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ABSTRACT

This study examined the impact of college general education science-technology-society (STS) and Physics courses on students' views about STS interactions. Two samples of convenience took part in the investigation, one consisting of 138 students enrolled in an STS course, and the other of 122 students enrolled in a physics course. Data were collected using 16 multiple-choice items selected from the "Views on Science-Technology-Society" (VOSTS) item pool, an empirically developed instrument, as a pretest and posttest. A new scoring procedure was developed for the VOSTS items, in which responses were classified as either Realistic, Has Merit, or Naive, with ordinal point values of 3, 2, or 1, respectively assigned to the categories. This allowed hypotheses to be tested using inferential statistics. The findings implied that general education physics courses should not be expected to help students develop more realistic understandings of STS interactions. Also, STS general education courses will have room for improvement if it is desired that they help students build appropriate views about STS interactions. Contains 34 references and 18 tables of statistical results. (Author)

AN EXAMINATION OF VIEWS ABOUT SCIENCE-TECHNOLOGY-SOCIETY INTERACTIONS AMONG COLLEGE STUDENTS IN GENERAL EDUCATION PHYSICS AND STS COURSES

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Abstract

This study examined the impact of college general education science-technology-society (STS) and Physics courses on students' views about STS interactions. Two samples of convenience took part in the investigation, one consisting of 138 students enrolled in an STS course, and the other of 122 students enrolled in a physics course. Data were collected using 16 multiple-choice items selected from the Views on Science-Technology-Society (VOSTS) item pool, an empirically developed instrument, as a pretest and posttest. A new scoring procedure was developed for the VOSTS items, in which responses were classified as either Realistic, Has Merit, or Naive, with ordinal point values of 3, 2, or 1, respectively assigned to the categories. This allowed hypotheses to be tested using inferential statistics. The findings implied that general education physics courses should not be expected to help students develop more realistic understandings of STS interactions. Also, STS general education courses still have room for improvement if it is desired that they help students built appropriate views about STS interactions.

AN EXAMINATION OF VIEWS ABOUT SCIENCE-TECHNOLOGY-SOCIETY INTERACTIONS AMONG COLLEGE STUDENTS IN GENERAL EDUCATION PHYSICS AND STS COURSES

It has been argued that for college students to become active and informed decision-makers on science and technology-related societal issues, college general education should promote an understanding of the nature of science and technology, and their interactions within society (Cole and Merrill, 1982; Roy, 1984; Cutcliffe, 1987; Fleming, 1989; Rubba, 1992). Science, technology, and society (STS) education purports to provide a viable approach to delivering those kinds of understandings. STS has received a great amount of scholarly attention and support over the past decade by those who see it as an educational initiative capable of fostering responsible citizenship (Cutcliffe, 1987, 1990; Foltz & Roy, 1991; Rubba & Wiesenmayer, 1985, 1988; Waks, 1992).

STS courses are offered at over 2000 universities and colleges across the nation, typically as general education electives (Foltz & Roy, 1991). Despite the rapid growth of STS programs at the college level over the past three decades, Cutcliffe (1990) reminds us that two basic questions remain unanswered: How successful has STS been in achieving the kinds of understandings it purports to offer? and Should STS become a required part of the general education of all students, and if so, at what level?

Traditionally, several standardized instruments have been used to assess students' views of STS topics. These include multiple-choice instruments and Likert-type scales, such as Science Process Inventory (Welch, 1966), Test on the Social Aspects of Science (Korth, 1968), Scientific Attitude Inventory (Moore & Sutman, 1970), and the Test on Understanding Science (Cooley & Klopfer, 1961). One major limiting aspect common to these objectively scored instruments is that they rely on the assumption that both researcher and student attribute the same meaning to the wording of each item. Munby (1982) referred to this assumption as "the doctrine of immaculate perception" (p. 207), casting doubt on the soundness of earlier research findings and inferences that are based on data collected with those instruments. Munby (1983) identified particular problems with the validity of the Scientific Attitude Inventory in an investigation involving the conceptual analyses of 30 studies. Items which purportedly assess attitude were shown to actually tap different research constructs.

More recent empirical evidence has supported the notion that generalizations made about the epistemological, technological and social contexts of science based on traditional objective instruments should be taken with caution. For instance, Aikenhead and Ryan (1989) found significant discrepancies between students' responses on multiple-choice and Likert-type paper-and-pencil assessments of views about STS and their responses in follow-up interviews. The interviews disclosed a wealth of information not contained in students' multiple-choice and Likert-type responses. An investigation done by Lederman and O'Malley (1990) corroborated those findings.

Yet another limitation of traditional objective instruments is that large differences that might exist in individual items' responses are usually hidden by group scores. By reporting solely the group scores, valuable information is lost about aspects assessed by specific items. Published reports of aggregate scores, in fact, conceal the underlying variance. (Lucas, 1975).

Gardner (1987) pointed out that standard methods of assessment that employ Likert and semantic differential types of scales cannot detect ambivalent responses, meaning that they ignore the possibility of a person holding both positive and negative feelings towards a certain object. Furthermore, because scoring methods traditionally utilize the sum of all individual item scores, ambivalence cannot be distinguished from neutrality in the final result. As a consequence, persons that have similar scores on a scale might hold different properties on the attribute being measured, which violates a fundamental principle of assessment.

The Problem

Though STS courses have existed for over three decades at the college level (Foltz & Roy, 1991), no studies have examined the purported contribution STS can make at the college level. This study attempted to contribute to our understanding in this area by examining whether and to what extent general education STS and natural sciences courses help college students build more informed, realistic views about the interactions among science, technology, and society (hereafter referred to as STS interactions). Inadequacies in traditional assessment instruments were overcome through use of a new type of instrument employed to assess the impact of a college general education STS and a physics courses on students' views about STS interactions.

The purpose of this study was three-fold: 1) to examine the impact of a general education STS course on college students' views about STS interactions, 2) to examine the impact of a general education physics course on college students' views about STS interactions, and 3) in the process, to informally compare, to the extent possible, the impact of these courses on students' views about STS interactions.

Samples

Two samples of convenience took part in the study, one consisting of 138 college students enrolled in a general education STS course, STS 200—Critical Issues in Science, Technology and Society, and the other comprising 122 college students enrolled in a general education physics course, PHYS 001—The Science of Physics, at a large eastern land grant university. Students opted to enroll in these courses to fulfill part of their general education requirements. Each course met three times per week for 50 minutes, each meeting over a 15 week semester. Students from these two courses became part of the samples by volunteering to participate in the investigation and by completing a pretest and posttest.

Over half (59.4%) of the subjects in the STS sample were 18-years-old, with 72.5% being males. The two largest percentages by declared major were engineering (27%) and education (15.3%). The age and gender distribution of the physics sample was more balanced, with 54.1% females, and with 24.6% being 18-years-old, 24.6% being 19-years-old, and 26.2% being 20 years-old. The two largest percentages by major were liberal arts (39.3%) and business administration (18.9%). Twenty-six percent and 52.5% of the STS 200 and PHYS 001 samples were upper-classmen, respectively. The vast majority of students in both samples (97.1% in the

STS 200 and 84.9% in the PHYS 001) had not completed any coursework in STS at the college level.

STS 200 is a three-credit course organized around the framework for a general education STS survey course described by Roy and Walker (1991). The course is divided into four major units or modules, namely, a) STS foundations, b) resources and their utilization, c) human needs and aspirations, and d) decisions and actions. A faculty member from the STS Program is the professor in charge of the course and delivers about one-fourth of the instruction. In addition, faculty members from various colleges (e.g., science, engineering, liberal arts) who are associated with the STS program, serve as guest instructors on a rotating basis. They present lectures on the respective modules' theme, using timely STS issues facing society as examples. STS issues, such as human impact on the environment, energy and resources, and biodiversity, were dealt with during the semester.

PHYS 001 is a three-credit general education physics lecture course taught by a professor of physics. Fundamental concepts in physics, such as Newtonian mechanics, waves, and modern physics, were addressed with an emphasis on qualitative understandings. The use of mathematics was limited. Some technological applications were provided and an historical overview was used whenever appropriate. There were no lab or recitation periods. Demonstrations were periodically used by the instructor.

Instrumentation and Data Collection

Pretest and posttest data were collected using 16 multiple-choice items selected from the 114 items in the Views on Science-Technology-Society (VOSTS) item pool, Form CDN.mc.5 (Aikenhead, Ryan, & Fleming, 1988). The VOSTS is an "empirically developed multiple-choice instrument" (Aikenhead, 1988, p. 622) designed to overcome weaknesses in traditional objective instruments on the nature of science and technology; that is, the multiple-choices under each item are paraphrases of students' written responses and follow-up interviews. Aikenhead (1988) showed that empirically developed items provide more lucid and accurate data on respondents views about STS than do Likert-type and researcher- composed multiple-choice items. This attribute differentiates the VOSTS from earlier STS inventories, and lends the VOSTS great potential for assessing students' views about STS topics in a more valid manner (Aikenhead & Ryan, 1989, 1992).

Because the VOSTS item pool was developed using written samples from and interview with Canadian high-school students and graduates to structure the multiple-choices, the appropriateness of using VOSTS items with college students needed to be assessed. A set of 37 items was tentatively selected by the authors for a pilot study, with the help of one of the former professors-in-charge of the STS 200 course. These items were administered to the students enrolled in STS 200 and PHYS 001 at the beginning and end of the eight week summer session that preceded the semester in which this study was competed.

The results of the pilot study indicated that the VOSTS items would be appropriate for the purpose of the investigation (Schoneweg, 1992). However, the 37 item pilot version of the instrument proved to be too long to be completed in the 30 minutes that the professors in the STS and physics courses would allocate for testing in the actual study. From the 37 items piloted the researchers identified those that would capture crucial understandings expressed in the National Science Teachers Association (1990; 1991) and National Council for the Social Studies (1990) position statements on STS, as well as to match intended STS 200 course goals, resulting in the 16 item instrument used in this study.

Aikenhead and Ryan (1992) claim that the validity of the VOSTS is established by the "trustworthiness" of the process followed in developing its items; that is, the use of student-generated ideas to construct the multiple-choices grants the instrument an inherent validity. Furthermore, they note that, because conventional item analysis procedures used to assess reliability assume that the instrument yields parametric scores, an assumption not valid for the VOSTS, the concept of reliability as it is traditionally employed does not apply to the VOSTS. [For a more thorough discussion of these subjects see also Rubba, Schoneweg, & Harkness (in press).] Hence, the validity of the 16 VOSTS items was accepted at face value, and the items were assumed to be reliable.

The pretest was administered on the first day of classes in STS 200 and PHYS 001, and the posttest 14 weeks later, again during class time. It took respondents approximately 25 minutes to complete the instrument on each occasion.

Instrument Scoring and Data Analysis

A special scoring procedure was devised for the VOSTS items to allow non-parametric inferential statistics to be used to test null hypotheses associated with purposes 1 and 2. Analysis of the data for purpose 3 was restricted to descriptive comparisons because an appropriate non-parametric inferential statistical tool was not available.

One way of looking at the multiple choices under a VOSTS item statement would be to identify the "correct" choice and label all of the other choices "wrong". However, given the choices under each VOSTS item express "reasoned" students' viewpoints, the use of a right/wrong classification scheme would ignore degrees of legitimacy that exist in some of the other choices (Rubba, Schoneweg & Harkness, in press).

According to Aikenhead (personal communications, 1991), VOSTS items do not lend themselves to traditional methods of inferential data analysis, except when choices are collapsed into categories, as done by Zoller et al. (1990). Aikenhead suggested establishing a three-category scoring scheme, Realistic/Has Merit/Naive (R/HM/N), that would also overcome the right/wrong difficulty. A panel of five expert judges, professionals representing the fields of science, science education, and STS, was charged with independently classifying the choices under each of the 16 items into the R/HM/N scheme according to the following definitions:

Realistic (R) -- the choice expresses an appropriate view of STS relative to the item stem;

Has Merit (HM) -- while not realistic, the choice expresses a number of legitimate points about STS relative to the item stem;

Naive (N) -- the choice expresses a view about STS, relative to the item stem, that is inappropriate or not legitimate.

Prior to the panel's work, the multiple-choices "I don't understand" and "I don't know enough about this subject to make a choice" under each VOSTS item were assigned to the Naive category by the researchers. The option "None of these choices fits my basic viewpoint" was not categorized.

Agreement among at least three of the five panel members was sought in order to categorize a choice as R, HM, or N. A sixth or a seventh judge was used in order to resolve the disagreement when judges split on a choice. The researchers used discretion and intervened in a few instances when the consensus opinion seemed to represent a misconception. The ordinal values of 3,2, and 1 were assigned to the R/HM/N categorized multiple-choices, respectively, to facilitate statistical testing.

Descriptive statistics were tabulated on the multiple-choices under each item, and on the categorized data. In addition, two separate sets of statistical tests were performed in analyzing the data for purposes 1 and 2. It was reasoned that, if a course had a positive impact on students' views of STS interactions, this would be reflected in a shift towards more realistic views along the scoring scale on a given item. Conversely, shifts towards the more naive end of the scale would indicate that the course had a less than desirable effect on students' views of the STS interactions dealt with in the given item.

The first set of statistical tests sought to examine changes in each sample's views about STS interactions on the aggregated 16 VOSTS items, from pretest to posttest. This involved calculating a mean change score for each sample, and submitting each value to a *t*-test for dependent samples (alpha=.05). The null hypotheses tested in this process were:

$H0_1$: The mean change score on the 16 VOSTS items for the STS sample does not differ from zero.

$H0_2$: The mean change score on the 16 VOSTS items for the Physics sample does not differ from zero.

The mean change score (pretest to posttest) for each sample on the 16 items was calculated by:

1. comparing each member's categorized choices (R/HM/N) on one item on the pretest and posttests, and assigning a value of -1, 0 or +1 to the change, depending on the direction of the change. For instance, if a subject selected a N or HM option in the pretest, and a R option in the posttest, he or she was assigned a change score of +1 on that item; the opposite change would be assigned a -1, and no change was assigned the score of 0. Scores were assigned irrespective of the magnitude of the change in order to avoid additional assumptions about interval scale data;
2. Summing these change scores for each subject across the 16 VOSTS items (values could range between -16 and +16); and
3. Calculating the mean of each sample's change scores on all 16 VOSTS items.

The second set of statistical tests employed in analyzing the data for purposes 1 and 2 sought to take a finer look at the data, by looking at changes from pre- to posttest for each of the 16 individual items. It consisted of performing a McNemar's analysis (alpha=.05) on each item for both samples. A total of 32 tests were performed. The McNemar's analysis would yield a significant value if, for a given item, the number of subjects within a sample moving "upwards" along the scoring scale (R=3, HM=2, N=1) was statistically different from the number of subjects moving "downwards," between pretest and posttest. The null hypotheses tested were:

$H0_3$: For the STS 200 sample, the number of subjects moving "upwards" along the scoring scale is the same as the number of subjects moving "downwards," between pretest and posttest.

$H0_4$: For the PHYS 001 sample, the number of subjects moving "upwards" along the scoring scale is the same as the number of subjects moving "downwards," between pretest and posttest.

Findings

Tables 1 through 16 contain descriptive statistics on each VOSTS item, presenting the response frequency and percentage data for each multiple-choice, and the response frequency and percentage data for each of the R/HM/N categories, on the pretest and posttest. These findings are highlighted in the descriptive discussion that follows.

Insert Tables 1 through 16 about here

In item 1 (Table 1), the posttest data indicates that the largest percentages of students in both samples (54.3% in STS 200 and 46.7% in PHYS 001) defined science in terms of a body of knowledge, a choice that was classified as HM. Somewhat more students in the PHYS 001 sample (25.6%) than in the STS 200 sample (20.3%) finished the course with a view of science as a process of exploring the unknown, classified as R by the panel. When asked about the nature of a scientific model (item 2) in the posttest, over half of the students in both samples (52.9% in STS 200 and 55.7% in PHYS 001) elected choices that were classified as HM, while 37.7% in STS 200 and 28.7% in PHYS 001 selected R choices (Table 2). At the beginning of the semester, roughly 37% of the subjects in both samples saw technology as the application of science, a choice classified as HM (item 3). By the end of the semester, though, the gap between the samples widened with respect to this choice, as 18.1% in STS 200 and 45.9% in PHYS 001 selected this view in the posttest (Table 3).

Item 4 (Table 4) addressed the connection between science and technology and the quality of life. A sizable percentage of students in the STS 200 sample selected N choices in the pretest (31.2%), and an even higher percentage did so in the posttest (58%). Fewer students (37.2%) selected N choices in the posttest in the PHYS 001 sample. Item 5 (Table 5) dealt with the influence of a country's politics on its scientists. Over half of the students in STS 200 (52.2%) and in PHYS 001 (55.8%) selected R choices in the pretest; however, in the posttest more students in STS 200 (74.6%) than in PHYS 001 (58.2%) picked R choices. A majority of students in STS

200 (66.7%) and in PHYS 001 (60.7%) elected R choices in the pretest when asked about their views on the influence of special interest groups on science and technology (item 6, Table 6). In the posttest, somewhat more students in the STS 200 sample selected R choices (78.3%), while the PHYS 001 sample's percentage of R choices remained virtually stable (62.5%). Item 7 (Table 7) addressed students' views of trade-offs of science and technology. Here the STS 200 sample presented a remarkable increase in the percentage of R responses between pretest (43.5%) and posttest (81.9%), while the respective percentages for the PHYS 001 sample were 56.6% and 50.8%. In item 8 (Table 8), students' views about competition for funds between science and technology and social programs were addressed. Interestingly, the only choice claiming that less money should be spent in science and technology and funds diverted to other societal needs, classified as HM, had the single widest percentage shift in STS 200, from 3.6% in the pretest to 24.8% in the posttest. In PHYS 001 the response distribution per category remained fairly stable over the course of the semester, with roughly 21% selecting N, about 15% selecting HM, and nearly 57% selecting R, in both testing occasions. Students' views about scientific decision making was the theme of item 9 (Table 9). The posttest data shows that over half of the students in both samples (61.3% in STS 200 and 54.1% in PHYS 001) selected choices that were classified as R.

The issue of technological decisions was addressed in item 10 (Table 10). The pattern of responses in STS 200 and PHYS 001 in both testing occasions is remarkably similar, with roughly 65% selecting R choices in the pretest and about 57% selecting R choices in the posttest, in both samples. When asked about their views of technology control (item 11), a majority (58%) in STS 200 selected R choices, while 37.5% did so in PHYS 001 on the posttest (Table 11). Item 12 (Table 12) addressed technology's contribution to the standard of living. In both testing occasions the PHYS 001 sample had somewhat more students selecting a R choice than the STS 200 sample; specifically in the posttest, while 62.8% of subjects in STS 200 selected a R choice, 71.7% did so in PHYS 001. In item 13 (Table 13), which addressed students' views of community and government control over scientific research agendas, the majority in STS 200 (about 71%) and in PHYS 001 (about 63%) selected choices classified as HM, in both testing occasions.

When asked about their views on corporations' control over scientific research agendas (item 14), 45.1% of the STS 200 sample selected R choices on the posttest. Interestingly, a sizable percentage in this sample (18%) selected the option "none of these choices fits my basic viewpoint" (not classified) on the posttest, which is markedly higher that the 5.9% selecting this choice in the pretest. In the PHYS 001 sample, over half (52.5%) of the students selected R choices on this item in the posttest. The issue of science and technology related societal decisions was addressed in item 15 (Table 15). The data indicate that over half of the students in both groups selected a R choice in the posttest (53.4% in STS 200 and 52.9% in PHYS 001). Finally, item 16 dealt with the contributions of science and technology in the resolution of social and practical problems (Table 16). In the posttest, choices classified as HM were selected by a majority in STS 200 (77.2%) and in PHYS 001 (68.9%).

The results of the two-tailed *t*-tests for dependent samples on the mean change scores for the STS 200 and PHYS 001 samples are presented on Table 17. Both tests yielded non-significant results ($p>.05$), indicating that the mean change score for both samples was equal to zero, for all practical purposes; therefore, the null hypotheses could not be rejected.

Insert Table 17 about here

Table 18 shows the results of the McNemar's tests performed for the STS 200 and PHYS 001 samples on each of the 16 VOSTS items. This Table also presents the frequency of respondents who moved "upwards" (U), "downwards" (D), or remained stable (S) along the scale R=3, HM=2, and N=1, between the pretest and posttest.

Insert Table 18 about here

For the STS 200 sample, the McNemar's statistic was significant at the .05 level for items 1, 6 and 16, at the .01 level for items 4 and 11, and at the .001 level for items 5 and 7. This indicated that the shifts that occurred in the sample's categorized responses (R/HM/N) between pretest and posttest for those seven items were asymmetrical; that is, it was found that statistically different numbers of respondents in STS 200 moved upwards and downwards along the scoring scale. The null hypothesis was rejected for those seven items. It should be noted, though, that for items 1, 4, and 16 the changes observed occurred in a negative direction; that is, more students moved "downwards" than "upwards" along the R/HM/N scale. For items 5, 6, 7, and 11 changes occurred in a positive direction; that is, more students moved "upwards" than "downwards" along the R/HM/N scale. For the nine remaining items, though, the null hypothesis was not rejected ($p>.05$) for the STS 200 sample, indicating that the shifts observed were symmetrical.

For the PHYS 001 sample, the McNemar's analyses yielded one statistically significant result ($p<.05$), namely for item 3, indicating that an asymmetrical shift occurred in the sample's categorized response distribution between the pretest and posttest for that item. Table 17 shows that more students moved "downwards" than "upwards" along the R/HM/N scale on this item. Thus, the null hypothesis was rejected for item 3, but not for the other 15 items, for the PHYS 001 sample.

A total of 32 McNemar's tests were performed. If all 32 of the null hypotheses were true, one would expect about two to be rejected by chance. This suggests that the effects were real and highly unlikely to be due to multiple testing.

Discussion and Conclusions

The *t*-test results presented on Table 17 indicated that for the STS 200 and the PHYS 001 samples there were no substantial gains or losses in the aggregated scores over the 16 items, since the mean change scores were found to be virtually zero. Thus, it was concluded that each sample's mean score remained stable over the period of the semester.

Nonetheless, a limitations of the *t*-test analysis was that it did not reveal whether results were due to pretest to posttest gains on some items and losses on other items mutually canceling each other, or to no actual gains; that is, the *t*-test results provided only a gross measure as to whether there were differences in students' views about STS interactions as a result of the courses. The next level of statistical analysis provided a finer insight into the data, as the McNemar's tests pin-pointed particular VOSTS items where shifts in students' views had occurred across the R/HM/N categories.

Specifically, for the STS 200 sample it was found that students moved towards more realistic views on the influence of a country's politics on its scientists (item 5), the influence of special interest groups on science and technology (item 6), trade-offs of science and technology (item 7), and technology control (item 11). Yet, these students moved towards more naive views on the definition of science (item 1), the connection between science and technology and the quality of life (item 4), and the contribution of science and technology in the resolution of social and practical problems (item 6).

These findings suggested that the STS 200 course did have an impact on students' views about STS 200 interactions as measured by the VOSTS items. However, in some areas students seemed to have developed some unanticipated misunderstandings. It was inferred that, while the STS course was effective in providing students with more realistic views of STS interactions in topics such as the influence of a country's politics on its scientists, the impact of special interest groups on science and technology, trade-offs of science and technology, or technology control, in other areas the presentation of information had a confounding effect. It seems plausible that students did start re-examining their existing beliefs on certain topics addressed by the VOSTS items as a result of the STS 200 course; however, the conceptual conflicts ensuing from this process might not have been appropriately resolved in some areas, leaving students with less than realistic views about some STS interactions. This seems to be the case with the definition of science, the connections of science and technology and the quality of life, and the contributions of science and technology to the solution of social and practical problems.

The findings for the PHYS 001 course, on the other hand, indicated that the course had virtually no impact on students' views of STS interactions, except for the definition of technology (item 3), where students appeared to have moved to less informed views at the end of the course. Technology is traditionally viewed as the application of science, and PHYS 001 might have inadvertedly conveyed this idea to the students. This inference is supported by a slight increase in the percentage of respondents who selected the option of technology as applied science, from 34.4% in the pretest to 45.9% in the posttest. These results might be explained by the way technology is treated in the textbook used and by the instruction in the PHYS 001 course. Throughout the text, occurrence of natural phenomena are illustrated in terms of technological developments. For instance, fluorescence and its applications to lamps, thermodynamics and the car, satellite motion and artificial probes, radioactivity and nuclear power plants. Similarly, the instructor frequently referred to technological applications of concept in his lectures. From these examples some students might have generalized, incorrectly, that technology is applied science.

Implications

The researchers found that the following implications ensue from this study. First, it should not be expected that college general education science courses, such as PHYS 001, help students develop more adequate, realistic understandings of the STS interactions. Even though courses like PHYS 001 are not intended for students majoring or minoring in scientific or technical fields, the main focus still is helping students gain a qualitative understanding of major science concepts and the applications of these as a part of a liberal or general education. Examples of technology are often provided in the process of helping students understand these science concepts, for instance, examples involving Newtonian mechanics or thermodynamics. However, the focus of college general education science remains scientific concepts understanding. Moreover, the examples of technology that are presented are typically described in a positive light. Students are not offered the opportunity to examine the societal implications of science and technology, given that issues like science and technology related trade-offs or decision/policy making are not pursued. In addition, either explicitly or implicitly, technology might be inappropriately defined as the application of science.

If it is desired that, as part of their general education, college students, even those majoring in scientific and technical fields, develop a appropriate understandings of the STS interactions, these understandings must be focused upon. STS courses were devised some 30 years ago specifically to fulfill this purpose, and are presently offered at about 2000 colleges and universities in the country (Roy, 1988; Cutcliffe, 1990).

Secondly, while the findings add support to the value of general education STS courses, they also imply that courses like STS 200 still have room for improvement. The fact that STS courses have an underlying interdisciplinary philosophy is a much desirable feature, as it helps students integrate knowledge from different areas, as argued by Foltz and Roy (1991). However, authors like Waks (1985) and Remy (1989) claim that the lack of a broad theoretical framework that integrates the natural and social sciences under a comprehensive interdisciplinary curriculum is still a limitation of STS courses. In the specific case of STS 200, it appears that this limitation surfaced when students developed some unanticipated misunderstandings at the end of the course. This may have been the result of a lack of sufficient focus of the lectures. In addition, because points of view were not always consistent among invited lecturers, students might have lacked an opportunity to adequately synthesize the information presented. It is therefore advised that the instruction delivered in general education STS courses provide continuity and a well-defined focus on the particular STS understanding it is desired for students to develop, in order to help students examine their existing beliefs and reconcile conflicts with the appropriate perspectives. Use of conceptual change teaching strategies (Posner, Strike, Hewson & Gertzog, 1982; Hewson & Hewson, 1983; Hashweh, 1986) may be very fruitful in this regard.

The scoring procedure used in this study with the VOSTS items to establish the R, HM, and N categories and quantify the findings appears to have great potential. However, the use of modal agreement among a panel of expert judges seems to be a limitation in the procedure (Rubba, Schoneweg & Harkness, in press). Further research should explore ways of strengthening that aspect. Furthermore, interviews with a sub-sample of the samples could be used in future studies in order to probe students' responses.

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Table 1
Descriptive Statistics on Item 1

Defining science is difficult because science is complex and does many things. But MAINLY science is:

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		5	3.6	6	4.3	10	8.2	3	2.5
E.	inventing or designing things (for example, artificial hearts, computers, space vehicles).	0	0	0	0	1	0.8	0	0
H.	no one can define science.	5	3.6	4	2.9	7	5.7	3	2.5
I.	I don't understand.	0	0	1	0.7	0	0	0	0
J.	I don't know enough ...	0	0	1	0.7	2	1.6	0	0
Has Merit		77	55.8	100	72.5	73	59.8	81	66.9
A.	a study of fields such as biology, chemistry and physics.	2	1.4	1	0.7	4	3.3	7	5.7
B.	a body of knowledge, such as principles, laws and theories, which explain the world around us (matter, energy and life).	49	35.5	75	54.3	53	43.4	57	46.7
D.	carrying out experiments to solve problems of interest about the world around us.	8	5.8	5	3.6	4	3.3	1	0.8
F.	finding and using knowledge to make this world a better place to live in (for example, curing diseases, solving pollution and improving agriculture).	18	13.0	15	10.9	12	9.8	16	13.1
G.	an organization of people (called scientists) who have ideas and techniques for discovering new knowledge.	0	0	4	2.9	0	0	0	0
Realistic		48	34.8	28	20.3	32	26.2	31	25.6
C.	exploring the unknown and discovering new things about our world and universe and how they work.	48	34.8	28	20.3	32	26.2	31	25.6
K.	None of these choices ...	8	5.8	4	2.9	7	5.7	6	5.0
	Missing							1	

Table 2
Descriptive Statistics on Item 2

Many scientific models used in research laboratories (such as the model of heat, the neuron, DNA, or the atom) are copies of reality.

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		10	7.2	8	5.8	18	14.9	17	13.9
A.	scientific models ARE copies of reality, because scientists say they are true, so they must be true.	0	0	2	1.4	1	0.8	0	0
B.	scientific models ARE copies of reality, because much scientific evidence has proven them true.	6	4.3	6	4.3	11	9.1	13	10.7
H.	I don't understand.	0	0	0	0	1	0.8	1	0.8
I.	I don't know enough ...	4	2.9	0	0	5	4.1	3	2.5
Has Merit		63	45.7	73	52.9	59	48.8	68	55.7
C.	scientific models ARE copies of reality, because they are true to life. Their purpose is to show us reality or teach something about it.	12	8.7	7	5.1	7	5.8	8	6.6
D.	scientific models come close to being copies of reality, because they are based on scientific observations and research.	51	37.0	66	47.8	52	43.0	60	49.2
Realistic		64	46.4	52	37.7	40	33.1	35	28.7
Scientific models are NOT copies of reality:									
E.	because they are simply helpful for learning and explaining, within their limitations.	35	25.4	36	26.1	24	19.8	21	17.2
F.	because they change with time and with the state of our knowledge, like theories do.	23	16.7	10	7.2	9	7.4	9	7.4
G.	because these models must be ideas or educated guesses, since you can't actually see the real thing.	6	4.3	6	4.3	7	5.8	5	4.1
J.	None of these choices ...	1	0.7	5	3.6	4	3.3	2	1.6
	Missing					1			

Table 3
Descriptive Statistics on Item 3

Defining what technology is can cause difficulties because technology does many things. But MAINLY technology is:

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		0	0	3	2.2	3	2.5	1	0.8
A.	very similar to science.	0	0	1	0.7	0	0	0	0
H.	I don't understand.	0	0	1	0.7	1	0.8	0	0
I.	I don't know enough ...	0	0	1	0.7	2	1.6	1	0.8
Has Merit		79	57.2	79	57.2	72	59.0	88	72.1
B.	the application of science.	52	37.7	25	18.1	42	34.4	56	45.9
C.	new processes, instruments, tools, machinery, appliances, gadgets, computers, or practical devices for everyday use.	22	15.9	37	26.8	22	18.0	21	17.2
D.	robotics, electronics, computers, communication systems, automation, etc..	1	0.7	4	2.9	1	0.8	2	1.6
F.	inventing, designing, and testing things (for example, artificial hearts, computers, space vehicles).	4	2.9	13	9.4	7	5.7	9	7.4
Realistic		56	40.6	48	34.8	42	34.4	29	23.8
E.	a technique for doing things, or a way of solving practical problems.	14	10.1	13	9.4	7	5.7	2	1.6
G.	ideas and techniques for designing and manufacturing things, for organizing workers, business people and consumers, for the progress of society.	42	30.4	35	25.4	35	28.7	27	22.1
J.	None of these choices ...	3	2.2	8	5.8	5	4.1	4	3.3

Table 4
Descriptive Statistics on Item 4

In order to improve the quality of living in the U.S., it would be better to spend money on technological research RATHER THAN scientific research.

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		43	31.2	80	58.0	51	41.8	45	37.2
A.	invest in technological research because it will improve production, economic growth, and unemployment. These are far more important than anything that scientific research has to offer.	2	1.4	11	8.0	1	0.8	3	2.5
B.	invest in both, because there is really no difference between science and technology.	2	1.4	1	0.7	2	1.6	0	0
E.	invest in both, because each in its own way brings advantages to society. For example, science brings medical and environmental advances, while technology brings improved conveniences and efficiency.	32	23.2	43	31.2	34	27.9	33	27.3
F.	invest in scientific research--that is, medical or environmental research--because these are more important than making better appliances, computers or other products of technological research.	2	1.4	5	3.6	4	3.3	2	1.7
G.	invest in scientific research because it improves the quality of life (for example, medical cures, answers to pollution, and increased knowledge). Technological research, on the other hand, has worsened the quality of life (for example, atomic bombs, pollution, automation, etc.).	2	1.4	4	2.9	3	2.5	4	3.3
H.	invest in neither. The quality of living will not improve with advances in science and technology, but will improve with investments in other sectors of society (for example, social welfare, education, job creation programs, the fine arts, foreign aid, etc.).	2	1.4	14	10.1	3	2.5	3	2.5

Table 4 (con't)

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
I.	I don't understand.	0	0	0	0	2	1.6	0	0
J.	I don't know enough ...	1	0.7	2	1.4	2	1.6	0	0
Has Merit		31	22.5	6	4.3	38	31.1	29	24.0
C.	invest in both, because scientific knowledge is needed to make technological advances.	31	22.5	6	4.3	38	31.1	29	24.0
Realistic		61	44.2	47	34.1	32	26.2	43	35.5
D.	invest in both, because they interact and complement each other equally. Technology gives as much to science as science gives to technology.	61	44.2	47	34.1	32	26.2	43	35.5
K.	None of these choices ...	3	2.2	5	3.6	1	0.8	4	3.3
	Missing							1	

Table 5
Descriptive Statistics on Item 5

A country's politics affect that country's scientists. This happens because scientists are very much a part of a country's society (that is, scientists are not isolated from their society).

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		24	17.4	10	7.2	20	16.7	22	18.0
D.	scientists ARE affected by their country's politics, because politics limit and control scientists by telling them what research to do.	3	2.2	3	2.2	3	2.5	0	0
E.	scientists ARE affected by their country's politics, because governments can force scientists to work on a project which scientists feel is wrong (for example, weapons research), and therefore not allow the scientists to work on projects beneficial to society.	4	2.9	0	0	4	3.3	4	3.3
G.	scientists ARE affected by their country's politics, because scientists try to understand and help society and thus, because of their involvement and importance to society, scientists are closely tied to society.	10	7.2	5	3.6	5	4.1	6	4.9
Scientists are NOT affected by their country's politics:									
I.	because scientific research has nothing to do with politics.	0	0	0	0	1	0.8	0	0
J.	because scientists are isolated from their society.	1	0.7	0	0	0	0	0	0
K.	I don't understand.	0	0	1	0.7	0	0	1	0.8
L.	I don't know enough ...	6	4.3	1	0.7	7	5.8	11	9.0
Has Merit		35	25.4	18	13.0	30	25.0	25	20.5
F.	scientists ARE affected by their country's politics, because scientists are a part of society and are affected like everyone else.	18	13.0	7	5.1	12	9.9	15	12.3
H.	it depends on the country, and the stability or type of government it has.	17	12.3	11	8.0	18	14.9	10	8.2

Table 5 (con't)

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Realistic		72	52.2	103	74.6	67	55.8	71	58.2
Scientists ARE affected by their country's politics:									
A.	because funding for science comes mainly from governments which control the way the money is spent. Scientists sometimes have to lobby for funds.	31	22.5	49	35.5	30	24.8	32	26.2
B.	because governments set policy for science by giving money to some research projects and not others.	15	10.9	23	16.7	19	15.7	11	9.0
C.	because governments set policy regarding new developments and new projects, whether the government funds them or not. Government policy affects the type of projects scientists will work on.	26	18.8	31	22.5	18	14.9	28	23.0
M.	None of these choices ...	7	5.1	7	5.1	3	2.5	4	3.3
	Missing					2			

Table 6
Descriptive Statistics on Item 6

Within the U.S. there are groups of people who feel strongly in favor of or strongly against some research field. Science and technology projects are influenced by these special interest groups such as environmentalists, religious organizations, and animal rights people).

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		19	13.8	9	6.5	24	19.7	22	18.3
B.	special interest groups do have an influence, because they have the power to tell scientists which projects are important to do or not to do.	3	2.2	1	0.7	3	2.5	0	0
F.	special interest groups try to have an influence but they don't always succeed because scientists and technologists have the final say.	6	4.3	2	1.4	7	5.7	9	7.5
Special interest groups do NOT have an influence:									
G.	because the government decides the direction that research will take.	2	1.4	4	2.9	1	0.8	2	1.7
H.	because science and government decide what projects are important and they do them no matter what special interest groups say.	4	2.9	0	0	5	4.1	5	4.2
I.	I don't understand.	0	0	1	0.7	0	0	0	0
J.	I don't know enough ...	4	2.9	1	0.7	8	6.6	6	5.0
Has Merit		13	9.4	11	8.0	17	13.9	15	12.5
A.	special interest groups do have an influence, because they have the power to stop some research projects and that field of science suffers.	9	6.5	3	2.2	7	5.7	3	2.5
E.	special interest groups do have an influence, because some special interest groups give money for certain research projects. Some other special interest groups give money to prevent certain research projects.	4	2.9	8	5.8	10	8.2	12	10.0

Table 6 (con't)

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Realistic		92	66.7	108	78.3	74	60.7	75	62.5
C.	special interest groups do have an influence, because they influence public opinion and therefore the scientists.	64	46.4	64	46.7	36	29.5	52	43.3
D.	special interest groups do have an influence, because they influence government policy and governments decide whether to fund a research project or not.	28	20.3	44	31.9	38	31.1	23	19.2
K.	None of these choices ...	14	10.1	10	7.2	7	5.7	8	6.7
	Missing							2	

Table 7
Descriptive Statistics on Item 7

We always have to make trade-offs (compromises) between the positive and negative effects of science and technology.

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		21	15.2	11	8.0	21	17.2	16	13.1
E.	there are always trade-offs...but the trade-offs make no sense. (For example: Why invent labor saving devices which cause more unemployment? or Why defend a country with nuclear weapons which threatens life on earth?)	7	5.1	6	4.3	14	11.5	9	7.4
F.	there are NOT always trade-offs...because some new developments benefit us without producing negative effects.	10	7.2	4	2.9	2	1.6	3	2.5
H.	there are NOT always trade-offs...because negative effects can be <u>eliminated</u> through careful planning and testing. Otherwise, a new development is not used.	2	1.4	0	0	2	1.6	2	1.6
I.	I don't understand.	0	0	0	0	0	0	0	0
J.	I don't know enough ...	2	1.4	1	0.7	3	2.5	2	1.6
Has Merit		49	35.5	8	5.8	30	24.6	39	32.0
D.	there are always trade-offs...because you can't get positive results without first trying a new idea and then working out its negative effects.	20	14.5	8	5.8	15	12.3	21	17.2
G.	there are NOT always trade-offs...because negative effects can be <u>minimized</u> through careful planning and testing.	29	21.0	0	0	15	12.3	18	14.8

Table 7 (con't)

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Realistic		60	43.5	113	81.9	69	56.6	62	50.8
A.	There are always trade-offs...because every new development has at least one negative result. If we didn't put up with the negative results, we would not progress to enjoy the benefits.	10	7.2	30	21.7	23	18.9	22	18.0
B.	there are always trade-offs...because scientists cannot predict the long-term effects of new developments, in spite of careful planning and testing. We have to take the chance.	30	21.7	37	26.8	22	18.0	20	16.4
C.	there are always trade-offs...because things that benefit some people will be negative for someone else. This depends on a person's viewpoint.	20	14.5	46	33.3	24	19.7	20	16.4
K.	None of these choices ...	8	5.8	6	4.3	2	1.6	5	4.1

Table 8
Descriptive Statistics on Item 8

More money should be spent on science and technology in the U.S. even though this money will not be available for other things, such as social programs, education, business incentives and lower taxes.

Choice	STS				PHYSICS			
	pretest		posttest		pretest		posttest	
	f	%	f	%	f	%	f	%
Naive	37	27.0	19	14.0	27	22.1	25	20.7
E. MORE money should be spent...so that American's daily lives can be improved; for example, by making things easier to do, creating new industries and jobs, helping the economy, and solving health problems.	15	10.9	7	5.1	9	7.4	7	5.7
C. MORE money should be spent...but only if the money is spent on such things as curing diseases, working on pollution or improving the food supply for the starving.	18	13.0	10	7.3	17	13.9	18	14.8
F. I don't understand.	0	0	0	0	0	0	0	0
G. I don't know enough ...	4	2.9	2	1.5	1	0.8	0	0
Has Merit	15	10.9	41	30.1	18	14.8	20	16.5
A. MORE money should be spent...so that the U.S. can be competitive with the rest of the world.	10	7.2	7	5.1	3	2.5	4	3.3
E. LESS money should be spent on science and technology so more money is available for such things as social programs, education, business incentives and lower taxes.	5	3.6	34	24.8	15	12.3	16	13.1
Realistic	77	56.2	62	45.6	70	57.4	68	56.2
D. the money should be spent in a balanced way as it is today. Science and technology are very important but they are not the only things that need money for progress in the U.S.	77	55.8	62	45.3	70	57.4	68	55.7
H. None of these choices ...	8	5.8	14	10.2	7	5.7	8	6.6
Missing	1		2				1	

Table 9
Descriptive Statistics on Item 9

When scientists disagree on an issue (for example, whether or not low-level radiation is harmful), they disagree mostly because they do NOT have all the facts. Such scientific opinion has NOTHING to do with moral values (right or wrong conduct) or with personal motives (personal recognition, pleasing employers, or pleasing funding agencies). Disagreements among scientists can occur:

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		30	21.7	34	24.8	32	26.2	38	31.1
B.	because different scientists are aware of different facts. Scientific opinion is based entirely on a <u>scientist's awareness</u> of the facts.	5	3.6	2	1.5	9	7.4	7	5.7
C.	when different scientists interpret the facts differently (or interpret the significance of the facts differently), this happens because of different scientific theories, <u>not</u> because of moral values or personal motives.	23	16.7	29	21.2	18	14.8	23	18.9
G.	because they have been influenced by companies or governments.	1	0.7	1	0.7	0	0	0	0
A.	I don't understand.	0	0	0	0	0	0	0	0
B.	I don't know enough ...	1	0.7	2	1.5	5	4.1	8	6.6
Has Merit		21	15.2	14	10.2	20	16.4	16	13.1
A.	because not all the facts have been discovered. Scientific opinion is based entirelv on observable facts and scientific understanding.	9	6.5	5	3.6	11	9.0	3	2.5
F.	when different scientists <u>interpret</u> the facts differently (or interpret the significance of the facts differently), this happens <u>mostly</u> because of personal opinions, moral values, personal priorities, or politics. (Often the disagreement is over possible risks and benefits to society.)	12	8.7	9	6.6	9	7.4	13	10.7

Table 9 (con't)

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Realistic		85	61.6	84	61.3	70	57.4	66	54.1
D.	mostly because of different or incomplete facts, but partly because of scientists' personal opinions, moral values, or personal motives.	13	9.4	15	10.9	13	10.7	8	6.6
E.	for a number of reasons--any combination of the following: lack of facts, misinformation, different theories, personal opinions, moral values, public recognition, and pressure from companies or governments.	72	52.2	69	59.4	57	46.7	58	47.5
C.	none of these choices ...	2	1.4	5	3.6	0	0	2	1.6
	Missing			1					

Table 10
Descriptive Statistics on Item 10

When a new technology is developed (for example, a better type of fertilizer), it may or may not be put into practice. The decision to use a new technology depends on whether the advantages to society outweigh the disadvantages to society.

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		2	1.5	2	1.4	4	3.3	2	1.7
E.	I don't understand.	0	0	1	0.7	0	0	0	0
F.	I don't know enough ...	2	1.5	1	0.7	4	3.3	2	1.7
Has Merit		40	29.2	50	36.2	33	27.0	45	37.2
A.	the decision to use a new technology depends mainly on the benefits to society, because if there are too many disadvantages, society won't accept it and may discourage its further development.	24	17.5	27	19.6	23	18.9	27	22.3
C.	it depends on your point of view. What is an advantage to some people may be a disadvantage to others.	16	11.7	23	16.7	10	8.2	18	14.9
Realistic		88	64.2	79	57.2	80	65.6	69	57.0
B.	the decision depends on more than just the technology's advantages and disadvantages. It depends on how well it works, its cost, and its efficiency.	67	48.9	60	43.5	61	50.0	50	41.3
D.	many new technologies have been put into practice to make money or gain power, even though their disadvantages were greater than their advantages.	21	15.3	19	13.8	19	15.6	19	15.7
G.	None of these choices ...	7	5.1	7	5.1	5	4.1	5	4.1
	Missing	1							

Table 11
Descriptive Statistics on Item 11

Technological developments can be controlled by citizens.

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		3	2.2	2	1.4	6	4.9	5	4.2
H.	I don't understand.	0	0	1	0.7	1	0.8	0	0
I.	I don't know enough ...	3	2.2	1	0.7	5	4.1	5	4.2
Has Merit		68	50.0	44	31.9	59	48.4	62	51.7
A.	yes, because from the citizen population comes each generation of the scientists and technologists who will develop the technology. Thus citizens slowly control the advances in technology through time.	4	2.9	4	2.9	11	9.0	4	3.3
B.	yes, because technological advances are sponsored by the government. By electing the government, citizens can control what is sponsored.	8	5.9	10	7.2	5	4.1	7	5.8
D.	yes, but only when it comes to putting new developments into use. Citizens cannot control the original development itself.	14	10.3	11	8.0	12	9.8	11	9.2
F.	no, citizens are NOT involved in controlling technological developments, because technology advances so rapidly that the average citizen is left ignorant of the development.	33	24.3	16	11.6	22	18.0	31	25.8
G.	no, citizens are NOT involved in controlling technological developments, because citizens are prevented from doing so by those with the power to develop the technology.	9	6.6	3	2.2	9	7.4	9	7.5

Table 11 (con't)

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Realistic		57	41.9	80	58.0	45	36.9	45	37.5
C.	yes, because technology serves the needs of consumers. Technological developments will occur in areas of high demand and where profits can be made in the market place.	42	30.9	50	36.2	35	28.7	35	29.2
E.	yes, but only when citizens get together and speak out, either for or against a new development. Organized people can change just about anything.	15	11.0	30	21.7	10	8.2	10	8.3
J.	None of these choices ...	8	5.9	12	8.7	12	9.8	8	6.7
	Missing	2						2	

Table 12
Descriptive Statistics on Item 12

More technology will improve the standard of living for Americans.

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		7	5.1	25	18.2	13	10.7	8	6.7
F.	no. We are irresponsible with the technology we have now; for example, our production of weapons and using our natural resources.	5	3.7	21	15.2	11	9.0	7	5.8
G.	I don't understand.	0	0	1	0.7	0	0	0	0
H.	I don't know enough ...	2	1.5	3	2.2	2	1.6	1	0.8
Has Merit		37	27.2	15	10.9	18	14.8	19	15.8
A.	yes, because technology has always improved the standard of living, and there is no reason for it to stop now.	4	2.9	2	1.4	3	2.5	3	2.5
B.	yes, because the more we know, the better we can solve our problems and take care of ourselves.	18	13.2	2	1.4	3	2.5	7	5.8
C.	yes, because technology creates jobs and prosperity. Technology helps life become easier, more efficient and more fun.	9	6.6	1	0.7	4	3.3	4	3.3
D.	yes, but only for those who can afford to use it. More technology will cut jobs and cause more people to fall below the poverty line.	6	4.4	10	7.2	8	6.6	5	4.2
Realistic		81	59.6	86	62.8	82	67.2	86	71.7
E.	yes and no. More technology would make life easier, healthier, and more efficient. BUT more technology would cause more pollution, unemployment and other problems. The standard of living may improve, but the quality of life may not.	81	59.6	86	62.3	82	67.2	86	71.7
I.	None of these choices ...	11	8.1	11	8.0	9	7.4	7	5.8
	Missing	2		1				2	

Table 13
Descriptive Statistics on Item 13

Community or government agencies should tell scientists what to investigate; otherwise scientists will investigate what is of interest only to them.

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		11	8.2	6	4.4	16	13.1	16	13.2
A.	community or government agencies should tell scientists what to investigate, so that the scientists' work can help improve society.	2	1.5	3	2.2	8	6.6	7	5.8
F.	scientists should decide what to investigate, because they alone know what needs to be studied. Governments often put their own interests ahead of society's needs.	6	4.5	2	1.5	4	3.3	4	3.3
H.	I don't understand.	0	0	0	0	0	0	1	0.8
I.	I don't know enough ...	3	2.2	1	0.7	4	3.3	4	3.3
Has Merit		98	73.1	96	71.1	77	63.1	77	63.6
B.	community or government agencies should tell scientists what to investigate, only for important public problems; otherwise scientists should decide what to investigate.	10	7.5	8	5.9	6	4.9	5	4.1
C.	all parties should have an equal say. Government agencies and scientists together should decide what needs to be studied, even though scientists are usually informed about society's needs.	45	33.6	57	42.2	46	37.7	40	33.1
E.	scientists should mostly decide because they know best which areas are ready for a break-through, which areas have the experts available, which areas have the available technology, and which areas have the greatest chance of helping society.	19	14.2	13	9.6	11	9.0	19	15.7
G.	scientists should be free to decide what to investigate, because they must be interested in their work in order to be creative and successful.	24	17.9	18	13.3	14	11.5	13	10.7

Table 13 (con't)

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Realistic		20	14.9	17	12.6	18	14.8	19	15.7
D.	scientists should <u>mostly</u> decide what to investigate, because they know what needs to be studied. Community or government agencies usually know little about science; their advice, however, might sometimes be helpful.	20	14.9	17	12.6	18	14.8	19	15.7
J.	None of these choices ...	5	3.7	16	11.9	11	9.0	9	7.4
	Missing	4		3				1	

Table 14
Descriptive Statistics on Item 14

Scientific research would be better off in the U.S. if the research were more closely controlled by corporations (for example, companies in high-technology, communications, pharmaceuticals, forestry, mining, manufacturing).

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		20	14.8	19	14.3	12	9.8	16	13.6
A.	corporations <u>should</u> mainly control science, because closer control by corporations would make science more useful and cause discoveries to be made more quickly through faster communication, better funding and more competition.	7	5.2	13	9.8	5	4.1	6	5.1
B.	corporations <u>should</u> mainly control science, in order to improve the cooperation between science and technology, and thus solve problems together.	11	8.1	2	1.5	2	1.6	2	1.2
G.	I don't understand.	1	0.7	2	1.5	0	0	1	0.8
H.	I don't know enough ...	1	0.7	2	1.5	5	4.1	7	5.9
Has Merit		49	36.3	30	22.6	43	35.2	35	29.7
C.	corporations <u>should</u> mainly control science, but the public or government agencies should have a say on what science tries to achieve.	6	4.4	9	6.8	4	3.3	5	4.2
E.	Corporations should <u>not</u> control science, because if corporations did, corporations would obstruct scientists from investigating important problems which the companies wanted kept quiet; for example, pollution by the corporation.	20	14.8	12	9.0	23	18.9	15	12.7
F.	science cannot be controlled by corporations. No one, not even the scientist, can control what science will discover.	23	17.0	9	6.8	16	13.1	15	12.7

Table 14 (con't)

Choice	STS				PHYSICS			
	pretest		posttest		pretest		posttest	
	f	%	f	%	f	%	f	%
Realistic	58	43.0	60	45.1	61	50.0	62	52.5
D. corporations should not control science, because if corporations did, scientific discoveries would be restricted to those discoveries that benefit the corporation (for example, making a profit). Important scientific discoveries that benefit the public are made by unrestricted pure science.	58	43.0	60	45.1	61	50.0	62	52.5
I. None of these choices ...	8	5.9	24	18.0	6	4.9	5	4.2
Missing	3		5				4	

Table 15
Descriptive Statistics on Item 15

Scientists and engineers should be the ones to decide on world food production and food distribution (for example, what crops to plant, where best to plant them, how to transport food efficiently, how to get food to those who need it, etc.) because scientists and engineers are the people who know the facts best.

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		16	11.9	16	12.2	14	11.5	22	18.5
A.	scientists and engineers should decide, because they have the training and facts which give them a better understanding of the issue.	3	2.2	6	4.6	3	2.5	2	1.7
B.	scientists and engineers should decide, because they have the knowledge and can make better decisions than government bureaucrats or private companies, both of whom have vested interests.	9	6.7	5	3.8	7	5.7	13	10.9
G.	the <u>public</u> should decide because the public serves as a check on the scientists and engineers. Scientists and engineers have idealistic and narrow views on the issue and thus pay little attention to consequences.	1	0.7	4	3.1	2	1.6	1	0.8
H.	I don't understand.	0	0	0	0	0	0	1	0.8
I.	I don't know enough ...	3	2.2	1	0.8	2	1.6	5	4.2
Has Merit		38	28.4	38	29.0	32	26.2	26	21.8
C.	scientists and engineers should decide, because they have the training and facts which give them a better understanding; BUT the public should be involved--either informed or consulted.	21	15.7	17	13.0	22	18.0	14	11.8
E.	the <u>government</u> should decide because the issue is basically a political one; BUT scientists and engineers should give advice.	8	6.0	4	3.1	3	2.5	3	2.5
F.	the <u>public</u> should decide because the decision affects everyone; BUT scientists and engineers should give advice.	9	6.7	17	13.0	7	5.7	9	7.6

Table 15 (con't)

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Realistic		76	56.7	70	53.4	70	57.4	63	52.9
D.	the decision should be <u>made equally</u>; viewpoints of scientists and engineers, other specialists, and the <u>informed</u> public should all be considered in decisions which affect our society.	76	56.7	70	53.4	70	57.4	63	52.9
J.	None of these choices ...	4	3.0	7	5.3	6	4.9	8	6.7
	Missing	4		7				3	

Table 16
Descriptive Statistics on Item 16

Science and technology offer a great deal of help in resolving such social problems as pollution and overpopulation.

Choice		STS				PHYSICS			
		pretest		posttest		pretest		posttest	
		f	%	f	%	f	%	f	%
Naive		8	6.0	9	7.1	9	7.4	10	8.4
E.	it's hard to see how science and technology could help very much in resolving these social problems. Social problems concern human nature; these problems have little to do with science and technology.	4	3.0	4	3.1	6	4.9	5	4.2
F.	science and technology only make social problems worse. It's the price we pay for advances in science and technology.	1	0.8	4	3.1	3	2.5	2	1.7
G.	I don't understand.	0	0	0	0	0	0	1	0.8
H.	I don't know enough ...	3	2.3	1	0.8	0	0	2	1.7
Has Merit		99	74.4	98	77.2	88	72.1	82	68.9
C.	science and technology solve many social problems, but science and technology also <u>cause</u> many of these problems.	45	33.8	55	43.0	42	34.4	45	37.8
D.	it's not a question of science and technology helping, but rather it's a question of <u>people</u> using science and technology wisely.	54	40.6	43	33.6	46	37.7	37	31.1
Realistic		25	18.8	12	9.4	21	17.2	23	19.3
A.	science and technology can certainly help to resolve these problems. The problems could use new ideas from science and new inventions from technology.	12	9.0	3	2.3	14	11.5	13	10.9
B.	Science and technology can help resolve some social problems but not others.	13	9.8	9	7.0	7	5.7	10	8.4
I.	None of these choices ...	1	0.8	8	6.3	4	3.3	4	3.4
	Missing	5		11		0		3	

Table 17
T-test Analysis of the Mean Change Scores

Sample	n	Mean	Std error	t	p
STS	138	0.43	0.27	1.59	0.115
Physics	122	-0.08	0.33	-0.25	0.802

Table 18
McNemar's Analysis for Item Response Distribution

Item	McNemar's Statistic							
	STS				PHYSICS			
	U	S	D	X^2 df=1	U	S	D	x^2 df=1
1	17	76	34	5.67*	25	64	20	1.80
2	26	71	35	1.33	23	67	26	0.18
3	24	72	32	1.14	14	70	30	5.82*
4	24	56	50	9.13**	30	65	21	1.59
5	42	67	15	12.79***	28	63	25	0.17
6	22	85	9	5.45*	22	66	19	0.22
7	53	64	9	31.23***	26	63	28	0.07
8	32	52	32	0.00	22	65	23	0.02
9	27	64	29	0.07	27	48	30	0.16
10	19	82	24	0.58	14	75	23	2.19
11	32	74	13	8.02**	22	61	21	0.02
12	21	70	26	0.53	18	75	14	0.50
13	15	81	17	0.12	18	69	17	0.03
14	30	49	24	0.647	27	58	25	0.08
15	27	59	34	0.80	25	52	31	0.64
16	9	84	22	5.45*	20	74	18	0.10

*p<.05; **p<.01; ***p<.001.