The Development of a New Instrument: "Views on Science-Technology-Society" (VOSTS)

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INTRODUCTION

Educators who plan science lessons, who develop science curricula, or who evaluate learning, often wonder about students' preconceptions of the material to be taught. Until now, attention has mainly focused on traditional science content (Driver, 1988; West and Pines, 1985). However, content related to the nature of science (for example, science's epistemology and its social context) is receiving increased attention because of interest in teaching science through a science-technology-society (STS) approach or teaching science in concert with the history and philosophy of science (Bybee, 1987; Hodson, 1988; Posner and Strike, 1989; Gruender and Tobin, 1991);

What are high school students' preconceptions concerning the epistemology and sociology of science? This question is addressed in two related articles that stem from the same research study. This first article describes the development of a new research instrument that monitors students' views on a broad range of STS topics, *Views on Science-Technology-Society* (VOSTS). The second article (Ryan and Aikenhead, in press) reports on how this instrument illuminates high school students' views on several topics associated with the epistemology of science.

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THE STUDY

The research project produced a new assessment instrument dealing with STS topics, *Views on Science-Technology-Society* (VOSTS) (Aikenhead and Ryan, 1989; Aikenhead et al., 1989b). VOSTS is a pool of 114 multiple-choice items that address a broad range of STS topics. The items were developed empirically over a six-year period with grade 11 and 12 Canadian students (described below). A detailed rationale for the VOSTS project is found elsewhere (Aikenhead et al., 1987; Aikenhead, 1988); an overview is provided here.

Rationale for a New Type of Instrument

Several standardized instruments have been used over the decades to assess student understanding of topics related to the epistemology and sociology of science (Aikenhead et al., 1987). However, these instruments have, by and large, been used with the erroneous assumption that students perceive and interpret the test statements in the same way as researchers do. This assumption of no ambiguity has been a traditional problem for science education researchers (Aikenhead, 1972, ch. 7; Gardner, 1987; Lederman and O'Malley, 1990). Ambiguity undermines test validity (Roid and Haladyna, 1981). An example will clarify this.

"Scientific knowledge is tentative" was a statement on the *Science Process Inventory* (SPI) (Welch, 1966) with which high school students were asked to agree or disagree. Aikenhead (1979) discovered that when offered the chance to respond "I do not understand," more than a quarter of grade 11 and 12 students did so. Therefore, whenever students responded "agree" or "disagree" to the SPI item "scientific knowledge is tentative," a number of those students simply did not understand what the statement meant. Yet the students' responses were grist for the psychometric mill of data analysis from which conclusions were formulated about what students believed. In an attempt to rectify this problem, Aikenhead et al. (1987) investigated what knowledge could be garnered from reading students' paragraph responses to items that previously had a Likert-type response format, for instance, the SPI statement above. After analyzing over 400 paragraph responses to statements on the topic of the tentativeness of science (although the term "tentative" was not mentioned in the wording of the statements), Aikenhead (1987) concluded that almost all students expressed viewpoints consistent with the tentativeness of science, but their underlying reasons belied a simple portrayal of those viewpoints:

> Their reasons varied widely and in contradictory ways: a reconstructionist view (about 45%), a cumulative view (roughly 20%), and an exclusively technological view (about 20%). (p. 484)

The results showed that there were at least three sets of reasons for students believing that scientific knowledge is tentative. Simply knowing that a student agreed with the VOSTS statement does not reveal unambiguously what the student meant.

In a more recent study of students' views on the tentativeness of science, Lederman and O'Malley (1990) identified the problem of language when they concluded, "Language is often used differently by students and researchers and this mismatch has almost certainly led to misinterpretations of students' perceptions in the past" (p. 237).

The problem of language was investigated in terms of the ambiguity harbored by four different response formats: Likert-type, written paragraph, semistructured interview, and empirically derived multiple-choice items (Aikenhead, 1988). Ambiguity was measured by the discrepancy between students' written responses (Likert-type, paragraphs, and multiple choice) and their interview responses. Four conclusions were reached:

1. "Likert-type responses offer only a guess at student beliefs, and the chances of an evaluator guessing accurately are very remote" (p. 615). Ambiguity often reached the 80% level.
2. For paragraph responses, "ambiguity lingered at approximately the 35% to 50% level" (p. 624). This was better than Likert-type responses. The ambiguity derived from the fact that some students tended to write incomplete or inarticulate paragraphs.
3. Semistructured interviews predictably "offered the most lucid and accurate data" (p. 625), but a great deal of time was needed to gather and analyze the data. Ambiguity was only about 5%.
4. "The empirically derived, multiple-choice response mode reduced the ambiguity to the 15 to 20% level." (p. 625)

Therefore, the original problem of ambiguity (researchers assuming that there is no ambiguity) can be effectively diminished by using empirically derived, multiple-choice items.

This research led directly to the development of VOSTS items--developed by producing choices empirically derived from students' writing and from a sequence of interviews. Before describing this development process, however, some general features of VOSTS are clarified in the following section. These characteristics support the claim that VOSTS is a new generation instrument.

General Characteristics of VOSTS

VOSTS is fundamentally different from instruments developed in the past. This difference is revealed by contrasting (1) the conventional psychometric perspective of earlier instruments, and (2) the "empirically derived" character of VOSTS. Within a conventional framework, researchers obtain test scores based on the fact that student responses are scored as correct or incorrect, or scaled in terms of a Likert-type response. Test scores can be used in parametric analyses to determine statistically significant differences, for instance, among groups of students, between pretest and posttest administrations of the instrument, or between a sample and its population. VOSTS, on the other hand, is a very different instrument. VOSTS conveys students' ideas, not numerical scores. The domain of the possible responses to a VOSTS item derives not from a theoretical or researcher-based viewpoint (as does the domain of the distractors in a multiple-choice item, for example) but empirically from the domain of student viewpoints. Student responses to VOSTS are qualitative data-student response patterns (Ryan and Aikenhead, in press). As will be discussed later, this shift in emphasis has implications when the issue of the instrument's validity is addressed.

The Development of a VOSTS Item

The specifics of how to develop an empirically derived item are given here. Sufficient detail is provided to enable the reader to understand the process and the conceptual issues involved in the development phase; those wishing to construct items for themselves are invited to contact the first author for further technical information. The process takes place in five steps. A summary of each step may be found at the conclusion to each subsection.

Step 1. The content for VOSTS statements is defined by the domain of science-technology-society (STS) content appropriate for high school students. This content was, in part, based on the theoretical models that validated the standardized instruments used in earlier years (Aikenhead et al., 1987). VOSTS content was also based on more recent literature concerning the epistemological, social, and technological aspects of science; for example, journals such as *Science, Technology & Human Values,* or *Bulletin of Science, Technology & Society,* and books or articles such as Barnes (1985), Barnes and Edge (1982), Fleming (1989), Gauld (1982), Holton (1978), Kuhn (1970), Snow (1987), and Ziman (1980, 1984).

A conceptual outline of the VOSTS content is shown in Table 1. In the future, the number of topics within each major section can expand, as can the number of sections themselves. In fact, at the present time, section three has been left blank in order to leave room for future development.

The numbering system in Table 1 defines the numbering system for the VOSTS item pool. Each VOSTS item is assigned a five-digit code; for example 90521. The first digit (9) corresponds to section nine in Table 1 ("epistemology"). The next two digits (05) refer to the topic number within that major section ("hypotheses, theories, and laws"). The fourth digit (2) indicates the item number within that topic. For instance, 90521 is the second item for topic "hypotheses, theories, and laws." Lastly, the fifth digit differentiates items that have slight but meaningful (as evidenced by student responses) variations in their wording, such as a different example or a different key word. Thus, item 90523 would have a small but meaningful change in its wording compared with item 90521. Only a few VOSTS items are like this.

VOSTS statements emphasize cognition (reasoned arguments) over affect (personal feelings). (The distinction can often be extremely fuzzy; Gardner, 1975; Schibeci, 1984.) Attention is not given to students' feelings about global or regional issues. Instead, VOSTS items focus on the reasons that students give to justify an opinion-their informed viewpoints, their cognitive beliefs.

The initial process of composing a VOSTS statement does not follow a particular formula. The goal is to write a clear statement on a well-defined issue, encouraging cognition over affect.

TABLE 1
VOSTS Conceptual Scheme

Definitions

1. <u>Science and Technology</u>

- 01. Defining science (e.g., instrumentalism, curiosity satisfaction, social enterprise).
- 02. Defining technology (e.g., social and human purposes; hardware, socioeconomic & cultural components).
- 03. Defining research & development (R&D).
- 04. Interdependence of science & technology (e.g., rejection that technology is simply applied science).

External Sociology of Science

2. <u>Influence of Society on Science/Technology</u>

- 01. Government (e.g., control over funding, policy & science activities; influence of politics).
- 02. Industry (e.g., corporate control dictated by profits).
- 03. Military (e.g., utilization of scientific human resources).
- 04. Ethics (e.g., influence on research program).
- 05. Education institutions (e.g., mandatory science education).
- 06. Special interest groups (e.g., health societies; nongovernmental & nonindustrial groups).
- 07. Public influence on scientists (e.g., upbringing, social interactions).

3. (future category)

4. <u>Influence of Science/Technology on Society</u>

- 01. Social responsibility of scientists/technologists (e.g., communicating with public, concern & accountability for risks & pollution, "whistle blowing").
- 02. Contribution to social decisions (e.g., technocratic vs. democratic decision making, moral & legal decisions, expert testimony, lobbying for funds).
- 03. Creation of social problems (e.g., trade-offs between positive & negative consequences, competition for funds).
- 04. Resolution of social & practical problems (e.g., technological fix; everyday type of problems).
- 05. Contribution to economic well-being (e.g., wealth & jobs).
- 06. Contribution to military power.
- 07. Contribution to social thinking (e.g., lexicon, metaphors).

5. <u>Influence of School Science on Society</u>

- 01. Bridging C. P. Snow's two cultures.
- 02. Social empowerment (e.g., consumer decisions).
- 03. School characterization of science.

TABLE 1 (Continued from previous page.)

Internal Sociology of Science

6. Characteristics of Scientists

- 01. Personal motivation of scientists.
- 02. Standards/values that guide scientists at work & home (e.g., open-mindedness, logicality, honesty, objectivity, skepticism, suspension of belief; as well as the opposite values: closed-mindedness, subjectivity, etc.).
- 03. Ideologies of scientists (e.g., religious views).
- 04. Abilities needed to do science (e.g., commitment, patience).
- 05. Gender effect on the process & product of science.
- 06. Underrepresentation of females.

7. Social Construction of Scientific Knowledge

- 01. Collectivization of science (e.g., loyalties to research team & employer).
- 02. Scientific decisions (e.g., disagreements among scientists, consensus making).
- 03. Professional communication among scientists (e.g., peer review, journals, press conferences).
- 04. Professional interaction in the face of competition (e.g., politics, secrecy, plagia rism).
- 05. Social interactions.
- 06. Individual's influence on scientific knowledge.
- 07. National influence on scientific knowledge & technique.
- 08. Private vs. public science.

8. Social Construction of Technology

- 01. Technological decisions.
- 02. Autonomous technology (e.g., technological imperative).

Epistemology

9. Nature of Scientific Knowledge

- 01. Nature of observations (e.g., theory ladenness, perception bound).
- 02. Nature of scientific models.
- 03. Nature of classification schemes.
- 04. Tentativeness of scientific knowledge.
- 05. Hypotheses, theories & laws (e.g., definition, role of assumptions, criteria for belief).
- 06. Scientific approach to investigations (e.g., nonlinearity, rejection of a stepwise procedure, "the scientific method" as a writing style).
- 07. Precision & uncertainty in scientific/technological knowledge (e.g., probabilistic reasoning).
- 08. Logical reasoning (e.g., cause/effect problems, epidemiology & etiology).
- 09. Fundamental assumptions for all science (e.g., uniformitarianism).
- 10. Epistemological status of scientific knowledge (e.g., ontology as an assumption, questioning logical positivism).
- 11. Paradigms vs. coherence of concepts across disciplines.

For every VOSTS statement, a converse statement is written, a procedure suggested by Moore and Sutman (1970). In some cases this simply means casting the statement in the negative. In other cases it means composing the opposite view. For example, if a democratic view on decision making was the focus of the initial statement, a technocratic view was written as the converse. This is illustrated by the following two statements:

> Scientists and engineers should be the last people to be given the authority to decide what types of energy Canada will use in the future (e.g., nuclear, hydro, solar, coal burning, etc.). Because the decision affects everyone in Canada, the public should be the ones to decide.

> Scientists and engineers should be given the authority to decide what types of energy Canada will use in the future (e.g., nuclear, hydro, solar, coal burning, etc.) because scientists and engineers are the people who know the facts best.

By changing the issue from energy to pollution standards, biotechnology, or building a nuclear reactor, other pairs of items were developed.

Each statement is then typed onto a standard student answer sheet. To ensure that students compose an *argumentative* paragraph response to a statement, they are asked to complete two tasks. The first task is to check a box to indicate whether they agree or disagree with the statement, or whether they cannot decide. The second task is to write, in the space provided on the answer sheet, a paragraph which justifies their choice in the first task. It is these paragraph responses which constitute the data for the subsequent steps.

In summary, the first step toward developing a VOSTS item is to compose one statement that addresses an STS topic and a second statement that expresses the opposite point of view. In response to one of these VOSTS statements, students check off a three-point scale (agree, disagree, cannot tell) and then write a paragraph justifying their choice.

Step 2. The argumentative paragraphs written by the students in step 1 are analyzed to discern common arguments or common justifications. The paragraph analysis identifies categories ("student positions") that represent common viewpoints or beliefs. These student positions should paraphrase the students' writing and adopt the students' vernacular as much as possible. The analysis of the paragraphs is the most difficult and most labor-intensive part of the entire process. In effect, the analysis yields a crude draft of an empirically developed multiple-choice item, designated "form mc.l."

For each VOSTS statement pair, 50 to 70 paragraphs are usually sufficient to ensure "theoretical saturation" of the categories that emerge (Glaser and Strauss, 1967). A *diversity* of students must be enlisted in order to capture a diversity of responses. The VOSTS project used a stratified sampling of a cross section of students from grades 11 and 12 (average age was 17.3 years) representing all regions of Canada (described below). The VOSTS project also involved three researchers in the analysis of the paragraphs. The researchers generally had different orientations toward STS topics. Two analyzers would discuss the analysis of the third. As a consequence of this discussion, sometimes the student positions were completely reworked. On most occasions, less drastic modifications were made. In all cases consensus was achieved. The average interjudge reliability on the eventual positions was 84% agreement. Without this public deliberation over the existence and wording of categories, evaluator bias could cause problems.

The precise wording of the VOSTS statement itself must also be determined. The paragraph responses for each statement are examined to uncover problems that would eliminate one of the two versions. Sometimes the student paragraphs indicate an inherent misunderstanding in one of the two statements, thus directing the evaluator to choose the other statement. In a few instances, the paragraph responses suggested that students were writing socially desirable responses to one of the versions; that version was eliminated. Also, at this stage students' paragraphs can directly or indirectly suggest ways to clarify the wording of the statement. As an example, the final version of the two statements quoted in Step 1 above was Item 40211:

> Scientists and engineers should be the ones to decide what types of energy Canada will use in the future (e.g., nuclear, hydro, solar, coal burning, etc.) because scientists and engineers are the people who know the facts best.

Next, the students' positions are recast into a more traditional multiple-choice style (for example, parallel sentence structure), without altering the original student paraphrases, but staying within the guidelines of appropriate vocabulary and sentence structure (Roid and Haladyna, 1981). The sequence of the student positions within each item should be carefully thought out. Usually the student positions range from one extreme (the one represented by the VOSTS statement) to the opposite extreme. The visual layout of a VOSTS item was originally determined by student suggestions offered during interviews. Recasting the item into a more traditional style yields form mc.2.

The number of student positions for a VOSTS item typically varies between five and 13. Three additional choices are always added in order to represent other possible responses:

> I don't understand.
> I don't know enough about this subject to make a choice. None of these choices fits my basic viewpoint.

The last of these three will provide a measure of how well the student positions represent student viewpoints.

In summary, the evaluator analyzes 50 to 70 paragraphs written in response to two statements representing both sides of an issue. The evaluator attempts to find common arguments or viewpoints expressed by the students (Aikenhead et al., 1987). These common arguments, called "student positions," are written in the students' language as much as possible. This form of the item, a very crude multiple choice, is designated "form mc.l." The student positions are then edited so they conform to a multiple-choice format. This editing results in form mc.2. One of the two initial statements is selected to become the item's statement.

Step 3. The next step is to obtain empirical feedback on how well form mc.2 of a VOSTS item captures the views that students were attempting to express in their paragraphs. Approximately 10 students per item participate in a semistructured interview. Again, diversity of student abilities yields a richer sampling of viewpoints.

Students first write paragraph responses to four VOSTS statements, justifying their initial reaction to the STS topics in a manner identical to step 1. Then the students read the multiple choice (form mc.2) for those same items and choose the "student position" that best expresses what they wanted to express in their paragraph.

Next, the evaluator reads a student's paragraph and categorizes it according to the student positions of the multiple choice. This analysis is then compared with the choice actually made by the student. Discrepancies are used to structure the interviews that ensue.

Interviews take place within a week of the writing session. The interview begins by a student rereading the VOSTS statement and his or her paragraph. The evaluator has the student discuss his or her interpretation of the VOSTS statement and clarify, if necessary, the view expressed in his or her paragraph. Then the student rereads the student positions for the same statement and the choice he or she had made. The evaluator asks about any perceived discrepancy between the paragraph response and the multiple-choice response. Other issues may be explored, too. The student may be asked to express his or her understanding of the student positions lying close to the one chosen, in order to discover if the various choices reflect the same differences in the mind of the student as they do in the mind of the evaluator. If any wording seems unclear to a student, he or she is asked how the wording might be improved. Students tend to give excellent suggestions, especially students who have some difficulty in reading. The layout of VOSTS items, for instance, came from the suggestions made by students. Although the layout is often contrary to conventional prescriptions for test construction, the VOSTS layout ensures better student comprehension.

The semistructured interviews provide data that guide the evaluator to construct items containing the least amount of ambiguity. As a result of these interviews, modifications are made to the VOSTS item yielding form mc.3.

In summary, students (about 10 per item) who did not participate in step 2 respond to the revised VOSTS statement in two ways: first, by writing a paragraph response, and then, second, by choosing one of the student positions in mc.2. This is followed by an interview to determine how well the wording of the multiple choice captured the students' viewpoints. The wording of the choices is revised and the item is polished into form mc.3.

Step 4. With a different group of students (about 10 per VOSTS item), the evaluator goes through one last check on the clarity of each item. In the presence of the evaluator, a student works through several VOSTS items expressing his or her thoughts verbally as each choice is considered. This allows the evaluator to tell if the student makes the same distinctions between the choices as the evaluator makes. In other words, the evaluator checks whether the meaning ascribed to the phrases in the item *by the student* corresponds to the meaning ascribed to the phrase *by the evaluator*. Students also comment on the clarity of the student positions, the suitability of the physical layout of the items, and the ease of responding.

Sometimes there is no need to make any revisions to an item at this stage, but usually there are a few minor as well as the occasional major improvement. The resulting form mc.4 is ready for the next step in the development of a VOSTS item.

In summary, a new group of students, working individually in the company of an evaluator, goes through the revised multiple-choice VOSTS item talking aloud about the choices made. This allows the evaluator to polish the item's wording for greater precision (into form mc.4).

Step 5. The last step in the development of a VOSTS items entails surveying a large sample of students for the purposes of (1) shortening an item by deleting student positions that receive a very low response; and (2) establishing baseline data against which other educators can compare their VOSTS results. An optical scan answer sheet was specially developed to facilitate the gathering of the data.

In the VOSTS project, a large sample of about 5000 students (described below) responded to form mc.4 of VOSTS. These students represented a cross section of Canadian 16- and 17-year-olds from every region of Canada. Based on the responses to form mc.4, some VOSTS items were shortened by eliminating one or two student positions that received less than four percent (an arbitrary figure) of the student response and that did not provide interesting feedback to the science educator. Low student response was not in itself a sufficient reason for deleting a position. An example will illustrate the point. An item concerning the political isolation of scientists from their society (item 20141) ended with the student position, "Scientists are NOT affected by their country's politics because scientists are isolated from their society." Although no students chose this position, it was left in the item because it represents a viewpoint opposite to the original statement. Its inclusion maintained a spectrum of positions within the item.

In summary, a large sample of students responds to the VOSTS item. Student positions in mc.4 that receive little or no student response and that do not provide interesting feedback are eliminated. This shortens the length of the item as much as possible without losing valuable information. The final revised item is designated form mc.5.

Sample

The 114 VOSTS items were developed over a six-year period through the fivestep process described above. Different sets of items were developed at three distinct times. Therefore, there were three distinct samples of students who participated in the VOSTS project. Each sampling of Canadian high school students followed procedures similar to those utilized by the International Association for the Evaluation of Educational Assessment (IEA) study in Canada (Connelly et al., 1984). Schools were chosen to ensure (1) an academic cross section of grade 11 or 12 students; (2) a regional representation from across Canada; and (3) a representative proportion of urban and rural students for that region. The same school jurisdictions were used in all three samples. Because each VOSTS item required a fair amount of reading, students were randomly assigned to respond to only 12 to 18 VOSTS items.

Therefore, the sample size *per VOSTS item* was reduced from a total sample size of about 5000 to a size of 2138, 2475, and 2377 for each of the three samples, respectively.

The percentage of students responding to each "student position" (the choices provided in a VOSTS item) was calculated, using an SPSS-x statistical package. A number of these results are reported in the second article of this two-part series (Ryan and Aikenhead, in press).

All regions of Canada were represented in the sample (Aikenhead and Ryan, 1989), including Quebec, a province with a distinctly French culture. In an earlier VOSTS study (Ryan, 1986), no appreciable differences were found among the responses of anglophone students from various regions of Canada. As a consequence, in the present study all anglophone responses to the English VOSTS items were combined (N = 1750 per item, on average). But due to the unique Quebequois culture, the francophone responses to the French VOSTS items were analyzed separately (N = 580 per item, on average) by Aikenhead et al., (1989a).

Validity

The validity of test instruments is an ever-present concern. Recent conceptual writing in the area has concentrated on two broad areas that may be called "internal reconceptualization" and "external reconceptualization"; only the latter will be elaborated here.

Internal reconceptualization, exemplified by recent work by Messick (1989), seeks to reinterpret and reposition the central tenets of traditional validity. An example of such work might be to debate the relationship among the traditional forms of validity: face, content, criterion, predictive, concurrent, and construct validity. The context of the debate is always that of the empirical paradigm.

Those working in the area of external reconceptualization seek to go beyond technical concerns of validity and to explore the meaning of the term within research models or paradigms other than the empirical. Mishler (1990) suggests "reformulating validation as the social construction of knowlege" (p. 417). In this way, he believes, the concept of validation can be useful in studies which derive from research paradigms other than the standard experiment-based model. The essence of such a view of validation is "trustworthiness" (Lincoln and Guba, 1985; Mishler, 1990; Ryan, 1987). The trust that one researcher has for the work of another is a matter of interpretation; one part-but only one part-of this interpretation is faith in the technical explication of validity. Acceptance of the idea of the social construction of knowledge, even in the empirical sciences, has pointed to the importance of trust in assessing validity. As Mishler (1990) puts it:

> This discovery-of the contextually grounded, experience-based, socially constructed nature of scientific knowledge-should be the cause for celebration rather than despair. It does not dispense with methods for systematic study but locates them in the world of practice rather than in the abstract spaces of Venn diagrams or Latin Squares. (p. 436)

The research methodology which underpins the VOSTS project is naturalistic. Accordingly, it seeks to uncover the perspective of the participants and to accept the legitimacy, in the participants' eyes, of that perspective. The format of the items and the responses, and the domain of the responses arise from attempts to reflect the perspective of the students who wrote the initial paragraphs and who reacted to the subsequent versions. The validity of the process and of the final instrument lies in the trust which subsequent researchers place in the process which has been described here.

While there is no scoring key to VOSTS, one can argue that some choices within a VOSTS item convey a more worldly understanding of the topic than some alternative naive choices do. This issue is explored in more detail in Ryan and Aikenhead (in press). VOSTS is an instrument that monitors students' views on STS topics. Its diagnostic function of monitoring students' preconceptions vastly overshadows its potential for yielding normative scores.

The new instrument requires a shift in perspective. No longer can science educators *suppose* how students might reasonably respond to an item. Rather, science educators must gather empirical data about how students *actually* respond to an item. This was the way VOSTS items were developed in the first place. For instance, one VOSTS item offers students 11 choices about what science mainly is (Ryan and Aikenhead, in press). This set of choices constitutes the domain of student viewpoints, expressed by students themselves. A conventional psychometric perspective might lead a science educator to *suppose* that students would want to make more than one choice. Because this concern was originally shared by the developers, students who wanted to pick more than one choice were instructed to pick the last choice provided in all VOSTS items, "None of these choices fits my basic viewpoint." Follow-up interviews with students suggested that the restriction of one choice did not increase the ambiguity of a student's response (Aikenhead, 1988). A national survey of students showed that very few selected the "none of these choices fit" response (Ryan and Aikenhead, in press). Therefore, one knows empirically that most students are not bothered by VOSTS's wide assortment of choices, within reason.

The shift from the conventional to the empirically derived instrument is illustrated, but not defined, by the application of item response theory. Item response theory provides information on the relationship among sets of items, for example, how a student will likely respond to item X, given the student's response to items Y and Z (Traub and Lam, 1985; Hambleton, 1983). Item response theory has been developed for Likert-type responses and for multiple-choice instruments developed within the traditional perspective (Traub & Lam, 1985). But the field of item response theory has not yet developed the mathematical equations that can analyze responses to VOSTS items.

CONCLUSION

VOSTS's five-step development procedure yields multiple-choice items that capture students' reasoned viewpoints on STS topics, and does so with greater clarity than paragraph responses, and with much greater clarity than Likert-type responses (Aikenhead, 1988). VOSTS represents a new generation of research instrument. The

VOSTS item pool is a reasonably accurate, efficient tool for both researchers and classroom teachers.

For researchers, the VOSTS item pool can serve as a point of departure for (1) generating a custom assessment instrument to suit a particular STS curriculum or teaching situation (by selecting and perhaps modifying items from the VOSTS item pool); (2) making cross-cultural comparisons (Aikenhead et al., 1989a); and (3) developing items for STS topics not found in the VOSTS item pool (by following the five steps described above). VOSTS items have been sensitive enough to detect differences in students who had studied an STS course and those who had not (Zoller et al., 1990). VOSTS items have been used successfully with university students (Fleming, 1988) and with teachers (Zoller et al., 1991), but must be modified for younger students such as 14-year-olds (Crelinsten et al., 1991).

Science teachers find VOSTS items useful for initiating class discussions on an STS topic and for selecting heterogeneous groups of students to work on an STS project. Moreover, a classroom teacher can accurately assess his or her students' viewpoints on an STS topic by reading students' *paragraph* responses to a VOSTS statement. This assessment, of course, depends on the teacher having discussed the STS idea in class, having acquainted students with writing paragraphs in science class, and having the time to read and grade the paragraphs. VOSTS can be used wherever science researchers and teachers require an empirically generated and student-derived snapshot of students' views on issues concerning science, technology, and society.

The second article of this two-part series (Ryan and Aikenhead, in press) reports on the student responses obtained during the fifth step of VOSTS's five-step development process, responses concerning the epistemology of science.

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NOTE: Copies of the complete VOSTS inventory of 114 items are available on a cost-recovery basis by writing to: VOSTS, Department of Curriculum Studies, College of Education, University of Saskatchewan, Saskatoon, SK. S7N OWO, Canada.

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