Adaptation for Younger Students

Building on the success of this project, parts of the existing questionnaire could be adapted to even younger grades. Even if only a few of the major issues covered in the questionnaire could

be expressed in a simplified form, it would be fascinating to compare answers across a wide range of grade levels, from junior to senior high school.

Other items in the original VOSTS instrument can also be adapted to develop new items. The present questionnaire, however, represent a good cross section of issues covered in VOSTS, and provides a manageable size of questionnaire for long-term monitoring purposes.

10.4.10 Use in Other Disciplines

While it is appropriate, and mandated, to teach the STS focus in science classes, there is tremendous scope for dealing with these issues in other disciplines as well. English teachers interested in developing debating skills can use scenarios from the STS literature. Several items in this questionnaire would be amenable to this approach. Historical examples abound of the ways in which science and technology affect world affairs. Some of the items could be used in history classes to stimulate discussion, or to introduce particular historical themes or topics. Other fields like geography, law, social sciences, home economics and industrial arts can incorporate many STS issues.

11.0 CONCLUSIONS

The questionnaire that was developed in this project was designed for secondary students, using the original VOSTS items as a starting point. The format evolved to something much simpler, which could not possibly include all of the subtleties contained in the original VOSTS instrument. Nonetheless, interesting and useful results were obtained with the simplified questionnaire.

The questionnaire effectively measures secondary students' understanding and attitudes regarding some very important issues, including:

- the nature of science and technology, and their relationship to each other
- the nature of the scientific community
- the role of science and technology in society
- the role of scientists and engineers in social decision-making
- the nature of scientific and technical information
- student interest in science and technology

The result is a tool that can be used to monitor students' attitudes of certain STS issues and concepts, as well as their attitudes toward science and technology themselves.

It is hoped that educators will use this questionnaire in a variety of ways, including those recommended in the previous section, but in other creative ways that they develop themselves.

As the STS focus becomes more integrated into science teaching in the classroom, other items should be developed that will complement the items developed for this project. While some questions will evolve as standards with which to make comparisons among different groups and to monitor change over time, others will be discarded or amended as teachers and students become more familiar with the STS focus. It is hoped that the efforts put into this particular project will provide educators and their students with a useful tool to help them understand the role of science and technology in their lives.

12.0 FOOTNOTES

1 For example, in item 2 a quarter of the students chose "technology is using what we know to make the world a better place to live in." It would be instructive to see whether these students also chose the "technological fix" answer in item 4.

2 The VOSTS items were designed to deal with this phenomenon. Each issue has several items that relate to it, some generalized and several with different concrete examples.

3 There is also the possibility, however, that the second option served as a "fence-sitter choice, situated half-way between "always" and "never".

4 27% of the students chose the "new technology requires science" option in item 28, out of a total of 41% who did not choose the first option (that technology leads to new science). This represents 65% of those who did not choose the first option.

5 The exception is Grade 12, Basic, which has only 6% of students choosing this option. However, the base size is very small.

6 See tables 23 and 28 in section 7.

7 The main reason for this is that there is not always one "correct" answer to the questions. What is more important is an understanding of the key issues, and an appreciation of the diversity of views that are held within society about science and technology. Classroom discussion of topics, essays, audio-visual presentations, debates and other methods are appropriate vehicles for exploring these topics, and for evaluating students' grasp of the issues.

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