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ABSTRACT

This guide is written for Saskatchewan science teachers (particularly grades 7-12) who wish to know more about features of the proposed new science curricula for Saskatchewan. The purpose is to clarify the expanding repertoire of science teaching strategies which a teacher will develop as he or she implements one of the new science courses in Saskatchewan. Suggestions on how to use the "new" strategies are also included. The guide describes and discusses instructional strategies often employed in teaching science through a science-technology-society-environment (STSE) emphasis. Discussions on the following strategies are included: (1) "Divergent Thinking"; (2) "Small Group Work"; (3) "Student-Centered Class Discussion"; (4) "Problem Solving"; (5) "Simulations"; (6) "Decision Making"; (7) "Controversies and Dilemmas"; (8) "Debating"; (9) "Resource Books"; (10) "Mass Media"; and (11) the "Community". Appendices include an evaluation sheet and a checklist for group assignments, a detailed analysis of debates and their evaluation, and an excerpt from "Science Technology Society" discussing "New Instructional Strategies". (KR)

SASKATCHEWAN INSTRUCTIONAL DEVELOPMENT & RESEARCH UNIT

TEACHING SCIENCE THROUGH A SCIENCE-TECHNOLOGY-SOCIETY-ENVIRONMENT APPROACH: AN INSTRUCTION GUIDE

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WHO SHOULD READ THIS GUIDE?

This Guide is written for Saskatchewan science teachers (particularly grades 7 to 12) who wish to know more about the instruction features of the proposed new science curricula for Saskatchewan.

PURPOSE

The purpose of the Guide is to clarify the *expanding repertoire* of science teaching strategies which a teacher will develop as he or she implements one of the new science courses in Saskatchewan. The Guide offers suggestions on how to use the "new" strategies.

The Guide describes and discusses instruction strategies often employed in teaching science through a science-technology-society-environment (STSE) emphasis. While these strategies have not been part of the normal repertoire of science teaching methods, the strategies are well known to teachers of other curriculum areas.

WHAT IS STSE SCIENCE?

STSE science instruction means teaching "scientific content and skills in a meaningful context of technology, society and the environment" (SCAC, p. 6). This necessarily includes the epistemology of science and the status of science as a social enterprise. It is important to note that traditional science content is *not* watered down in STSE science. Rather, traditional science content is taught with the explicit purpose to connect science "with the technological, social and environmental aspects of a student's everyday life" (SCAC, p. 7). In other words, students will be instructed to make meaning out of their science content so that this content is available to them when, as adults, they are faced with issues or decisions related to science, technology and the environment. This explicit purpose of STSE science corresponds to the province's educational goals of scientific and technological literacy.

The traditional emphases for science instruction (i.e., preparing for the next science course, demonstrating the conceptual structure of a science discipline) are *not* abandoned in STSE science. Instead, they have less influence over the scope and sequence of the science curriculum. The rigour and sophistication inherent in STSE science is balanced by the students' motivation to learn the application, synthesis and evaluation of scientific knowledge in an everyday context. The everyday context creates in students' minds the *need to know* scientific subject matter and skills. This technological-social context structures the scope and sequence of a unit, it does *not* diminish the traditional science content and skills.

SCIENCE INSTRUCTION METHODS

In an STSE science course, students' meaning of science will expand. From thinking that science is merely the memorization of what is needed for the next course, students will make personal sense out of science concepts. For this to occur, teachers will be expected to expand their repertoire of instruction strategies. More instructional strategies are needed in order for students to explore the technological and social meaning of the science content. "New" strategies include, for example, student-centred class discussions, simulations, resolving dilemmas, and using the mass media. Some science teachers will already be comfortably familiar with these methods.

Table 1 outlines in a simple way a catalogue of STSE science instruction methods. Various classroom *configurations* (setups) use various *approaches* and various *resources*. The starred items in Table 1 are generally associated more with STSE science teaching than with traditional science teaching. The starred items, therefore, are the teaching methods with which many science teachers may be less familiar. These "new" methods constitute the content of this Guide.

DIVERGENT THINKING

(There's Often No Right Answer)

The everyday world finds science interacting with ethics, economics and politics (to name only a few social areas). This complex state of affairs leads to several legitimate perspectives on an issue, trade-offs and even inconsistencies. Hence, when dealing with science in its social context, there is often no one right answer. Students who find security in a singular right answer - "convergent" thinkers - need special encouragement to handle the initial ambiguities and the divergent thinking inherent in some STSE topics, particularly the dilemmas. Both convergent and divergent thinking are required in STSE science.

> EXAMPLE:
> When studying the scientific concept of concentration, students are asked to calculate the parts per million PCB concentration in a catch of fish (convergent thinking), and then students are asked whether the whole catch should be destroyed or not (divergent thinking, if there are two reasonable answers).

As an aside, many British students who would have become creative engineers and research scientists, opted out of science and technology careers because they only experienced convergent thinking in their school science (Bondi, 1985). The traditional science course *discouraged* potentially excellent future scientists. It is expected that a significant inclusion of divergent thinking in STSE science will enhance the quality of the

Table 1. Science Instruction Methods

Classroom Configurations	Approaches	Resources
lecture	ideas/skills centred (facts, concepts, thinking process)	textbooks
demonstration	convergent thinking vs. * divergent thinking	computer software
teacher-centred class discussion (question/answer/elaboration)	lab work	* resource books
individual student work	* problem solving	* mass media
* small group work	* simulations	* community
* student-centred class discussion	* decision making	
	* controversies/dilemmas	
	* debating	

* Associated more with the "STSE" emphasis for science teaching than with the "preparation for the next science course" emphasis for science teaching.

future manpower pool of creative engineers and scientists. Divergent thinking tends to activate higher reasoning capabilities associated with creativity and critical thinking.

Divergent thinking occurs when there is more than one good answer. On examinations, students are graded on the quality of their *reasons* that support their answer.

SMALL GROUP WORK

Working in groups of two to six students is a very effective configuration for some STSE lessons. Students become more intellectually active and take more responsibility for their learning. Students also improve their critical thinking competencies, subject matter achievement (both high achievers and low achievers), self-esteem and attitude toward science (Johnson, Johnson, & Smith, 1986). The more cooperative the members become, the more successful the group work. Small groups fail when one person does all the work or when the group is simply a homework Bee.

Group work does not mean that teachers absent themselves from the classroom. The teacher's role is to manage the groups, teaching them how to best meet the objectives, the ones the teacher sets for them. Science in the real world is done, for the most part, by *research teams*. Team work is now an essential ingredient to good science and technology.

EXAMPLE:
Teams of three students investigated possible variables that affected the period of a pendulum. Each research team member took responsibility for different facets of their project. At an "international conference," each team presented its findings and endeavoured to convince other teams to accept these findings. While there was competition between teams over who had the most accurate data and slickest presentation, the cooperation within each team allowed each team member to be more open about asking "stupid" questions and revealing biases toward certain scientific interpretations. The teacher was able to address these student misinterpretations as the teacher interacted with each group.

Basic Ingredients to Successful Group Work

1. Group work should be organized in such a way that group members become *dependent on each other in positive ways*; such as the division of labour in carrying out roles, getting resources and completing the task. In the pendulum lab example above, each research team needed someone to manage the team (double check that the meticulous directions were being followed), someone to manipulate the equipment, someone to observe a stop watch, and someone to record the data. Because graphing was required, students who had forgotten how to communicate

with graphs became dependent upon those who could teach them. The "teachers" also learned more about graphing by answering their peers' questions.

2. *Individuals are still accountable* for mastering the material or developing the skills required by the teacher. Evaluation can still take place on an individual basis. However, group work is usually most effective when a group mark (modified by individual evaluations) is assigned to each member of the group based on the group's collective accomplishment. The *collective* evaluation encourages individual accountability and positive dependence on one another. In the pendulum lab, for example, each group member received a mark that reflected the quality of the team's presentation (e.g., clarity and comprehensibility), but on a unit test, each member was marked individually on how well he or she was able to discuss the role of bias in scientific decisions.

3. *Social skills* that need to be developed become evident as groups work on a task. The teacher's role is *not* to solve these little problems, but to help the group resolve the problems themselves. High school students are normally very mature at interpersonal skills. Handling a (positively or negatively) domineering group member is, however, difficult for most adolescents. A pendulum lab team complained to the teacher about Jason who wouldn't help out. The teacher would not alter his group-grade strategy but asked the group what would be fair to both them and Jason. They unanimously decided, including Jason, that Jason would become a team of one. The fact that the students came up with the solution meant they had themselves to blame or congratulate, not the teacher, for the consequences.

   Although developing social skills is not a high priority for scientific literacy (other than scientific team work), it is nevertheless a Common Essential Learning in Saskatchewan.

How to Implement Group Work

The following suggestions offer a general procedure for implementing small group work. The suggestions are specific enough to give guidance, but are flexible enough for adaptation to diverse classroom needs and circumstances.

1. *Familiarity of students with group work.* Working in groups is a complex skill that must be developed. (Rural high school students who attend small schools often have a natural advantage in this regard over urban students who attend large schools.) Students, therefore, need coaching when they attempt to work in small groups. Their familiarity with roles and responsibilities takes time. Teachers who rely heavily on group work tend to use special activities that teach students the roles and responsibilities for group work. There are a number of simulation activities, for instance, that teach students the rules of working in small groups. Many require some risk taking on the part of the teacher. However, one simulation, "Dangerous Parallel," requires no risk on the part of the science teacher, but it does take about three days to complete. Students learn their group-work roles by

"working" within a highly structured and motivated environment. Such an activity at the beginning of the school year increases immeasurably the efficiency of group work throughout the year.

2. *Group size.* This will vary from two to six, depending on the complexity of the task, the class enrollment, availability of resources, etc.

3. *Assignment to groups.* Group membership can be student selected, randomly assigned, or teacher assigned. Considerable research on this topic suggests that the greatest productivity arises when the *teacher* decides on the group composition. The teacher has the best understanding of what must be accomplished and, therefore, which combinations of students will most effectively reach those accomplishments. However, when the task requires students to investigate at home (e.g., building a model of a Borkenstein breathalyzer), students themselves will likely select their groups best because they know who lives near each other for easy access for working together. Random assignment sounds "fair," but is usually not a very rational decision. Friends in the same group often initiate agendas different from the group's task agenda. However, when the group task is uninteresting to students, friendship grouping is used to "ease the pain."

4. *Composition.* Heterogeneous student groups have been shown to work more effectively than homogeneous groups. This is also true of professional research teams in science and engineering. Heterogeneous grouping is essential for decision making and controversies. However, when a class has a number of dominant students who tend to take over a group, it is often a good idea to group the dominant students together, thereby giving the shyer students greater opportunity to participate.

5. *Duration.* Students often react more positively when groups are reformulated with different members for each new task. However, a teacher may wish to establish "discussion groups" and "lab groups," for instance, which maintain the same group composition over a long period of time. These groups would meet on a more routine basis. Their advantage is the group cohesiveness that often develops over time.

6. *Seating arrangements.* The physical arrangement of chairs and tables turns out to be very important to the success of small groups. Each time a teacher plans a small group activity, he or she automatically decides on the most helpful and convenient seating arrangement. Interference between two groups can be avoided, for instance, by a slight twist of one desk. Group discussions need eye contact to sustain themselves, as well. In the role of manager, the teacher constantly monitors the success of the seating arrangement.

7. *Structuring the learning materials.* Students can waste valuable time searching inefficiently for resource materials. On the other hand, however, if the teacher always supplies the information, how are students going to learn to inquire independently? The degree of structure in the learning materials will depend on the maturity of the students, the objectives of the task, and the time the teacher

has available. When implementing a new course, a teacher may be helped considerably by students collecting materials on a topic. These materials can then be handed out by the teacher the following year.

The pendulum lab example mentioned above happened to be highly structured in order that planned discrepancies would emerge for the benefit of class discussion. However, the lab which followed lacked any structure. One of its objectives was to force students to decide how scientists proceed when there are no directions. The pendulum lab served as model for students.

8. *Clarifying the task to be accomplished.* The outcomes for any successful small group ·· ·· must be clear to all members. What is the expected finished product? How w . ıne evaluation work? What are the group roles that must be filled? Ineffective groups spend time wondering what the teacher wants. A work sheet or set of written directions helps students understand the group's objectives.

   Not all groups need to do the same task. Different groups can work on different facets of a larger problem (e.g., six teams could investigate six different variables associated with the pendulum's period). Alternatively, if all groups attacked the same problem or issue, it should be instructive to have a method by which each group can share its results with the whole class (a student-centred class discussion, described below).

9. *Structuring the positive dependence among members.* The basic ingredients to successful group work must be planned out. Differentiated roles and responsibilities can be written into the student directions. For example:
   Procedure:

   1. Elect a team leader.

   2. The leader will appoint a recorder, a writer, and a library search person.

   3. Remember, criticize ideas, not people.

   4. Your mark will be based on how well your group takes advantage of each member's expertise and on how logical and thorough your argument is supporting your conclusion.

10. *Interacting with and monitoring group work.* A teacher who is managing a class engaged in group work does not mark exams or take telephone calls while students are working. A teacher's time is taken by joining groups for various reasons: to clarify or provide assistance on how to achieve the task, to teach collaborative or communication skills, to underscore an important contribution by a student, to take advantage of "teachable moments," to collect information that will be valuable later when the teacher's role changes to class discussion leader (to sustain a student-centred discussion by engaging specific students who have certain ideas), to fill out formal checklists for evaluation purposes (e.g., contributed ideas, asked questions, listened actively, expressed encouragement, challenged an idea, etc.).

The B.C. Ministry of Education (1986) has several suggestions for group-work checklists.

STUDENT-CENTRED CLASS DISCUSSION

Student-centred class discussion is characterized by the predominance of student-student verbal interaction; that is, the sequence of speakers is comprised mostly of students. The teacher's role is to probe students for their understanding, perceptions and reasons (not the teacher's "correct" answers) and to encourage students to interact; for instance, by getting them to critically analyze what was said (e.g., "Do you accept what Ken just said, Jean?"), or by posing questions that channel the discussion along a fruitful path (e.g., "Will that reason always apply?"). What emerges from a student-centred discussion is a class understanding of the various points brought out and developed *by the class* and the reasoning that supports those points. The teacher ends the discussion by summarizing the ideas which developed in the discussion, using the students' language as much as appropriate. There may not be one right answer, but there must be well-reasoned conclusions.

The fact that the reasoned conclusions emerge from a class discussion does *NOT* mean that students already knew the answer. The class constructs a conclusion themselves, out of their previous ideas and present analysis.

Small groups generally operate in a student-centred discussion configuration. A student-centred *class* discussion pools the ideas of more students.

Students should be expected to take notes during some discussions. A teacher can help by jotting notes on the chalkboard or on the overhead projector. This activity by the teacher will help prevent the teacher from joining in the discussion and showing students how much he or she knows. *The most difficult task for the science teacher in a discussion is to keep quiet.* Perhaps it might help to remember what an ancient sage said: "He who does the talking, does the learning." That is the basic psychology behind a student-centred class discussion.

Of course, the class must be properly prepared to talk about something worthwhile. High school students rarely have enough general knowledge to make discussions fruitful. Therefore, students must prepare for a discussion. Often STSE materials have activities which include a series of questions. Instead of treating these questions as homework to be handed in, a teacher can assign the questions as preparation for a class discussion. Have students jot down their thoughts, and then hold a class discussion to arrive at a class consensus on an appropriate answer. Thus, the homework is the preparation for the discussion, and the students' tentative answers become the central focus to the discussion. Students should pool their ideas and critically analyze them before reaching a consensus. The teacher *orchestrates* the critical analysis. The teacher seldom contributes anything but paraphrasing and encouragement.

EXAMPLE:
After learning about atoms and Dalton's conceptual contribution to science, students read that none of his assumptions are believed today. Then the text posed the question, "What value are scientific assumptions if their truth doesn't mean all that much?". Because students had dealt with the problems of "truth" and because they had prepared a tentative answer to the text's question, the students engaged in a lively "debate" over the question. The teacher kept asking "How do you know?" and consistently used the students' answers to further the discussion, and not her own ideas.

Lab activities often lend themselves to discussing the questions posed in the text. A student-centred class discussion will reveal a host of commonsense conceptions ("misconceptions") which students continue to harbour in spite of clever demonstrations and hands-on activities (e.g., "Do atoms reproduce?"). Usually a *teacher*-centred class discussion (characterized by a teacher's question, followed by a student's response, followed by a teacher's elaboration) never unearths these preconceptions and, therefore, little learning actually occurs in spite of the fact that the correct words were uttered out loud in the classroom.

How to be a Good Leader

Being a good discussion leader takes much practice, enthusiasm, patience, sensitivity and organization (i.e., preparation of clever discussion questions). The following suggestions may help to initiate or to polish one's skill as a leader of a student-centred class discussion.

1. *Organized preparation.* Students must prepare for a discussion, either by working on a common activity individually or in a small-group configuration, or by working on complementary activities; e.g., different points of view on an issue.

2. *Seating arrangement.* Eye contact is often essential for most discussions. Thus sitting in a circle is ideal. The "body language" of the teacher is important, too. For example, teachers who *sit with* their students in a circle usually have better discussions than teachers who sit in a "privileged" position in the classroom. The more provocative the discussion, however, the less important the seating arrangement becomes. A teacher's "privileged" seating position may be necessary for ensuring control over a particularly lively discussion.

3. *Initiating the discussion.* Begin with specific concrete questions that lead to information which you want students to analyze further; i.e., begin with "low level" thinking questions and move toward "higher level" thinking questions. Use a wait-time of at least five seconds.

4. *Sustaining a discussion.*

   a. Do not evaluate a contribution but accept all contributions for discussion purposes. The *most successful* discussions have the *least teacher talk*. Do *not* display your rich array of knowledge.

   b. Encourage all students to join in. Pinpoint discrepancies and ask quicker thinking students to make sense out of them. Invite quieter students to summarize, paraphrase or explain another student's contribution.

   c. Seek out different points of view.

   d. Be sensitive to students' feelings and idiosyncrasies.

   e. Maintain an aura of enthusiasm.

   f. Encourage students to talk to each other by getting them to argue or by *not* giving the speaker your eye contact.

   g. Look for fallacies in reasoning, but encourage *students* to argue over the fallacies.

   h. Insist on common courtesy to the person speaking. A lively class discussion can degenerate into several unwanted, though lively, small group discussions.

   i. Turn student questions back to the class for reasoned answers; don't necessarily answer them yourself.

5. *Bringing closure to the discussion.* Summarize the main points or crucial issues. An informative summary (notes on the chalkboard perhaps) gives students a sense of accomplishment as well as a sense of what is important to remember. A summary is *not* a list of points the teacher hoped would emerge from the discussion.

PROBLEM SOLVING

Convergent problem solving ("working out the correct answer to the problems at the end of the chapter") provides students with the disciplined opportunity to use science concepts. The STSE method often makes greater demands on students by expecting students to solve word problems which relate to everyday life. This STSE approach (context-embedded problem solving) is more difficult for two reasons:

1. Students cannot easily memorize isolated algorithms. In an everyday context, students try to make their own sense out of the science concepts (higher level thinking).

2. Everyday contexts are more complex and have more variables to consider; thus, more information must be processed by the students before a problem is solved. Teaching methods for typical STSE problem solving (context-embedded problems) require teachers to coach students. Small-group work can sometimes help. Also, a full class discussion can occur by having a student write on the chalkboard what other students dictate as a solution to the problem. While teachers become frustrated at the extra time it takes to work through a problem this way, the problem-solving process is made very explicit to many students.

EXAMPLE:

1. A context-free concentration problem: what volume of a 40% solution should be mixed with water to make a 4.0 litre 2% solution?

2. A context-embedded concentration problem (the same problem): Mrs. Johnston wants to mix a vodka fruit punch for her guests who drink alcohol. She decides that 4 litres of punch in total should be enough. She wants the punch to be weaker in alcohol content than light beer, so she decides on a 2% alcohol concentration. The vodka has an alcohol concentration of 40%. How much vodka should she add to the fruit punch in order to make 4.0 litres of punch with a 2% alcohol concentration?

The disadvantage of context-embedded problems is that they take longer for students to work through. But on the other hand, teachers generally find that students learn the science concepts to a greater depth (i.e., can use them in higher level thinking), and that certain contexts tend to interest female students (e.g., Henry's law applied to cologne, or writing recipes as problem solving). Context-free problems tend to favour male students.

STSE instruction also includes divergent problem solving for which there is more than one correct way to resolve a situation. Technological puzzles that require students to design something (e.g., a soap molecule or a model of a breathalyzer) are typical divergent problems. A class presentation of the various solutions, accompanied by a student-centred critique of the solutions, guarantees an excellent class discussion. Again, this type of activity is more time consuming and challenging for students, but it does involve them to a greater degree in the instruction.

SIMULATIONS

Simulations are characterized by role playing in artificial situations. Good simulations involve students in situations that allow students to stretch their thinking capabilities, explore different points of view, and apply their scientific knowledge to lifelike situations or decisions. Simulations encompass a broad range of approaches. Regular science labs can be simulations if students consciously play the role of scientists.

Students enjoy playing, for instance, the role of a lawyer for which calculations and critical thinking about scientific concepts are brought to bear in the preparation of a court case. Students enjoy applying their scientific knowledge to real-life situations. Students develop the thinking capacity to apply scientific knowledge in everyday situations. Role playing demands *active* learning. Thus, simulations do much more than simply motivate students.

Student preparation and presentation takes class time. The educational advantages to role playing make the time investment worthwhile, as long as the time is spent efficiently. Consequently, you should set time limits and, within reason, keep to them. Students will always want more time to prepare their case. Give them reasonable class time (so you can assist them) and schedule the simulations so students can spend extra time outside the class if they wish.

Well run simulations are:

1. highly structured so students know exactly what their roles are and what the objectives are (role cards for each student can be helpful);

2. well prepared by students so students do not rely on creative spontaneity, but rather on carefully thought-out presentations;

3. organized so the classroom furniture reflects the situation (e.g., a courtroom);

4. led by a strong personality, usually the teacher, who ensures that the class keeps to the simulation at all times (e.g., the judge in a court case or a senator as chair of an inquiry);

5. organized by a teacher sensitive to individual students and to the positive and negative consequences that would ensue from a student playing various roles;

6. organized so that there are backup students ready to take over in case of absences, and who are ready to give psychological support to the main players (small group configurations are often used in preparing for a simulation);

7. held after students have had sufficient time to prepare and rehearse;

8. structured to encourage students to do extra preparation research and to use props;

9. followed by a *debriefing session* in which the class discusses the main points brought up in the simulation, and the teacher summarizes these important ideas. (Making notes on the board may be useful sometimes.) A debriefing session with students out of their simulation roles can make a very effective student-centred class discussion. The debriefing session can be the most productive aspect of

some simulations. The active participation of students in the role playing naturally leads to their highly motivated intellectual participation in a debriefing discussion. Discussion questions are sometimes assigned to students ahead of time, in order to improve the quality of the simulation's debriefing session. Other times, simulations need only a short teacher-centred debriefing session.

It takes practice before students become proficient at role playing. Thus, the first efforts are often halting presentations because of incomplete student preparation or student shyness. The patient teacher, however, is rewarded with high quality role playing by students who learn from these early attempts.

Active learning in a simulation appears more chaotic than passive learning. However, class discipline problems actually *decrease* in simulations, provided that the teacher ensures that on-task behaviour is causing the "chaos." The noisiest simulations are sometimes the most productive.

Occasionally a science teacher will have a class of students who have the talent to write and produce their own simulation or mini-play. Inspired by an idea or event in a science unit (e.g., uranium mining), students would be expected to research their script in order to portray informative and authentic positions. Producing satirical commercials is much more light-hearted. If possible, videotape the productions to show at a school event. The science curriculum is too full to spend much class time on such an activity, though the work may be achieved in conjunction with other courses (e.g., creative writing or drama) or as an extracurricular activity out of class.

DECISION MAKING

The essential aspect of decision making is making a choice among alternative courses of action. Various courses of action may be suggested to students, or students may be required to develop their own choices. In either case, students will evaluate the positive and negative consequences to the choices and then pick the best choice.

In STSE science, decision making invariably deals with, but is not restricted to, science/technology-related social issues (e.g., What should a town do about disposing of PCBs in their neighbourhood?).

Decision making can use a simulation approach in which students play the roles of various special interest groups or key decision makers. Alternatively, a decision-making approach can use a student-centred class discussion configuration, or a small group work configuration, by addressing the decision without any role playing.

In any case, thoughtful decisions require (1) accurate information along with logical reasoning, and (2) an awareness of the values that guide the decision (implicitly or explicitly). All decisions, even scientific ones, are guided by values. Scientific decisions can be guided by such values as accuracy, credibility, suspension of belief, suspension of disbelief, or longing to understand. The technology-related or social-related nature of STSE science often leads to public policy decisions - a general decision which prescribes ways of handling a public situation. But sometimes the decision comes down to a legal one, a moral one, an economic one, or a political one.

In all cases, a student's understanding of science is brought to bear on the decision at hand. Sometimes it is a specific concept (e.g., What exactly is a species? or What does ethanol do to brain neurons?), while other times it has more to do with the nature of science (e.g., How is probabilistic reasoning properly communicated?, What kind of evidence is required for theory building?, or What value would lead a scientist to take such a position?). Decision making in STSE science makes explicit to students the role that science plays in making the decision.

For certain topics, it is certainly possible to engage in good decision making but ignore science content or skills. Such decision making, however, belongs in other school subjects, not STSE science.

Most STSE materials offer decision-making guides for students to follow. Such guides structure a small group task or a full class discussion. By filling out a decision-making chart, for instance, students can work through a decision. Table 2 illustrates a chart that was developed with high school students. Less sophisticated or more sophisticated decision-making guides will be found in various STSE materials. A succinct illustration of the Table 2 decision-making guide is provided in Table 3.

Decision making is usually an integral part of STSE instruction. The reason for this relates to the goals of science education. A scientifically literate person is able to make a science-related everyday decision, informed by an appropriate understanding of science. Thus, one of the products of teaching science is thoughtful decision making (by future scientists and engineers, by key decision makers in government, industry and law, and by the average layperson attentive to current issues). To achieve an acceptable level of scientific literacy, students need to practice thoughtful decision making. The skill of making thoughtful decisions is learned through practice and modelling, just like the skill of solving scientific problems is learned through practice at doing the problems at the end of the chapter.

Decision making in STSE science can be accomplished by various classroom configurations (individual student work, small group work, or student-centred class discussion) and by various approaches (lab work, simulations, and controversies/dilemmas). Decision making and problem solving are both different aspects of the more general approach to instruction called inquiry (Welch, Klopfer, Aikenhead, & Robinson, 1981). Good STSE decision-making activities are particularly well received by students who find such activities engaging, challenging, informative and concrete.

Table 2. An STSE Decision-Making Guide

(1) Issue:			
(2) Decision Question:			
(3) Type of Decision:			
(4) Possible Choices:	(5) Risk/Benefit Analysis	(6) Validity & Probability	(7) Values Assumed
Alternative 1	Negative Consequences		
	Positive Consequences		
Alternative 2	Negative Consequences		
	Positive Consequences		
Alternative 3	Negative Consequences		
	Positive Consequences		
Alternative 4	Negative Consequences		
	Positive Consequences		
(8) Priority of Values (from most to least important):			
(9) Choice & Reason:			
(10) Action Recommended (what, by whom & when):			

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Table 3. An Abbreviated Illustration of a Decision

the issue:	Whether Rechem is burning PCBs as efficiently as they claim.
the decision question:	For the immediate future, should Rechem's burning process be halted?
type of decision:	This decision is NOT a scientific, technological, legal, political or moral decision. Rather, it is a "public policy" decision -- a general decision which prescribes ways of handling a public situation. A public policy decision is not restricted by moral, political, military, legal, or any other type of decision; but it can be informed by those types of decisions.
alternatives to choose:	A. halt the burning immediately B. continue the burning as usual C. ? (Fill in another alternative if you think of one.)
risk/benifit analysis:	For each alternative, list the negative consequences and the positive benefits of taking the action.
logic check:	Double check the validity of your risk/benefit arguments for each alternative. (How logical are your conclusions? Are they based on false causes? How probable are your conclusions?)
values awareness:	What things or ideas are most highly valued by each alternative? You're looking for some basic assumptions of what is valuable to a person. These basic assumptions are hidden in each alternative. Your job is to detect what they are and clarify them. Examples of values include: generating wealth for a country, loyalty, being in balance with nature, causing no harm to people, justice, abiding by the laws, honesty. There are basic values assumed by each alternative. The values may not necessarily be your own personal values, but you must recognize them and clarify them, anyway. In order to help you identify the value assumptions, ask yourself the question: What would people highly value if they firmly believed in alternative X?
values priority:	Of all the values you listed above, which value is most important to you personally, in this situation? Prioritize the other values from second in importance to least important.
choose:	What alternative do you choose; after weighing the consequences, the logic of your thinking, the probabilities, and your values?
action:	How could the people of New Inn put your choice into action?

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CONTROVERSIES AND DILEMMAS

Everyday events (e.g., biotechnology, nuclear power, toxic chemicals) often involve controversy or often put people in dilemmas. An STSE emphasis to science teaching - teaching science content in an everyday context - will naturally include a controversy or dilemma. Students are usually intrigued and will work hard to resolve controversies and dilemmas, even those students who show little interest for science. In this approach to STSE science, students are pushed to their intellectual limits by the requirement for rational, thoughtful and informed thinking.

> EXAMPLE:
> Should a local pulp industry be closed down (putting people out of work) because dioxins have been found downstream (threatening the health of the town's residents)?

Many science teachers subscribe to the goal of "teaching students to think." The toughest test, and therefore the most productive learning approach, is to engage students in thinking their way through controversies or dilemmas.

Controversies and dilemmas, almost by definition, have no "correct" answer. Thus, divergent thinking and higher level thinking are encouraged. Controversies and dilemmas can be handled in various classroom configurations (individual student work, small group work, or student-centred class discussion) and by the approaches of decision making and/or simulations. For highly controversial issues, role playing in a simulation has the advantage of allowing students to step into and out of different perspectives without having to expose their true feelings. Decision making has the advantage of structuring the students' critical thinking which is so necessary to rationally resolve controversies and dilemmas.

A teacher's position can become difficult and unsettling if a teacher has not clearly planned how to handle the controversy or dilemma. The purpose for engaging in such instruction is to put science into students' everyday life. Thus, the teacher's role is to ensure rational, thoughtful and informed thinking. Teachers do *NOT* advocate or teach a particular position. While a teacher should feel free to tell students where he or she stands on an issue (for instance, during a debriefing discussion), the teacher models an inquiring, critical mind. A science teacher is particularly suited for this role because science teachers have been trained by their university science professors to inquire, to search for reasons, to demand evidence, and to insist on logical reasoning.

Controversies or dilemmas, like decisions, are also embroiled in values. The teacher's role is to help students become aware of the various pertinent, fundamental values, *not* to indoctrinate students with any one perspective. During class discussions, therefore, a teacher *manages* the discussion (a neutral chairperson) rather than participates in the discussion (by taking sides). The suggestions discussed above (pages 9-11) on how to manage a student-centred discussion are germane here. The following points pertain specifically to controversies and dilemmas.

Transfer of Scientific Understanding

Because moral reasoning often dominates controversies and dilemmas, the role of science may be lost. This loss should be avoided in STSE science instruction. Science and technology can inform a moral decision by providing information about harm; e.g., What harm do dioxins cause to the human body? Reasons and evidence are required in rational moral arguments (Manenschijn, 1985; Thomas, 1985). In addition, the logical and critical thinking *skills* and *predispositions* developed in the STSE science course are directly transferable to a moral argument. More importantly, students do not usually transfer such skills unless explicit instruction occurs (e.g., coaching students as they try to transfer their capabilities developed within a science domain to a moral domain).

Epistemology and Sociology of Science Prerequisite

The status of scientific knowledge and the social construction of that knowledge often occupy an important place in a controversy (e.g., Is it rational to ask if there is zero chance of contacting AIDS from contact on a sports field?). The epistemology and sociology of science are *prerequisite* ideas that help to resolve a controversy in a way appropriate to STSE instruction. Therefore, controversies and dilemmas are not usually attempted at the beginning of an STSE course. Some grasp of the epistemology and sociology of science is often needed for resolving controversies and dilemmas.

Value-laden Scientific Knowledge

Many science teachers have been trained to believe that a deeper understanding of the facts of science leads directly to resolving science-related controversies. The underlying assumption to this belief is that scientific knowledge (e.g., a conceptual model) is value-free. This assumption, however, crumbles under inspection. In some idealistic, philosophical sense, scientific knowledge may have a value-free status. But as soon as someone decides to use that knowledge to support or counter a position in the social domain (i.e., a controversial situation or dilemma), the intention to which that knowledge is put becomes inextricably tied up with the knowledge claim itself, and consequently the scientific knowledge *in use* becomes value laden (Aikenhead, 1985). Therefore, science teachers must develop an awareness of the value-laden nature of scientific knowledge as it is used in controversies and dilemmas.

A deeper understanding of the facts of science does not produce consensus within the scientific community over a science-related social issue. Scientists often disagree over the *appropriateness* of a model or over the *relevance* of a fact. Ideological differences tend to become more poignant for scientists and technologists than for the general public. Thus, more scientific facts by themselves will not necessarily help students resolve a dilemma. Scientific facts will likely polarize the students, just as the facts polarize scientists.

Community Values

Some controversies and dilemmas (e.g., abortion) are not acceptable for public education discourse in some communities. A teacher obviously must be sensitive to the community as a whole, as well as to individual students.

However, a teacher can restrict a class discussion within a controversial issue (e.g., Can science determine when a fetus is human?) in order to teach an STSE concept (e.g., the type of questions science is able to address). It should be explicitly clear to students that the bigger issue itself will not be discussed in class.

The following ideas will help take some of the risk out of controversies and dilemmas, and to establish a good rapport with the community. (For a more extensive description of the science teacher as a classroom manager of controversial topics, see Hickman's chapter in Bybee, 1985.)

a. The goal of the controversy/dilemma approach is understanding and developing one's own capacities. The goal is *NOT* to win an argument or champion a cause.

b. Teachers should ensure that they have written, informed support from the school's principal.

c. The teacher's role will be to promote critical thinking and open-mindedness. While students will likely discover their teacher's opinion on the controversy, this opinion is offered as one of several legitimate views, and offered in the spirit of openness and mutual respect. The teacher's authority will be divorced from the teacher's opinion.

d. The actual instruction of values (What values *should* a student hold?) is left to the parents. Parents should be apprised in writing of the controversies to be addressed. Parents should anticipate having value-related conversations at home as a result of the class discussion. Parents should be cognizant of the science teacher's desire to assure parents of their sole role in the moral instruction of their children. The province's Common Essential Learning, "personal and social values and skills," is explicitly addressed here.

e. Emotional controversies or dilemmas should not be attempted until a teacher feels comfortable with his or her class, nor until a teacher has established an open and trusting classroom atmosphere for students, along with the routine of student-centred class discussions.

f. Relevant information, acceptable to the school authorities, must be provided to students so they can adequately prepare themselves for an effective discussion.

Sufficient resources are needed to ensure that any reasonable or traditional viewpoint is adequately represented.

g. Ideas, not people, are critiqued. While this advice is applicable to all other approaches for science teaching, it becomes particularly important when dealing with controversies and dilemmas.

Structured Academic Conflict

A particular version of controversy instruction was developed at the Cooperative Learning Centre at Minneapolis (Johnson et al., 1986). The instruction begins by the teacher assigning four students to a group. The four are divided into two pairs who are assigned opposing positions on the controversy. In the end, the group of four must reach a consensus and hand in a group report to be evaluated.

The two students who argue for the same side meet in order to plan their argument and to master the information pertinent to their position. Then the four meet. Each pair presents its argument persuasively to the other two. The listening pair takes careful notes. Together, the four will have to learn both sides in order to prepare a good group report.

Then the pairs reverse their positions. Forcefully they present the opposite side, adding new ideas and elaborating on the other pair's position.

Finally, the advocacy aspect of the group is dropped and the four students reach a consensus on a synthesized position best supported by the facts, logic and values. (Instruction in decision making will help students critically analyze the various positions within a controversy.) The group writes a report clarifying the facts, logic and values that led to their synthesis or consensus.

The teacher's role is to interact with each group in such a way as to help the group evaluate their own performance. The teacher helps a group in its reflection, self-analysis and the improvement of the group's collaborative skills needed for effective group work.

The student's role can be summarized by the following rules:

1. I am critical of ideas, not people.

2. I focus on making the best decision possible, not on "winning."

3. I encourage everyone to participate and master all the relevant information.

4. I listen to everyone's ideas, even if I do not agree.

5. I restate what someone has said if it is not clear.

6. I first consider all the ideas and facts supporting both sides, and then I try to put them together in a way that makes sense.

7. I try to understand both sides of the issue.

8. I change my mind when the evidence clearly indicates that I should do so.

Hypothetical Dilemma Discussions

A variation on the "structured academic conflict" format is the "hypothetical dilemma discussion" developed by Iozzi (1982) at the Institute for Science, Technology and Social Science Education in New Jersey. Table 4 summarizes the steps suggested for the teacher and student.

Background information familiarizes students with the basic ideas required for understanding the dilemma. The materials are intended to bridge the gap between the complex real world of the student and the hypothetical dilemma situation to be presented.

The dilemma is then presented to students. The teacher checks to see if students fully understand the dilemma. The following questions will be helpful:

a. Do you feel that this is a hard dilemma to resolve?

b. John, please summarize the solutions?

c. What things will the main character have to consider when resolving the dilemma (or when making a choice)?

d. What are the main points in the conflict?

e. Who would primarily be affected by a decision one way or another?

Next the class is put into a small group configuration. (See pages 4-8 above.) It is recommended by Iozzi that dilemma discussions be initiated in small groups, followed by a student-centred class discussion. Dilemma discussions tend to revolve more around moral issues than around facts and reasoning. Thus, the group composition should be supportive for each student so that individual feelings can be expressed in an atmosphere conducive to self disclosure and so that the underlying values can be identified more objectively. A group recorder should be selected for summarizing the group's final conclusions. These will initiate the class discussion that follows. A teacher joins a group if their discussion begins to lag or gets off the topic. The following types of questions will be helpful:

Table 4. Dilemma Discussion of a Hypothetical Situation

SCHEMA FOR DILEMMA DISCUSSION

Teacher Activities		Student Activities
assign readings, exercises, etc.	BACKGROUND INFORMATION ↓	readings, films, exercises
check students' understanding	PRESENTATION OF DILEMMA ↓	identify situation, clarify terms
set up small groups	SELECT ALTERNATIVE POSITIONS ↓	indicate preliminary action choice
help stimulate discussion (probe questions)	SMALL GROUP DISCUSSION ↓	examine individual reasons react to probe questions
coordinate class focus (probe questions)	CLASS DISCUSSIONS ↓	examine different reasons - group reports discuss issues, consequences, implications
bring discussion to close, summarize main reasons	SUMMARIES ↓	present main ideas, reasons - review discussion
determine types of relevant activities	EXTENSION ACTIVITIES (optional)	further research, essays, analogous dilemmas, etc

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a. clarifying: What do you mean "concealing evidence is immoral"? What does "immoral" mean to you?

b. perception check: Kim, what is George saying?

c. issue clarification: What should the guidelines be for that toxic chemical?

d. specific conflict resolution: Should rich companies have more power in our courts than the average citizen?

e. personalization of the conflict: What would you do if you were in her position?

f. universal positions: What would happen if every chemical company filed for bankruptcy at the first sign of a lawsuit?

g. rationale check: How did you come to that conclusion?

As mentioned in the section on student-centred class discussions, class discussions usually go more smoothly if students have individually answered some questions which require students to reflect on the main issues. Good classroom materials provide such questions for homework.

The entire class comes together to hear each small group's conclusions. Questions and challenges arise. Reasons should be critically analyzed. Values should be clarified. The class as a whole moves toward a single solution to the dilemma. Such a discussion corresponds closely to group decision making, discussed above (pages 13-17).

In closing the discussion, the teacher summarizes the major points made (a debriefing) including the reasons that lead to the preferred solution to the dilemma. Unresolved differences among students should be stated and left without judgment. Agreeing to disagree is a respectable disengagement. The debriefing by the teacher might include pointing out how the hypothetical dilemma situation relates to a real-life situation.

Moral discussions and science education have similar educational goals: improving learning skills, improving students' self-esteem, improving attitudes toward the science course, improving knowledge of key science concepts, facilitating intellectual growth.

Summary

Controversies and dilemmas are a special case of the decision making approach to science teaching. Not all decisions, however, are controversial or revolve around a dilemma. The ideas in this Guide related to productive small group work and effective decision making apply to controversies and dilemmas.

DEBATING

Closely associated with a controversy approach to STSE science is the debating approach. Some topics and some students make debating an effective STSE lesson. Debating is a useful communication skill for the real world. On the other hand, scoring debating points forces students to adopt an advocacy posture that may not be sensitive to diverse points of view. A debriefing session by the teacher and judges should be written into the plans for a debate.

Debates can be as formal or informal as a teacher wishes. There are basically two styles of debate, British and American. An extensive description of debating, including tips for debaters, may be found on pages 105-121 in the B.C. Ministry of Education publication *Science and Technology 11* (1986). Students must be given plenty of time, in class or out of class, to research their position and prepare their cases.

RESOURCE BOOKS

Reading in traditional science typically means reading fairly short, but highly concentrated, passages of didactic material. Reading in STSE science typically includes traditional science reading, plus more lengthy passages intended for the general public. STSE science tends to increase the emphasis on reading. Discussions, simulations and decision making usually require students to prepare themselves through reading books, pamphlets and articles, in addition to the textbook.

An STSE lesson sometimes requires a teacher to gather together many of these print resources. However, a scientifically literate student will search out information on his or her own. How do students develop this skill and predisposition? Students must participate in the search for information themselves. Thus, a teacher must plan the extent to which students will search out information themselves. A productive STSE lesson may require no information searching by students, or the lesson may require extensive searching, depending on the time available, the task, and the students' abilities.

One advantage of heterogeneous groups is the diversity of reading and information searching abilities within the group. The better readers should be expected to complete more reading, but the group work should also be a learning experience for the less able readers. There are a number of "tricks" which the more able readers will pass on to the less able readers, as long as the teacher spells out this expectation for the group.

The following points may help the less able reader to improve on his or her reading skills:

1. *Underlining the text.* As students read text, they should pick out the most important parts and underline them or brush them over with a yellow felt pen. This helps students when they need to reread the material for review or for summarizing the text.

2. *Glossary.* Students develop a list of words which they believe are key to the topic. The group of students working together is responsible for writing the meaning or explanation of each term. Those will be checked by the teacher who ensures their accuracy.

3. *Editing.* Students write a precis of the text for an audience younger than themselves. For instance, a grade 11 class may be required to write a summary of an article so that a grade 6 class could use the rewritten text as a resource.

4. *Concept chart.* The logical connections within some passages can be represented by a chart which shows how topics and/or ideas are related. For example, constructing a flow chart of how a breathalyzer works will help students read text on why the breathalyzer works the way it does.

5. *Argument construction.* The logical essence of a text passage can be summarized by listing the premises that the author claims support the conclusion. By abstracting the "bare bones" of an argument from a text gives weaker students a concrete framework in which to read the text.

6. *Concept mapping.* The teacher gives students a list of words that are important for understanding the passage. Rather than look up their meaning in a dictionary, students are required to cluster the words in groups according to their conceptual relationships. From a word list (for example: g/100 ml, protein, parts per million, lipid, haemoglobin), students make up categories according to the meaning students associate with the words; for example, g/100 ml and parts per million are concentrations; protein and lipids are molecules found in cell membranes; and haemoglobin is left as a single item group. Each cluster is circled. Lines and arrows may be drawn among the clusters to indicate relationships. Words having no meaning to a student are clustered together separately.

By looking at students' concept maps, a teacher can readily notice what meaning students have gained from the reading. While there are no "correct" concept maps, some will reflect greater comprehension than others.

Poorer readers are helped by studying the concept maps of better readers. Thus, teachers ought to keep on file examples of excellent concept maps and provide them to less able readers.

MASS MEDIA

Newspapers and television are everyday sources of information for students and adults. Students interpret what they read and see in terms of what they already understand. Therefore, media items related to science and technology will be interpreted in terms of what a person understands about science and technology. This *interpretive* use of scientific knowledge defines how most people generally put their science education into practice (Aikenhead, 1980; Broudy, 1969). STSE science is predicated on this interpretive use of scientific knowledge. (Recalling and applying scientific knowledge are rarely needed in the real world.) STSE science, therefore, incorporates the media because that same media will be the context in which students will actually use their science content and skills.

> EXAMPLE:
> The public media now use the phrase "science and technology," while a few years ago only "science" was used. This situation could introduce students to the *need* to distinguish between the social enterprise of science and the social enterprise of technology. If the media make the distinction, then so should the scientifically literate reader.

Media items are not usually as clear cut as science text passages. Before handing students a newspaper article to read, for example, a teacher may wish to underline key sentences in the article.

Viewing videos or films in the classroom should be preceded by a list of questions to be answered by students as they view the material. Teachers should feel free to stop the video or film at convenient places, giving students a chance to write down answers, to discuss a point, or to answer the teacher's questions. Viewing must be an *active* process, not a passive one similar to TV viewing at home; otherwise the educational value is lost. It is helpful to *dim* the classroom lights rather than turn them off all together. This way students can easily read their writing, and their eyes will not hurt when the lights are turned up during intermittent discussion breaks.

Media items are not always as accurate as science text passages. Therefore, the reader or viewer must constantly exercise vigilance and critical thinking. An STSE science lesson can effectively draw upon a misconception in the media as easily as a correct conception. Science fiction movies viewed at home can raise excellent questions in students' minds, questions that clarify misconceptions students have harboured for a long time.

TV items (newscasts, science programs) bring out ideas very vividly. Sometimes the vividness supersedes the content. ("The media is the message.") The vividness of information can become a legitimate point of discussion when interpreting a media item. Often a TV item brings the real world into the classroom, thereby formulating the connection between science content and the everyday world.

STSE science instruction methods incorporate the mass media whenever possible. Bulletin boards with print media (e.g., headlines, articles, stories, science & technology pages, advertisements, and posters) are helpful, too. Teachers seldom have enough time, however, to accumulate many print materials. If the teacher's edition of a particular unit does not provide such media, a teacher could assign students the task of collecting material for the unit (i.e., bonus points for what they bring in). File this material for use the next year. Over a few years, substantial material can be acquired this way.

Occasionally, a group of students will produce their own video (e.g., a skit, a "documentary," or an advertisement) that illustrates STSE science content. Such a project can be most beneficial and rewarding. See page 13.

THE COMMUNITY

STSE science is about using the everyday world as a context for teaching science content and skills. Similar to the mass media, the community can provide a valuable resource for STSE science lessons, either as a source of learning or as a place to apply what has been learned.

It is only natural that topics for discussion in STSE science will extend beyond a science teacher's general knowledge. Science teachers are not expected to know everything (in spite of the cultural myth to the contrary). The community then becomes a worthwhile resource. The teacher can *model* for his or her students what a scientifically literate person does when he or she does not know something. Alternately, a teacher can develop an assignment for students, in collaboration with people in the community, for which students draw upon the community to learn something about science and technology. A teacher can then learn this content by evaluating the students' work. The more the teacher learns, the higher the grade given to the student's assignment. Teachers can learn from students.

The following ideas offer suggestions for incorporating the community into STSE science instruction:

1. *Field trips.* Taking students to where science and technology are happening is a rewarding event. Field trips need not require expensive travel to spectacular sights. Short excursions to a sewage plant, fire station, supermarket, photographer, hospital, creamery, or any local industry, for example, will be less disruptive to the school schedule but will be just as effective for an STSE unit. Science is everywhere. A few well-planned field trips per year will make a great impact on students. Hints for successful field trips include:

    a. Make appropriate arrangements with the principal and parents.

    b. Make preparations well in advance. Teachers should visit the site themselves to become familiar with the physical layout and the information resources for an STSE lesson.

    c. Structure the visit carefully. Students need to have concrete objectives in mind (e.g., fill in work sheets composed by the teacher to ensure intellectually active participation by students, specific questions to raise with people at the site, or lists of materials to gather). Students need to know what to anticipate and the behaviour expected of them.

d. Integration with the science unit. Visits should be an integral part of a science unit, rather than an isolated diversion. Some background knowledge by students is usually a prerequisite for an intelligent visit. However, visits can also serve as points of departure for follow-up classroom instruction. In any case, the trip should fit logically into the content of the science unit.

e. Talk with the people at the site so they know what your objectives are. Decide on the division of labour for instructing the students. Do not assume that knowledgeable workers can clearly describe their work to students. The teacher has the advantage of knowing what content knowledge students will bring to the visit.

f. Negotiate with fellow teachers. A certain amount of disruption to the school routine is inevitable. Hence, principal approval and cooperation with colleagues are most crucial to a successful field trip.

g. Concrete events at the site. Students will likely be naive observers. Therefore, it is important that concrete events are viewed with a minimum of inferences (What is really happening behind that wall?). A visit to an oil refinery, for example, is almost useless if students only experience kilometers of pipes. The teacher may offer suggestions to the people at the site on how to make the content more concrete to students (see point b. above).

h. Follow-up. The educational impact of a visit is enhanced by follow-up activities back in the classroom (e.g., a debriefing lecture, a student-centred class discussion, group reports, or lab work).

2. *Visitors.* The next best thing to taking students out into the community is to bring a representative into the classroom, thus helping to put your science course into the context of the real world. The selection of a good speaker is important. Some companies or institutes have people already designated for this task.

   Much of the advice concerning field trips and mass media apply to visitors. Preplanning is essential. Involve students as much as possible in planning and running the event. Students can be excellent sources for contacts (with doctors, lawyers, company managers, etc.). Students also make good welcoming parties, introductions and written thank you's.

   Brief the visitor about what students already know and what your objectives are. Encourage the visitor to use street language to introduce technical language. The visitor should lecture as little as possible, leaving time for lots of questions from students. The teacher should be prepared to act as "translator" or facilitator at a moment of impasse during the visitor's talk. Encourage the speaker to bring, or send ahead of time, some physical props or posters. Concrete materials peek students' curiosity and encourage intellectual involvement. Plan key questions for students to ask.

A visitor may make a return engagement each year. One can expect visitors to get better at talking with students after each presentation. Be prepared to videotape a speaker just in case he or she is unable to return.

EXAMPLE:
A police constable visited a classroom to demonstrate the Borkenstein breathalyzer. On one occasion, his presentation came when students had just begun to study the breathalyzer. On another occasion, it came at the conclusion to their study. Each visit made a valuable contribution to the STSE unit. The second occasion (when students had a strong background knowledge) turned out to be a better learning experience. The teacher was able to talk up the visit ahead of time, and students were able to relate to the technical aspects and to ask more informed questions. The constable had read the student text material and was able to refer to it specifically. His comments legitimized for students the authenticity of their science instruction. The visits were videotaped and the better one was used with other classes. The police constable could not visit every classroom studying the STSE unit.

High school science teachers make excellent visitors to elementary classrooms.

3. *Public opinion polls.* Science is about collecting and making sense out of empirical quantitative data. The critical thinking skills associated with manipulating empirical data can be taught in a social context as well as, or even better than, in a science lab context. In an opinion poll the community becomes the data source. The topic may be a science-related social issue, but the data have all the characteristics of any laboratory measurement. In a social context, students can deal with the concepts of measurement error, sample size, consistency, accuracy, variables, inferences, and correlations versus cause-effect relationships. Students conduct the interviews, collate the results and interpret their findings. Public opinion polls, therefore, forge another link between school science and the everyday world.

CONCLUSION

Managing a classroom is an extremely complex set of tasks. Teachers possess a rich encyclopedia of *practical knowledge* that handles many more variables than any education theory can handle. Day by day, teachers must deal with unique individuals in unique situations. This challenge is met in part by establishing routine classroom practices. A teacher's instruction strategies form the nucleus of classroom practice.

Instruction strategies are an essential component to a teacher's personal practical knowledge. The selection and use of an instruction strategy depend on a complex set of circumstances, including (1) the teacher's own experience with the strategy (How was the teacher taught science?); (2) the teacher's intention for the instruction (Prepare students for university science course? Prepare students to deal wisely with a changing world accelerated by scientific and technological breakthroughs?); and (3) the teacher's assumption about how students learn (Clear lecture notes? Lots of drill? Memorization? Making sense for oneself?). All three of these key variables relate to STSE instruction. Each is discussed below in turn.

For many science teachers implementing an STSE science course, the instruction strategies described in this Guide were not part of their own high school science teachers' repertoire of methods. These relatively unfamiliar strategies will therefore take time to perfect and will require practice over several years. Realistically then, the purpose of this Guide is only to create an *awareness* of a potential repertoire of instruction strategies. The incorporation of these strategies into the teacher's practical knowledge is a personal undertaking, not unlike scientific inquiry itself. In a sense, a science teacher becomes a researcher as he or she tries out a "theoretical" strategy, collects data, and then modifies his or her "theory" in light of the data. Trial and error approaches will get one started. Collaboration with fellow teachers (science or otherwise) will help considerably. For instance, an informal "supervision" session by a social studies colleague may immeasurably improve one's capabilities as a discussion leader. To practice a new instruction strategy takes patience, a sense of humour, and an inquiring attitude.

A teacher's intention for instruction is an essential aspect to implementing an STSE science course. The Saskatchewan science curriculum has been redesigned to give higher priority to preparing students to deal wisely with a changing world accelerated by scientific and technological breakthroughs (the STSE emphasis). A committee of University of Saskatchewan science professors heartily supports this new high priority. The science professors are confident that by achieving this goal, students will also be well prepared for university science courses. In some cases, better students will opt to take science degrees rather than avoid them. Thus, preparing students for university science courses is not abandoned in teaching STSE science; it remains a high priority but not as high as the STSE priority.

A teacher's assumption about how students learn greatly affects how a teacher carries out instruction. The STSE instruction strategies discussed in this Guide are predicated on the assumption that students ultimately construct their own meaning of what they believe (just as science teachers do in developing their personal practical knowledge of instruction). This "constructivist" psychology of learning corresponds rather closely to how the scientific community itself develops new knowledge of the physical and biological world. However, the constructivist psychology of learning does *not* correspond to the period of fact cramming (the first three years of university science or engineering) which science teachers have all experienced, and which sets a foundation for graduate studies. Therefore, STSE instruction strategies relate more to how science is carried out in the real world, than to how undergraduates prepare themselves for graduate school. The teacher facilitates the students' construction of knowledge by orchestrating classroom practices with valid information. All the methods listed in Table 1 apply. The methods discussed in this Guide, however, specifically assume a constructivist view of learning. Consequently, the degree of success at implementing these "new" strategies varies as the degree to which a teacher assumes a constructivist view of learning.

In summary, this Guide offers some science teachers new ideas about how to achieve the renewed goals for Saskatchewan science teaching. This Guide also provides a basis for reflection by teachers already familiar with the "new" instruction ideas. In either case, the Guide's success can be measured by its *catalytic* effect on an individual teacher's practical knowledge. The Guide can only serve as an educational catalyst. The "reactants" are in the hands of each individual science teacher.

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APPENDIXES

Appendix A

Excerpts from

<u>Science and Technology 11 Instructional Resources Manual</u>
British Columbia Ministry of Education
Curriculum Development Branch
Publication Services
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Section 1: Group Work Evaluation
Section 2: Debating

Group Assignments : Evaluation

Three approaches to evaluation of group work are suggested here. 1) self evaluation, 2) teacher evaluation, and 3) observer evaluation. To facilitate evaluation by the first two methods, a Self-Evaluation Checklist and an Evaluation Checklist for Teachers are provided, though as noted, teachers and students could use the same criteria.

Self Evaluation: Groups should be encouraged to evaluate themselves. They could.

- evaluate their research and planning work;
- evaluate their skills with the group processes by using group needs as criteria Follow-up discussion should consider reasons for any conflict or breakdown of group dynamics and suggest ways to resolve them.
- evaluate presentations, talks, and reports by using checklists provided.

Teacher Evaluation (must occur during and after group work): You could use the same criteria as students do and evaluate on the basis of the following three phases:

- Definition and Planning Phase
  - Does the group have realistic goals?
  - Is the problem clear?
  - Have the main points been considered?
  - What plan has the group decided upon?
  - Do group members know their responsibilities?
  - Will all points of view be considered?
  - Will several alternatives be explored?

- Discussion Phase
  - Are group guidelines being followed?
  - Are leadership responsibilities being carried out?
  - Is the group considerate of other groups?
  - Are group needs being met?
  - Is each member contributing?

- Summary Phase
  - Has the group been able to come to a conclusion satisfactory to all members?
  - Have goals been achieved?
  - Is the thinking accurate and logical?

3 Observer Evaluation: In some situations, it may be worthwhile to place an observer beside a group. (The observers could be students absent at the start of group formation or members of a group held up due to an absence or other circumstance.) Observers should be given specific evaluation tasks, and should report to the group and to you They could use any of the self-evaluation sheets or they could be asked to see how a group is meeting one or two specific needs. They should offer positive suggestions for improvement of group dynamics

SCT 11 — Evaluation Sheet

Self-Evaluation Checklist for Groups

Judging Facts and Opinions; Reliability of Resources	YES	NO
(1) Did the group separate facts from opinions?		
(2) Did members support opinions and conclusions with facts?		
(3) Were sources of information reliable?		
(4) Were a variety of resources used?		
Errors in Thinking		
(1) Were several solutions or alternatives discussed?		
(2) Were conclusions supported with examples?		
(3) Were several examples provided or was one example used to "prove the rule"?		
(4) Were cause and effect statements true. (Note: Just because two events happen in sequence is not proof that one was the cause or effect of the other.)		
Group Communication and Cooperation		
(1) Did each member know the duties or role assigned?		
(2) Did the group find ways to resolve conflict?		
(3) Did the group use specific strategies to identify alternatives, determine a plan of action, and make decisions?		
(4) Were different viewpoints within the group considered?		
(5) Were members considerate of each other?		

SCT 11 — Evaluation Sheet

Group Goals	YES	NO
(1) Were goals clear?		
(2) Were goals realistic?		
(3) Were goals "shared"?		
(4) Were goals realized?		
(5) If goals were not realized, what factors interfered with their realization?		
Group Formation		
(1) Was the method of formation suited to the task?		
(2) Were people with varied expertise present?		
(3) Were several points of view represented?		
(4) Was the size of the group suited to the task?		
(5) If answers to any of the above are "no," suggest better ways to form a group for this task.		
Group Planning and Follow-Through		
(1) Was the topic selected and narrowed realistically?		
(2) Were a variety of resources used?		
(3) Was information well organized?		
(4) Were analysis and interpretation carried out and shared?		
(5) Did the "product" meet the criteria identified at the outset?		
(6) Were conclusions and decisions supported, logical?		

Evaluation Checklist for Teachers

Criteria (for each student to be evaluated, assign a mark out of 5 on every criterion; the total mark will be out of 50).

	0	1	2	3	4	5
Understands the topic or problem						
Listens while others speak						
Appears to be interested in and willing to hear others						
Interjects ideas appropriately (politely and at the correct time)						
Considers viewpoints of others						
Takes part in and contributes to discussion						
Relates discussion to the topic						
Tries to get to the point without unnecessary delay						
Refers to but does not repeat the ideas of others						
Speaks clearly; expresses ideas clearly						
TOTALS						

Debating

Debate is formal discussion that begins with a statement of point of view on an issue Formal debate is one of the fundamental activities of democracy and, through various international organizations such as the United Nations, it is also a tool for resolution of global problems and issues.

Because a debate explores different points of view, it is an ideal strategy for exploration of issues. Specifically, debates in the Science and Technology 11 classroom will provide opportunities for students to:

- explore different points of view,
- respond critically to technological issues,
- practise and observe a technique that is used both nationally and internationally to resolve issues.

Debate format varies from rigid adherence to a set of prescribed rules to informal, more loosely controlled dialogue and discussion The teacher must choose a suitable format

For experienced debaters, the formal debate may be appropriate The two major forms of formal debate are:

1) British Formal Debate:
   - Debate format is modeled after parliamentary debate procedure.
   - The debaters' emphasis is on winning the votes of the audience rather than demonstrating debating skill.
   - Teamwork is not stressed.
   - The procedure is as follows:
     (1) Selected debaters speak for and against the motion.
     (2) Debate is thrown open to the membership or audience.
     (3) A vote is taken on the merits of the proposition.

2) American Formal Debate:
   - Debate format is modeled after courtroom procedures
   - Speakers operate as a team, and the activity is competitive
   - The goal of debaters is to impress the judges with their superior debating skill rather than to sway the audience.
   - The decision is based on the skill shown in debate rather than upon the merits of the question

You and your class should clearly understand the purpose of the debate before deciding which format to use. For greater class participation and issue clarification, the British format has considerable merit. The American format may be more suited to an exploration of logic, argument, opinion, or analysis, and the formation of conclusions. You may find that by combining some of the characteristics of each you can develop your own formats that maximize class participation, clarify issues, and develop debater skills. This goal may be accomplished by holding an American-style debate that is then opened to the class for discussion and a vote on the proposition. Debaters may also be evaluated on their debating skills.

The resource materials provided in this manual are related more closely to the American debate format. They should be adapted to meet the needs of the class. The series of activities provided for inexperienced debaters can be used by the teacher as preparation for formal debate or independently as a useful tool to ensure that discussion is meaningful.

Choosing Questions for a Debate

Choose an interesting, two-sided question, and state it clearly, briefly, and definitely. It should be a timely and vital one that is unsettled Avoid broad or complicated questions, propositions that can never be proved or disproved, and any proposition that is stated in the negative As an exercise, you could have students criticize these as questions for debate:

- Th bus is more useful than the automobile.
- Cigarette smoking is injurious to boys.
- The pen is mightier than the sword.
- Canada should not belong to the United Nations.
- Law is a better profession than medicine.

Within the individual modules, you will find suggested debate topics that relate to the suggested activities. Other possible STS debate resolutions include the following:

- Cigarette advertising should be banned.
- The United States controls Canadian energy resources.
- Women have more limited opportunities in technology than do men in Canadian society

- It is necessary for young people to have an understanding of how technology helps them to be successful in life.
- The use of chemical insecticides should be banned in Canada
- The right to own an automobile should be limited to one per family to cut down on pollution and use of resources.
- Every couple should be allowed to have as many children as they want.
- Canada and the U S. should enter an agreement on joint use of North American energy resources (coal, oil, water, natural gas).

Parts of a Debate

The Introduction clears the way for the argument The body of the argument is the presentation of evidence to support a point of view on an issue(s). The conclusion is the summary of this evidence.

INTRODUCTION:

- Give the history of the question, if necessary.
- Define words or expressions that may not be clear to the audience.
- State the main issues.
- Win the sympathy of the audience. The introduction should be simple, straightforward, modest, and fair. Explain. Do not argue or overstate.
- Analyse the question so that it is clear to your audience that you have selected the real issues, and that if you prove them, the decision must be in your favour

BODY OF ARGUMENT:

- Present a logical and emphatic grouping of facts, authoritative opinion, and reasoning to prove the main issues.
- Do not advance any weak arguments One good reason is more convincing than several poor ones.
- Hit hard.

SUMMARY OR CONCLUSION:

- Restate the main issues of the debate

Order of Speakers

In direct proof, the order of speakers is First affirmative, First negative, Second affirmative, etc. In rebuttal, the negative usually speaks first This plan gives the affirmative the advantage of the last speech — a fair arrangement because the burden of proof rests upon the affirmative In other words, if neither side advances definite proof or if the negative speakers overthrow the arguments of the affirmative, even without presenting any of their own, the affirmative speakers have lost the debate, because they have failed to prove the proposition.

Roles of Debaters

FIRST AFFIRMATIVE clears the way for argument by presenting the introduction and then the evidence to support a point of view on an issue or issues, spends half time on introductory matter and the rest on evidence; attempts to gain sympathy of the audience.

FIRST NEGATIVE supplies any introductory material omitted by First affirmative; either accepts or rejects definition of terms and issues; proceeds to support point of view on an issue; should be knowledgeable about subject, clear, earnest, and fair, should have enthusiasm and a sense of humour, endeavouring to win the audience over to the negative side.

THE LAST SPEAKER ON EACH SIDE concludes with a clear, brief, forceful restatement of the main issues and evidence

REBUTTAL asks the two questions, "How do you know?" and "What of it?"; denies opponents' facts or statistics when they are erroneous or misleading; points out if his or her authorities are prejudiced or unreliable, his or her reasoning is faulty, and his or her statements are inconsistent; shows that opponents' evidence is inadequate or beside the point; strikes at opponents' main issues, does not advance constructive arguments; does not attempt to refute arguments that can't be overthrown; reviews quickly and compares the arguments of the two sides.

Rules of Debate (American Formal)

DEFINITIONS

- The affirmative must define the essential terms of the resolution.
- The negative should make an issue of the definitions only if it feels that those provided by the affirmative are patently unreasonable. If this does happen, the judge should accept the definition that is best supported by evidence and argument throughout the debate.
- Generally, the negative should not first accept and then later object to the definitions. Failure to challenge a definition is understood to be acceptance of it.

TEAM OBLIGATIONS

- If possible, the affirmative must present a plan for revising the status quo. The affirmative need not show that the plan is legal or constitutional, but must be prepared to deal with negative attacks on its feasibility.
- The negative may offer any counter plan but must show that counter plan to be significantly different and demonstrably more desirable than the affirmative's proposal The use of a counter plan usually implies acceptance of the need for change

PROOF

- An assertion or factually unsupported statement carries no weight in a debate.
- The amount of proof required in a debate is generally less than is required in a court of law. The affirmative is not obliged to produce "proof beyond a reasonable doubt."
- Evidence must be accurate. A judge who feels that it is not may request full documentation of the material.
- A judge who is certain that the evidence has been deliberately falsified is justified in awarding the debate to the other team on this point alone.
- Visual aids are permissible in a debate Once introduced, they are also available for the opponents' use.

PROCEDURE

- No new constructive contentions may be introduced in the rebuttal speeches unless it is the first opportunity to answer a direct question and the contention answers the question.
- New evidence may be presented at any time.
- Refutation may take place at any time and is not restricted to the rebuttal speeches.
- Either team, when advocating a plan of action, should explain it early enough in the debate to give the opposition an opportunity to reply in a constructive speech.

COURTESY

- Debaters shall address the presiding officer as "Chairperson" and shall not refer to opponents or colleagues by name.
- Debaters shall not breach normal courtesy by grimacing or whispering loudly while an opponent is speaking. Heckling is permitted in the British or parliamentary style only.
- Debaters shall not, either by word or action, seek to belittle their opponents. Debates must be a clash of issues and not personalities

RULES FOR CROSS-EXAMINATION STYLE

- The examiner shall control the cross-examination. The debater taking the role of witness, however, shall be allowed reasonable time to answer.
- The witness has the right to qualify answers, but such qualifications must be brief.
- The witness must answer all relevant questions.
- Debaters shall not seek assistance from a colleague while asking or answering questions.
- The witness shall not ask questions, except to request clarification.
- Judges are requested to penalize speech-making by the examiner, lack of cooperation on the part of the witness, stalling, irrelevance, flippancy, discourtesy, brow-beating, or any attempt to belittle or discredit an opponent.

Tips for Debaters

Debating can be very easy and enjoyable if the debaters remember certain simple but essential things. The pointers listed below can improve the quality of debates regardless of the topic.

- A good debate topic is one that is suited to the knowledge, interest, and experience of both the debaters and the audience. The topic should be debatable; that is, the statement made should be neither true or false.

- The topic should be put in the affirmative, not in the negative. Affirmative statements help avoid confusion as to what the subject is. Remember to limit the topic to one subject.

- A debate topic gives or puts forth a proposition. There are two kinds of propositions: the first is the one of fact, asking the question, "Is this true?"; the second is a proposition of policy, asking, "Should this be changed?"

- Word the topic clearly so that there can be no confusion about what the debaters must prove to be either true or false.

- Learn all that you can about the topic. Make full use of the library, your experience, and your previous knowledge of the subject. Study the origin and history of the [illegible]. Define the terms of the topic, and know what it says. Survey all the evidence and arguments, both for and against the topic. Decide which arguments are pertinent and which are irrelevant to the topic. Use both opinions and facts: a fact is a statement that can be proved to be true; an opinion is one person's interpretation of the facts.

- Try to incorporate the following qualities into your presentation:

  CLARITY: absolutely necessary since the audience cannot return to a statement to search out its meaning.

  ACCURACY: say exactly what you mean. Exaggeration and inaccuracy destroy your credibility. One foolish statement is usually enough to lose a debate.

  UNITY: omit everything that doesn't bear directly on the main issue you are debating

  COHERENCE: tell the audience what you are going to tell them, tell them, then tell them that you have told them. The second speaker, for example, should begin by restating briefly the evidence presented by first speaker and identifying what will be stated next.

  EMPHASIS: the beginning must catch the attention and win the sympathy of the audience, the body of the speech must present convincing proof, and the end must clinch the point.

How to Start Debating in the Classroom

(1) Explain that debating is a form of discussion.

(2) Choose an easy topic for discussion (in the form of a resolution) such as:
- that Canada should nationalize its mineral and oil resources;
- that the use of internal combustion engines in automotive vehicles should be prohibited,
- that every able-bodied high school student should be required to pass a test in computer literacy as a prerequisite to graduation.

(3) Next, divide the class by an imaginary line down the centre of the room, forming two groups: "Pro" and "Con." Students in the back row could be designated as "neutrals" and could then act as judges, giving their verdict at the end of the session.

(4) Call on someone (or ask for a volunteer) from the Pro side to stand up and state one reason why he or she is in favour of the resolution. Then ask someone from the Con side to state one reason against the resolution. Continue this process, alternating from side to side.

(5) When this routine is understood by the students, one of them could be appointed to act as Chairperson of the discussion.

(6) Each side could appoint a Secretary to write down the points made by the speakers.

(7) The next phase could be an exercise in rebuttal. Alternately, one point at a time, the Pro and Con secretaries present the arguments given by their teams, then a representative from the opposition attempts to refute them. This exercise is continued until the lists of points are exhausted.

(8) At the end of the session, the back-row judges would be asked to take a vote among themselves and to pronounce the majority verdict, based solely on the arguments and evidence presented by the various speakers, not on personal opinions.

HOW TO CONDUCT PRACTICE DEBATES

The transition from discussion to actual debating is quite easy. A practice debate may be organized as follows.

(1) Divide the entire class into two teams of approximately equal strength.

(2) Choose a resolution for debate, define its terms, and determine which team will take the affirmative and which the negative side.

(3) Fix a date for the debate, allowing one or two weeks for preparation, depending on the difficulty of the topic.

(4) Each team will then proceed as follows.
- The team will select two of its mem s to be the principal debaters These two debaters will each prepare three-minute speeches each covering a different aspect of the topic, but will work together to make a continuous presentation. They must not duplicate each other's materials except in recapitulations, which are also used to emphasize the main argument.
- The other team members will also study the topic and be ready to make short speeches from the floor, for or against the resolution, or by way of rebuttal.
- Each team will nominate a Chairperson. Since there can only be one Chairperson, the matter will be settled by lot, and the unsuccessful candidate will assume the role of Timer

(5) When the actual debate takes place, the procedure will be as follows.
- The class will be physically divided into two groups — those supporting the resolution and those opposed.
- The Chairperson will be in the front centre, with the two principal debaters for the Affirmative on his or her other right and the two for the Negative on his or her left, all seated at desks facing the audience.
- The Timer will sit in the front centre facing the Chairperson, and will be equipped with two signal cards, one marked with a large figure "1," and the other with the figure "O" (zero). The Timer will signal by raising the "1" card when the speaker has one minute remaining, and the "O" card when time has expired.
- The judge or judges will be seated at the back of the room. Judges can be furnished with score sheets (the Informal Debate Evaluation sheet can be adapted for this purpose).

- When everyone is ready, the Chairperson will proceed as follows.
  - Call the meeting to order.
  - Announce the topic and introduce the four speakers.
  - Call on the 1st Affirmative speaker (time limit - 3 minutes).
  - Call on the 1st Negative speaker (time limit - 3 minutes).
  - Call on the 2nd Affirmative speaker (time limit - 3 minutes).
  - Call on the 2nd Negative speaker (time limit - 3 minutes).
  - Call on 1st Negative for rebuttal (time limit - 1 minute).
  - Call on 1st Affirmative for rebuttal (time limit - 1 minute).
  - Invite short speeches from the floor, starting with the Affirmative side and alternating with the Negative side until a maximum of ten speakers have been heard from each side. (No speaker should be heard more than once, nor for longer than one minute; all students must speak if time permits.)
- After due deliberation, the judge or judges will announce the result.
- Teacher will close with a constructive commentary intended to improve the quality of future debates. The Debate Evaluation form included at the end of this section could be used for recording marks.

Formal Debate Outline

Chairperson

1. Welcomes debaters and audience.

2. Gives statement of resolution (BIRT): "Be it resolved that"...followed by statement of the position.

3. Introduces speakers:
"Speaking for the affirmative we have.. "
"Speaking for the negative we have..."
"Our first speaker will be..."

First Affirmative — Time: 4 min

1. Greeting: "Honorable judges, ladies, and gentlemen the resolution before us today is..."

2. Defines resolution: defines any terms of the resolution; redefines resolution in light of the term definitions.

3. Outlines 3 or 4 points of the argument. (Limits scope of debate.) "As the first speaker of the affirmative, I will clearly give you our (3-4) major reasons why the resolution should stand. They are..."
   (1) ______________________ and support
   (2) ______________________ and support
   (3) ______________________ and support
   (4) ______________________ and support

4. Speaks to one point of the argument.

5. Closes: "I have clearly indicated what the major problems are. On the basis of my research, the main argument has been.... My partner will respond to the other three."

Cross-Examination by Second Negative — Time: 3 min

Questions the First affirmative on points of his or her argument (ideally, tries to get opponent to admit he or she was wrong); avoids allowing opponent "speech" time (i e , time for long explanations).

First Negative — Time: 4 min

1. Greeting and statement. "My partner and I cannot support this resolution.

2. Defines any terms the affirmative did not define or challenges affirmatives definition(s); otherwise negative must use definitions already presented.

3. Offers a short rebuttal of first affirmative.

4. Outlines 3 or 4 major points of their argument
   They are:
   (1) ______________________ and support
   (2) ______________________ and support
   (3) ______________________ and support
   (4) ______________________ and support

5. Speaks to one or two points.

6. Closes: "Ladies and gentlemen, we feel confident that you will agree that (resolution) must fall."

Cross-Examination by First Affirmative — Time: 3 min

Second Affirmative — Time. 7 min

1. Greeting and review of partner's argument.

2. Rebuts the nega ve statement. "Before speaking, I will respond to the standpoint of the opposition." 44

3. Speaks to remainder of affirmative arguments. "Now let us look at the suggested benefits of the resolution not yet discussed. They are..."
   (1) ______________________ and support
   (2) ______________________ and support
   (3) ______________________ and support

4. Closes: "We have clearly shown the benefits of the resolution/and or the problems that arise if the resolution is not supported. Clearly the resolution must stand."

Cross-Examination by First Negative Time: 3 min

Second Negative Time: 7 min

1. Greeting.

2. Rebuts rebuttal of first negative." Before looking at ... I ..."

3. Looks at "suggested" benefits of the resolution and states rebuttals:
"The affirmation stated that..."
(1) ______________________ and rebut
(2) ______________________ and rebut
(3) ______________________ and rebut
(4) ______________________ and rebut

4. Speaks to remainder of negatives arguments. "Now for the body of my speech, I will show you how the resolution, rather than solving problems, creates new ones."
(1) ______________________ and support (example)
(2) ______________________ and support (example)

5. Closes: "Ladies and gentlemen, the resolution (state it) not only does not solve problems raised by the affirmative, it creates new problems The resolution must fall."

Cross-Examination by Second Affirmative Time: 3 min

Final Rebuttals (1) First Negative Time: 2 min
(2) First Affirmative Time: 3 min

1. Repeat the resolution.

2 Summarize team's main arguments.

3 Review the main weaknesses of the other team's arguments

4. Emphatically restate his or her team's position. No new material may be entered in these rebuttals.

AFFIRMATIVE'S JOB

1. Define the resolution.

2. Defend the resolution by presenting three or four points for each of the following:
- attack the status quo in general senses (traditional values);
- isolate problems in the status quo;
- research the historical/social context of the resolution;
- present logically sound arguments for change;
- present a plan for change — who, what, where, when, how;
- demonstrate how the change (the plan) resolves the problems of the status quo.

THE NEGATIVE'S JOB

1. Show that the affirmative's defense is not convincing because
- definitions were unclear;
- arguments were not logical;
- of weak authority/support research;
- of the cost, feasibility, or acceptability of the plan;
- the plan creates "new" problems or;
- the plan doesn't solve the problems.

2. Show that the status quo is
- traditionally acceptable/culturally correct;
- tied in with basic values.

3. Show that other solutions to the "so-called" problem are more effective than those proposed by the affirmative or suggested in the resolution.

Evaluation of Debating

For informal debates, use the Debate Evaluation form provided at the end of this section on Debating. The same form can also be adapted for the evaluation of formal debates, although there you may wish to incorporate the following criteria into your evaluation procedures.

- ORGANIZATION: An effective introduction is one that defines the terms in the resolution, outlines the plans for dealing with the issues, and attracts the interest of the audience. (Judges should remember that once the definition has been established, further definitions by later speakers are superfluous.) Each point made should be clear and distinct, and the speech organized so as to draw the listeners along a well-defined route to the desired conclusions. The conclusion should contain an effective summary of the main contentions dealt with in the speech.

- MATERIAL: The contentions raised should be argued logically and backed by examples, statistics, and well-known authorities.

- DELIVERY: Audibility, enunciation, variety (in tone, speed, and volume to maintain interest and give emphasis), deportment, avoidance of distracting mannerisms, good eye contact, avoidance of script reading, and naturalness (instead of obvious artifice and memorization) can all be assessed.

- REBUTTAL AND DEFENSE: The use of logic and evidence in refutation and defense in the constructive speeches of the First negative, Second affirmative, and Second negative should be looked for; both First negative and First affirmative have final speeches specifically for rebuttal.

- CROSS-EXAMINATION: Asking questions — Does examiner develop a series of questions that succeed in drawing valuable admissions from the respondent? Is the examination organized around central issues rather than a multitude of unrelated points? Is examiner courteous and respectful toward the respondent?

In answering questions, is the respondent poised, relevant, and effective in combating any attempt to undermine his or her contentions? Does he or she have resort for waffling, facetiousness, or other evasive tactics? Is he or she cooperative or over-defensive? Does he or she respect the right of the examiner to control the cross-examination time?

- PARLIAMENTARY PROCEDURE: Does the debater show familiarity with the style of debate? Are opportunities for heckling and asking questions employed? Is this done to enhance the level of debate? Are points of order and personal privilege over-used? Is the custom of addressing remarks to the Chairperson observed?

- DISCOURTESY: Depending upon the gravity of the offense, demote the speaker one or two grades in the individual evaluation under the section for delivery.

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Informal Debate Evaluation

AFFIRMATIVE

	Maximum Marks	MAIN SPEAKERS First	MAIN SPEAKERS Second
Introduction	5		
Content	25		
Delivery	10		
Conclusion	5		
Audience Response	5		
	Total		

FINAL SCORE	
First Speaker	
Second Speaker	
Floor Speakers	
Rebuttal	
Total	

NEGATIVE

	Maximum Marks	MAIN SPEAKERS First	MAIN SPEAKERS Second
Introduction	5		
Content	25		
Delivery	10		
Conclusion	5		
Audience Response	5		
	Total		

FINAL SCORE	
First Speaker	
Second Speaker	
Floor Speakers	
Rebuttal	
Total	

FLOOR SPEAKERS

Maximum Marks: 2 per speaker

REMARKS

Introduction)
Conclusion)
Audience Response) A mark of 5 would be superlative, 4 excellent, 3 very good, 2 good, 1 fair, 0 poor.

Content: Overall impression of the substance of the speech: argument/reasoning, facts, examples/evidence/authorities quoted, organizat
Delivery: Audibility, enunciation, variety, conviction, deportment.
A mark of 10 would be superlative, 9 excellent, 8 very good, 7 good, 6 fair, 5 poor.
Penalties: Minus 5 for "reading" notes to the extent of being a distraction to the listeners.

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Appendix B

Excerpt from Science Technology Society

1985 Yearbook of the National Science Teachers Association
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WASHINGTON, DC 20009
U.S.A.

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"Charting a Course Through Risk and Controversy: Strategies for Science Teachers"

Faith M. Hickman

Part IV
New Instructional Strategies

Charting a Course Through Risk and Controversy: Strategies for Science Teachers

Faith M. Hickman
University of Colorado
Boulder, Colorado

> Our world today seems to consist of many complex nonlinear problems which feed on one another. The economy depends on resources, the availability of resources depends on geography and politics, politics depends on military strength, military strength depends on technology, technology depends on ideas and resources, ideas depend on politics for acceptance and support, and so on. Our world can be described as a complex system of interacting factors. It is a network of factors whose causes and effects are not easily identified.
>
> —Thomas L. Saaty

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In 1980 the Marsh and McLennan companies conducted a public opinion survey in which they asked respondents from a wide range of occupations to compare the amount of risk facing today's society with the risks of 20 years before. Of 401 top corporate executives polled, 38 percent said they believed there is more risk today than two decades ago. Increased risk was perceived by 60 percent of investors and lenders, 55 percent of members of Congress, and 43 percent of federal regulators. These reactions are conservative in comparison with the response of the general public, a staggering 78 percent of whom said they believed things are riskier now than they were in 1960 (Crouch & Wilson, 1982).

Life is in fact considerably *less* dangerous now than it was in 1960. By all objective measures—whether accident rates, infant mortality rates, or life expectancy statistics—life in this country today is less threatening than at any place ever before in human history. Why the dramatic discrepancy between facts and perception? Crouch and Wilson (1982) believe that a perceived awareness of so many *more* risks than previously has caused the state of alarm. Perhaps people count threats by number only and fail to estimate the magnitude of each. Perhaps also, as Saaty suggests, the interconnectedness of all aspects of modern life contributes to a feeling of overwhelming complexity and concomitant risk. Very likely the rapidity of change is also a contributing factor. Change today occurs so swiftly that risk is perceived in the process of change itself.

One of the responsibilities that falls to the science teacher (and the social studies teacher as well) is to help young people identify and understand the risks in today's world. Such teaching must convey knowledge that is truly meaningful to the learner, since exposure to a litany of dilemmas seems neither to enlighten nor liberate, as the results of the public opinion poll attest. Much has been written about the importance of addressing issues of science and society in the classroom, but little has been said about how such instruction might be conducted. Science-related social issues are always complex and almost always controversial How, exactly, is the teacher to handle this complexity and controversiality?

Instructional Strategies: Some Desirable Characteristics

In January 1984 the Exxon Education Foundation (1984) hosted a meeting of some of the nation's top educational leaders. The purpose of this blue-ribbon conference was "to explore some of the major issues raised by the current call for science education reform and to make recommendations regarding what steps should be taken to ensure that the needed improvements in elementary and secondary (K–12) science will actually be made in schools across the country" (p. 3). The conferees concluded that scientific and technological literacy should be established as one of the primary goals of education for all students.

They presented two arguments in favor of a reformulation of the K-12 science curriculum: first, that an understanding of science and technology is the key to participating in the affairs of a world that is likely to continue to change rapidly, and second, that because technological changes occur in all aspects of our lives (at work, in civic affairs, and in personal lives), scientific and technological literacy is necessary for all individuals, no matter what their careers or lifestyles may be. In sum, the conferees suggested that meeting the goal of scientific and technological literacy demands a future-oriented science curriculum, one that presents basic concepts and also teaches reasoning and comprehension skills, intellectual tools that can be applied to daily life experiences.

Just a few months later *Educational Leadership* devoted an entire issue to the topic of teaching thinking skills. Brandt (1984) commented in an introductory article that "good teachers have always tried—with varying success—to teach for thinking: to teach academic content in a way that strengthens students' cognitive abilities" (p. 3). Presumably because these individual efforts have generally not done the job, new curricula are being offered that include direct instruction in the development of various thinking skills. For example, in the same issue, Paul (1984) suggested that the current approach to teaching problem solving be changed:

> There is a fundamental difference between the kinds of problems one faces in technical domains and those in the logically messy "real world." Solutions to technical problems are typically determined by one self-consistent close-textured system of ideas and procedures In contrast, the problems of everyday life are rarely settled in a rational manner. . . . To this point the schools, to the extent they have addressed problem solving, have focused their efforts on technical problems and technical reason and procedure, and have either illicitly reduced real-world problems to them or have tacitly inculcated into students the prefabricated "apodictic answers" of the dominant social majority or some favored minority. (pp. 5–6)

The development of scientific and technological literacy requires that these suggestions be carried out, and also demands that issues of science and society form the core of the curriculum. Further, the treatment of such issues must not only expose the character of the issues, but also, and perhaps more importantly, encourage students to sharpen their cognitive skills. Instruction must provide students with opportunities to "get inside" issues and work their way out through the tangled web of cause and effect relationships that characterizes real-world problems.

In previous papers, I have discussed the pros and cons of dealing with controversial issues in class (Hickman, 1982a) and the attitudes of teachers toward including issues of science and society in the curriculum (Hickman, 1982b). In the 1984 NSTA Yearbook, I described one practical way of constructing curricula around such real-world issues (Hickman, 1984). I now will suggest several instructional strategies appropriate for teaching such curricula. Each of these strategies shares the assumptions that:

- the teacher operates as a manager;
- small-group discussion is used as the dominant mode of instruction;
- controversy is used as a motivational force for substantive learning;
- sufficient factual information is brought into the discussion to

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avoid having students merely exchange opinions founded in ignorance.

The Teacher as Manager

What sort of a job is teaching, anyway? I recall when a teacher-friend attended an informal meeting crowded with representatives from higher education, medicine, and business. The conferees introduced themselves—with their long, impressive-sounding titles. My friend, rising to the spirit of the occasion, introduced himself as Director of Room 343 at George Washington High School. His wit produced a good laugh, but it also made an important point. Teaching is essentially management—nothing more and nothing less.

What does the teacher manage? The four most important variables are people, material resources, learning environments, and time. First, the teacher manages people. Students are organized in ways appropriate to the performance of particular tasks: they work alone, in pairs, in small groups, or together as a class in a social arrangement chosen by the teacher. Principals, instructional aides, service personnel, parents, school board members, guest speakers, and district-level administrators are all subject at times to the teacher's management decisions. The teacher is a manager of talents and other human resources, including power, knowledge, expertise, and political support.

Second, the teacher is a manager of material resources. The maintenance, inventory, and use of supplies and equipment for laboratory and field investigations all require management. Choosing and planning the use of textbooks, reference materials, slides, tapes, and other learning tools also requires managment. The material resources of the community and outdoor environment—the high-tech equipment of industry, the samples from the local geological study site, the reptile collection at the zoo, the star maps at the planetarium, the trilobites at the museum, and the wildflowers growing along the nature trail—are often overlooked, although they are of critical importance.

Third, the teacher must manage the learning environment—not the objects present at a particular place, but the way in which the setting is used to promote learning. It is not enough to take a class to the museum to see the trilobites; this is little more then the "show and tell" approach used in the lower grades. The teacher must establish a learning environment that makes the study of trilobites meaningful, useful, memorable. Perhaps the learning environment will center on the theme of change over time: the significance of the trilobites lies partly in their usefulness in examining the earth's past in order to better predict its

future. This use of a thematic context for learning is an effective stimulus to learning.

Finally, the teacher manages time. This is without question the most significant and far-reaching management task of all. The average teacher at the high school level is given less than 150 hours with each class each year to teach whatever it is decided the students should know about a particular subject. Obviously, this amount of time does not allow for even a cursory survey of the knowledge of any field, or even a quick tiptoe through the subject matter chosen (often arbitrarily) by the textbook writer. How then is the teacher to manage that most precious commodity—instructional time?

The excellent manager uses wisdom, humor, creativity, common sense, an abiding respect for the tentative nature of knowledge, and a deep trust in young people to develop the students' judgment skills Time is managed with both precision and flexibility. No single fact is so important that students will suffer from missing it. No lecture is so significant that it will change the course of a young person's life. Instead, much time is spent on developing ideas. More time than originally planned for a topic is taken if needed. Topics are dropped quickly if they appear to be leading nowhere. Time is devoted to discussing each student's personal encounters with the themes and principles being studied. Awareness that different students learn different things at different times affects teaching strategies, and all are the better for it.

The teacher who succeeds in orchestrating this complex counterpoint of people, material resources, learning environments, and time becomes a master of management. Fortunately, teaching in the context of the potentially controversial issues of science and society is an opportunity that requires only a combination of techniques no more difficult to master than those required for presenting the trilobite collection effectively. It involves creating a learning environment in which meaning and purpose are clearly defined and then directing a series of carefully planned learning experiences.

The concept of teaching as a form of management allows us to see how the variables in instruction can be manipulated to promote students' understanding of complex problems. The management approach also promotes rejection of the static view of course content implicit in most textbooks. Good managers have the opportunity to make full use of all the variables. Finally, viewing teaching as management makes available to the teaching profession a source of guidance previously overlooked: the enormous body of literature on business management, corporate supervision, and personnel administration.

Small-Group Discussion

Discussion will be to science education in the 1980s what the laboratory was to the new curricula of the 1960s. Scientific and technological literacy has a strong verbal component. It requires the ability to comprehend and dissect verbal arguments, and the competence to assess alternatives and express them through use of that most slippery of tools, the spoken language.

Teachers who grieve the loss of some class time from the laboratory should recall that the laboratory is only a means to an end, not an end in itself. When our goal is (as it often should be) to give students experience with designing experiments, testing hypotheses, or collecting data, then the laboratory is the preferred mode of instruction. When, however, we wish to engage students in an analysis of social issues rooted in science but unanswerable within exclusively scientific paradigms, then verbal discourse is the method of choice.

When we think of discussion in the classroom we usually picture the common format in which the teacher asks a question and a single student responds, then the teacher asks another question and another student responds. This pattern is sometimes useful, but it is not particularly conducive to reflection or in-depth analysis on the part of the students. Far better is the use of the small group—a team of two or three, but no more than four—that is given the mission to consider some problem in depth over a period of minutes (say, 15) or days, and then report its findings to the rest of the class. The 10 or so small groups in a class may all work on the same problem. In such cases, the team findings will still display marked dissimilarities. At other times small groups may be assigned different questions for study and debate, with synthesis and closure coming later, following reports from the groups and challenges from the entire class.

The small-group format has several advantages. It encourages the participation of reticent students who might not otherwise contribute. It employs students' natural strengths as leaders and creative thinkers. Peer pressure makes it likely that each individual will contribute significantly. In addition, small-group work frees the teacher to assist students on a personal basis, and to engage in informal conversation with individual groups to shore up sagging motivation, clarify issues, raise additional questions, and influence the direction of inquiry toward useful sources of information.

A relative of the small-group discussion is the independent investigation. The major differences are that investigations may be conducted by individual students if so desired, and that the investigations typically require more time (weeks or months) and make heavier use of outside information sources. Several curricular programs—for example *Investigating Your Environment*, *Energy and Society: Investigations in Decision Making*, and *Investigating the Human Environment: Land Use* (Biological Sciences Curriculum Study, 1975, 1977, 1984, respectively)—employ the independent-investigation approach to learning about issues of science and society.

Controversy as a Motivational Force

It is, of course, one thing to imagine small groups of students buzzing industriously, and quite another to envision controversy rearing its (presumably) ugly head. The business world has long been aware (certainly more so than the teaching profession has been) that there are actually *benefits* of conflict. Fahs (1982) might as well have directed his comments to the teacher as the corporate manager when he wrote:

> If no consistent efforts are made to assess, refine and apply communicative abilities, then the overall quality of decision-making, problem-solving and information transfer can be expected to suffer. Similarly, if no opportunities are provided . . . to [express] differing viewpoints, ideas and solutions, then there is little possibility . . . to realize any of the productive effects of conflict, let alone the positive communicative and self-esteem effects (p. 29)

Teachers who squirm about Fah's notion of the sin of omission may find it worthwhile to look at just what opportunity is being lost by avoiding controversy. It turns out that conflict is not the monster we may have thought it to be, but instead a sine qua non for learning. In 1979 Johnson and Johnson reviewed the research available at that time on the relationship between learning and controversy in the classroom and found that in most classrooms conflicts were avoided and suppressed, and that teachers and students lacked skill in conflict management. On the other hand, the bulk of the research supported the desirability of using controversy in the classroom:

- Controversy is an effective motivator for learning. "When the student realizes that other students or the teacher have a different conclusion and that they challenge and contest his conclusion, a state of internal conceptual conflict, uncertainty, or disequilibrium is aroused. That uncertainty motivates an active search . . . for more information, new experiences, and a more adequate cognitive perspective and reasoning process in hopes of resolving the uncertainty" (p. 53).

- Theorists of cognitive development, including Piaget, have suggested that interpersonal controversy promotes cognitive development—including the ability to think logically—and discourages egocentric reasoning. This hypothesis has been borne out in studies of conservers and nonconservers of resources who worked together on conservation tasks.
- Theorists of moral development, including Kohlberg, have postulated that controversy promotes the development of moral thought, and this hypothesis has subsequently been supported by experience. It has been found, however, that merely presenting students with differing opinions does not mean that productive conflict will ensue. The conflicts must be perceived by the students as related to their own stages of cognitive and moral development.
- Controversy can promote high-quality problem solving and decision making Research has shown that disagreements provide incentive for amassing a greater volume and variety of facts as well as increased attention to already available information. These shifts in knowledge result in shifts in judgment among the participants.
- Most interpersonal interaction promotes creativity, increasing "the number of ideas, quality of ideas, feelings of stimulation and enjoyment, and originality of expression in creative problem-solving" (p. 57). Interaction involving controversy is particularly effective, for it encourages seeking more creative solutions to problems and provides a greater sense of satisfaction to group members.

Lunstrum (1981) suggests that controversy stimulates motivation to read DeBono (1983) asserts that aquiring thinking skills can enhance a learner's self-image. Curtis and Shaver (1980) found that even poor students "when adequately motivated . . . can respond to a variety of rather complex source materials" (p. 307) Bell (1982) claims an additional benefit—the enhancement of what science teachers call "process skills." He advocates use of structured debates (a specific format for discussion of controversial issues) as a way of promoting critical thinking, because "ferreting out unstated assumptions, predicting probable effects, distinguishing facts from hypotheses, testing and comprehending relationships, and integrating disparate elements into a pattern or structure are what one does in debate" (p. 208).

Promotion of Students' Acquisition and Use of Information

If discussion is so powerful, and controversy so enlightening, then the

teacher, as manager of the learning situation, should apply techniques that make full use of these methods. One continual concern of teachers is how to encourage the use of factual material in discussions while discouraging off-the-cuff overstatements students make in ignorance, that at their worst spread ignorance or cause unnecessary polarization. Any experienced teacher can attest to the fact that having access to reference materials and resource support personnel is not sufficient to make students take advantage of what is available to them. After researching the behavior of consumers, Ratchford (1982) offered the following hypotheses about information seeking. For each of these I have added comment from the perspective of the classroom:

- *The more highly the individual values the product, the more information that person will acquire.* If students can select a topic for themselves, they may be more likely to seek information than if the topic is imposed. Furthermore, if there is an important outcome in sight—for example, an opportunity to convince a governing body or public decision maker of one's point of view—then information may be even more ardently sought and more avidly used.
- *The more obvious differences there are among choices, the more information will be sought.* Discussions of issues must, of course, always begin with some definition and clarification of the issue. The next logical step is to identify a variety of possible actions and to identify the differences among these alternatives. The extent to which students see a range of divergent choices may determine the extent to which they will be willing to investigate in depth. 52
- *The possession of correct information at the start reduces future information seeking.* The more students already know—or think they know—the less likely they are to seek new information. Issues selected for study should not be so familiar that they generate a (usually false) sense of expertise. It is also productive to demonstrate the ways that the information students already possess is flawed or incomplete.
- *Information acquisition varies inversely with the cost or effort of the search.* Cost may be monetary or a function of time and lost opportunities to engage in more attractive activities Here, having easy access to information or access through such entertaining means as computer simulations or personal interviews can help.
- *When information has carry-over effects, it is acquired earlier and a larger inventory is established.* If the study of one issue can contribute in some way to the study of another at some later time—and the relevance

of the first to the second is sufficient to promote transfer of knowledge—then information acquisition and retention may be enhanced.

- *Educated consumers use information efficiently, and hence are motivated to search for information.* It is worth the teacher's time to make sure students know how to use the library, search in telephone directories, make telephone inquiries, conduct interviews, and write effective letters. Such skills pay off not only in the science classroom but in life as well.

Supervising the Discussion Groups

Now, what about directing the discussion itself, assuming that adequate information is available and some diversity of opinion is present? Teachers can take a lesson from personnel managers, who suggest the following (Fahs, 1982):

- Invite reticent individuals into the discussion and give them explicit suggestions to encourage them to participate. This approach is more easily accomplished in small-group discussions; it is best avoided in large-group situations, where calling on students may embarrass them or seem punitive.
- Make sure the same team members are not performing the same tasks all the time. Rotate responsibility for recording and leading the discussion, and for reporting.
- Don't play favorites. Promote involvement and self-confidence on the part of all participants.
- Allow adequate time for interaction among students and between students and teacher. Suppressing disagreements and limiting numbers of comments "solely in the interest of reaching a decision within the prescribed time-frame . . . may ultimately reduce the decision's quality" (p. 30).
- Insist the points of view be supported with reasons and with data or other forms of evidence.
- Be careful in using the devil's advocate position. It may be effective in prodding students to think more deeply, but may also backfire and cause emotional conflicts that distort the issue.
- Convey the message to students: "I am yours, right now, for as long as is necessary" (p. 31). The goal, from the teacher's perspective, is to create a setting that holds the student's attention. Distractions and interruptions must be kept to a minimum—resist the urge, for example, to interrupt small-group work with an announcement that might be left for a later time.

- Be responsive. Remember that students' questions deserve answers, ideas deserve serious consideration, and suggestions deserve consideration, and, when appropriate, action. Honor requests for examples of opinions, as long as the requests are made for educationally valid reasons and the examples are understood to be opinion only. Provide assistance in finding information and admit it when you "don't know" an answer or can't help. Show appreciation for all serious student efforts.

Four Instructional Strategies for STS Curricula

Let's look at some classroom situations in which certain desirable commitments for teaching issues of science and society are in evidence. The teachers and students have agreed to address the potentially controversial science-related social issues as a regular part of the curriculum. The teacher feels comfortable operating in the role of manager, and the teacher and the students possess some knowledge of discussion skills. Assume also that a topic has been selected that meets such criteria as the availability of pertinent primary source materials, the potential for powerful and conflicting value components, and a multidisciplinary range of concepts.

What are some of the major themes that the lessons can develop in the minds of students? What specific intellectual competencies can the lessons encourage? While there are many others, four are considered here: decision making, conflict management, risk assessment, and cost-benefit analysis. Although these are not necessarily the most important themes that may be addressed, they are nevertheless ubiquitous, residing in virtually every social issue, and are universal enough to find application in a great many of life's major choices.

Decision Making

Teaching to promote students' decision making skills is like running in marathons. Most people agree it is a good idea, most admire the runner's achievement, but few people actually participate in marathons. Those teachers who believe that decision making is embedded in everything they do in class are fooling only themselves. Decision making no more enters significantly in the activities of most science classes than a stroll through the park resembles a marathon run. Decision making must be recognized as an explicit, planned part of the curriculum, or it probably will not be included at all.

By now, the steps of the decision making process are as familiar to most science teachers as the scientific method. Problem recognition leads to the generation of alternative courses of action, description of the consequences of the course of action, analysis of the consequences in terms of well-articulated value positions, and finally selection of an alternative. This process may be followed with demonstrations of data and presentations of arguments to support the choice, and then an evaluation of the suitability of the choice against a set of specific previously established criteria. Of course, this process is applied no more precisely in real life than in the scientific research model, because both hypothetical and actual problems are subject to the vagaries of chance, and to personality, vested-interest, deliberate falsification, and shortsightedness.

If decision making deserves a prominent place in the science classroom, how should it be treated? First, a situation is presented for discussion and some options are identified within the situation itself. In the 1984 NSTA Yearbook I described in detail a subject for study taken from real events (Hickman, 1984). Until 1974 the Manville Corporation was the world's leading distributor of asbestos. In 1982 Manville declared bankruptcy, citing as the reason the burden of future liability likely to be incurred as a result of lawsuits from victims of asbestosis. One question to be decided in this case involves responsibility. Assuming that sufferers from this disease are due monetary compensation, who should pay? Workmen's compensation? Manville's insurance companies? The Manville Corporation itself? The Public Health Service (because it set supposedly "safe" exposure levels)? The Navy (because many of the workers' exposures occurred during ship building in World War II)? One way to deal with this topic is to ask students to work in small groups to review the case and pretend that they must decide with whom the liability rests. Require documentation of each group's decision making process and support for its conclusion.

Oxenfeldt (1979) suggests a device that formalizes the process by assigning numbers in rows and columns representing the criteria and options. The system requires making decisions on quantification of the relative importance of the various criteria for decision making; it also provides an accessible display of the value differences among alternatives

Suppose, for example, that the issue under consideration is taken from the local newspaper. Perhaps the community is debating where to build a new airport. No one doubts that the facility is needed, but there is a hot dispute about where the airport should be erected. The cost of construction is about the same at each of the three possible sites, but the

sites vary in other factors: the accessibility of the location to the community members, the destruction of the natural environment that building and using the airport would cause, and harmful effects such as noise pollution and declining property values that would be borne by nearby residents. The sites are described as follows:

Site A. This site is 27 miles from the heart of the city, situated in a low-lying marshy area known to be important to the breeding of water birds and certain species of fish. The area is about 5 miles from the nearest housing development and lies within a half mile of the municipal golf course.

Site B. This site is 48 miles from the heart of the city. It takes over an hour to travel there from the convention center and tourist attractions. The site, like the countryside surrounding it, consists of sagebrush and unirrigated farm land used mostly for crops of feed corn or open range grazing of stock. There are two small ranches within 10 miles of the site. Otherwise, it is isolated from residential areas.

Site C. This site lies immediately adjacent to the present airport and is only 7 miles from the downtown business area. It may be reached from the convention center and tourist hotels in about 20 minutes, even in heavy traffic. Housing values around the existing airport are quite low, because of the noise produced by jet aircraft. Expanding the airport will greatly diminish the value of 400 luxury homes that were built about 10 years ago to the north and east of the present airport, off the usual flight path. This area is a pinion-juniper forest, a rare and productive ecosystem that naturalists are interested in preserving.

One way Oxenfeldt's scheme may be employed is in the following manner. First, each of the three sites may be given a rating (on a scale of 0 to 100) to describe how each site meets the three criteria described above. This exercise might yield results like those shown in Table 1.

Table 1. Evaluation of Airport Sites According to Three Criteria

Criteria	Site A	Site B	Site C
Accessibility	45	20	90
Lack of environmental disruption	55	70	50
Lack of noise pollution	80	90	40
Total	180	180	180

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When the process of assigning values is completed, students may well end up, as in the example in Table 1, with a tie, or close to it. Each alternative represents a different mix of trade-offs. The next step leads to the decision, for now the group must decide the relative importance of each of the three criteria. Weights are assigned (the weights should total 100 percent), and the values of the alternatives are normalized (expressed as a percent of the largest value among the three) in order to prevent distortion. An example of the resulting weighted alternatives, where the stance has been chosen that accessibility is more important than either of the other two criteria, is given in Table 2.

Table 2. Weighted and Normalized Evaluation of Three Airport Sites

Criteria	Importance (weights)	Normalized Site Values (independent of weights)			Weighted Descriptions of Alternatives (importance times normalized value)		
		A	B	C	A	B	C
Accessibility	50%	50	22	100	25	11	50
Lack of environmental disruption	20%	79	100	71	16	20	14
Lack of noise pollution	30%	89	100	44	27	30	13
Total	100%				68	61	77

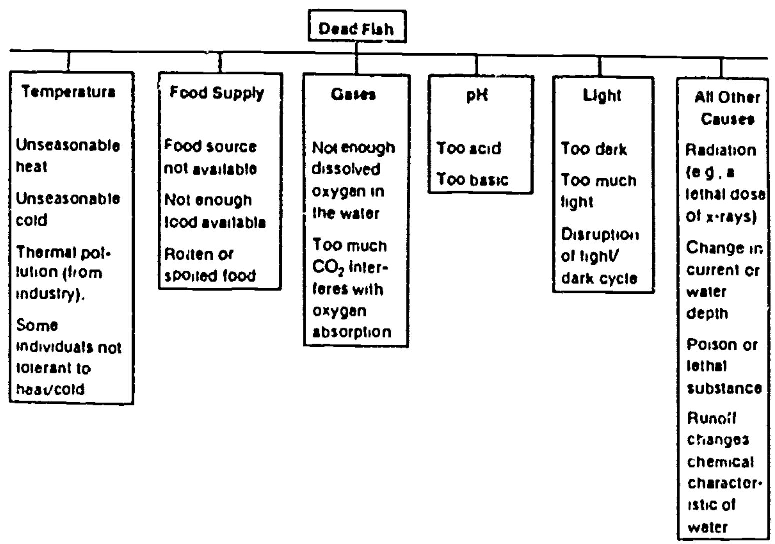
As Table 2 shows, Site C has become the winner because of the degree of importance the students assigned to accessibility. It is not hard to imagine choosing instead to assign higher values to environmental protection or noise control (or both) and correspondingly lower values to the convenience of travelers It is also possible to create examples in which an alternative fails on the most important criterion, but does so well on others that it emerges as the preferred choice.

This method has the advantage of being systematic and easy for students to follow. The mathematical manipulations are within the grasp of most high school students. In classes where this numerical analysis may not be appropriate, the idea of weighting the criteria is still useful. It is the process of creating and assigning the weights and values

that matters most, not the end result. In our example, for instance, one kind of evidence and argument is required to justify rating Site B higher in terms of lack of environmental disruption than Site C. Another kind of justification is required for rating accessibility as more important than noise control.

Another decision making tool that deserves greater use in classrooms is the fault tree, in which the possible causes of the problem being investigated are organized into categories. Once "things that can go wrong" are determined, organized, and displayed, it is easier for the problem solver to seek out the root of the trouble and take appropriate action. Suppose, for example, some dead fish are observed floating on the surface of the lake. The following figure shows a fault tree that was constructed by a 10th-grade biology class as a result of their attempts to hypothesize about the cause of the problem. After constructing the fault tree the class was ready to test hypotheses, collect relevant data, and reach a decision about what should or should not be done about the lake.

A Student-Constructed Fault Tree



Fault trees, like any decision making tool, must be used with caution. Perhaps because they look so neatly organized, interpreters may overlook the fact that some details may be missing. There is also a tendency to exaggerate the impact of causes assigned to specific categories as opposed to those lumped under "all other" (Fischhoff, Slovic, & Lichtenstein, 1978). For the secondary school student, however, again the value is not in the use, but in the construction. Thinking of possible explanations, organizing these ideas into a useful form, and employing the form as a stimulus for further research are skills promoted by use of this teaching strategy.

Conflict Management

Conflict is often aroused in situations that require decisions. If only opinions are at stake, individuals may simply agree to disagree. But if collective action is required, the conflict must be resolved. The skill of conflict management is important for the teacher to master for use as a classroom strategy. It is important for the students to master it (perhaps through the classroom exercise) for use as a life skill.

The basic dictum of conflict management is: "A crisis can be almost anything you want it to be" (Horne, 1983, p. 22). It is not the event but an individual's reaction to the event that determines the outcome. Conflict is by no means a negative to be avoided at all costs, although its negative aspects are well known. On the contrary, conflict is viewed in the business world as "an essential catalyst for change, which is itself essential for progress and profitable growth" (Leslie, 1983, p. 33). While conflict may sire strikes, absenteeism, personality clashes, demarcation disputes, autocratic management, and high employee turnover, it also provides impetus for the reappraisal of traditional methods, greater understanding of the needs and motivations of other workers, release of tensions, greater flexibility and adaptability, and improved job satisfaction and morale (Leslie, 1983). The trick is to reap the positive benefits at the lowest possible cost. Hart's checklist (Hart, 1983, pp. 70–71), reproduced in Table 3, is as useful to the classroom manager as to the plant manager.

Though conflict in the classroom can stimulate learning, its benefits may be left unrealized if the climate for dealing with conflict is not properly managed. It is essential that the teacher establish clear rules. The conflict is between ideas, not persons. Name calling and personal attacks are forbidden, as are emotional outbursts that divert time and attention away from the issue at hand. Students need to master the use

Table 3. Positive and Negative Outcomes of Conflict

Conflict is Destructive When It	Conflict is Constructive When It
diverts energy from more important activities and issues	opens up issues of importance, resulting in their clarification
destroys the morale of people or reinforces poor self-concepts	results in solving problems
polarizes groups, increasing internal cohesiveness while reducing group cooperation	increases involvement of individuals in issues of importance to them
deepens differences in values	serves as a release of pent-up emotions, anxiety, and stress
produces irresponsible and regrettable behavior such as name calling and fighting	helps build cohesiveness among people by sharing the conflict, celebrating its settlement, and learning more about each other through it
increases stress	helps individuals grow and apply what they've learned to future situations

Note. From Hart (1983).

of Horne's five questions (1983): Can I persuade you to change your mind? Are there points in the conflict on which I am willing to change my mind? Are there points that can be dismissed? Are there points on which all can agree? Are there points on which we totally disagree?

The answers to these five questions may help determine the strategy to be used in seeking conflict resolution. Caffarella (1984) offers a comprehensive list of strategies and tactics, each of which is appropriate in certain situations. My adaptation of that list appears as Table 4.

Tables 3 and 4 can be shared with students for use as guides for their individual and group deliberations. Point out that conflict, when it arises, should be kept on the positive side (as described in Table 3), and that students may gain experience in managing conflict through several of the tactics suggested in Table 4. When conflicts arise, suggest that students refer to Horne's five questions, and then search out a tactic that seems to suit the situation best. After the conflict passes, ask students to reflect on their experience. What strategies and tactics were used? Might other tactics have proved more satisfactory? How should similar situations be handled in the future? What was learned from the conflict experience?

Table 4. Strategies and Tactics for Managing Conflict Situations

Strategies	Tactics
Neutralization—parties attack or countenance the opposition	• Coercion—parties use threats to suppress the opposing side • Compromise—parties find a mutually acceptable alternative that partially satisfies both sides, thus "splitting the difference" • Suppression/Smoothing Over—participants deny or "play down" the conflict and dismiss it • Avoidance/Denial—parties refuse to admit the conflict exists • Outside Support—one party brings in an outside expert to support its view over the other side's
Submission—parties agree to outside intervention under a set of rules	• Arbitration—an independent person hears both sides and makes a decision which is binding on both parties • Mediation—both parties consent to intervention by a mediator, but the advice need not be taken by either party • Court Action—a judicial body makes a decision • Special Referendum—parties submit the question to a direct vote of the people • Statute—participants look for a law that applies to the conflict topic
Resolution—parties use conflict as a way of resolving problems	• Confrontation—both parties "talk out" the problem • Negotiation/Indirect Persuasion—a third party facilitates dialogue and enforces rules of fair play • Consensus and Integrative Decision Making—the parties in conflict review the problem, generate possible solutions, evaluate alternatives, and agree to a single solution

Note Adapted from Caffarella (1984).

Risk Assessment

Any discussion of technology inevitably leads to the subject of risk. Educators have recognized the connection linking the rapid rate of future change not with science—the acquisition of knowledge—' t with technology—its application (Exxon Education Foundation, 198[illegible] an-gers lie not so much in what we know, but in what we do.

The analysis and assessment of risk is an emergent field of specialization within the business community. In most business firms, risk management involves running an employee-safety program and purchasing insurance to protect against calamity (Dillon, Feldhaus, & Farrell, 1984). In other companies, the management of risk has more to do with investments and financial losses; for example, in the petroleum industry

the risk of hitting a dry hole must be balanced in some rational way against potential benefit—the possibility of locating profitable oil reserves (Ball, 1983).

Chapman and Cooper (1983) describe risk as having an "undesirable implication of uncertainty. Sometimes 'risk' is a convenient short form for 'source of risk' and sometimes 'risk' is a convenient short form for 'the probability of realizing a source of risk'" (p. 238). Dillon and his colleagues define risk as "the possibility of loss or injury" (Dillon, Feldhaus, & Farrell, 1984, p. 50).

Whether applied to profits or safety, the concept of risk may well be as important in the science classroom as it is in industry. The logical skills used in risk management are not beyond the cognitive competencies of high school students. Three steps are involved in risk management (Miller, 1981):

1. *Risk identification*—determining and describing the sources of risk. Evaluation may rely on past experience or use of checklists.

2. *Risk assessment*—judging both the likelihood and potential severity of each risk. Some risks may be deemed potentially catastrophic but highly improbable. Others may have less severe consequences, but higher probability.

3. *Risk treatment*—dealing with the problem using one of the following basic strategies: (a) risk assumption—taking responsibility for preventing the potential risk itself, perhaps by devising some self-protection strategy; (b) prevention—taking steps to prevent the serious consequences of a risk from developing; (c) avoidance—eliminating the source of risk; and (d) transfer—shifting the burden of coping with the consequences from one party to another.

A simple example may demonstrate how secondary school students might learn how to participate in risk management through class discussions. Riding a bicycle at night is a risky enterprise. The sources of risk are many, perhaps the major one being the failure of drivers to see the bicyclist. The probability of a serious or fatal accident is small to moderate, depending upon the particular situation. Furthermore, older people would probably rate the risk higher than the young (because declining tolerance for, or increased understanding of, risk may be a function of maturity). However, the severity of the consequence is judged great by all.

How is this risk to be treated? The strategy of risk assumption suggests that the rider may choose to bear the burden of the risk, taking protective steps such as using reflectors and lights, and wearing white clothing. Risk prevention suggests protection, not against an accident itself, but against fatal outcomes; therefore, use of a helmet and protective clothing may be in order. Risk avoidance is another approach; one may choose not to ride a bicycle at night, no matter how great the desire. Finally, there is the possibility of transferring part of the risk to a third party. Life insurance and hospitalization coverage do not change the probability or consequences of the accident for the individual, but they certainly shift the financial burden from the hapless rider's family.

The class discussion of the risk of bicycle riding may be extended to include other questions. For example, individuals are more likely to accept a risk if it is voluntary rather than imposed by some external authority (Dardis, Davenport, Kurin, & Marr, 1983). Ask students to contrast how they might feel, for example, about riding a bicycle at night because they wanted to with being forced to do so by a totalitarian government. There is also the problem of such unpredictable factors as the condition of the road, the width of the shoulder, and the amount of automobile traffic, which often may not be determined.

Predicting that the expense of risk management will rise relative to other costs in the business world, Seiple (1982) suggests that one of the reasons is the rapid rate of change in technology. New technology brings about exposures to loss and risk that did not exist in the past. Attempts to predict new risks will always be only partially successful. Nevertheless, trying to anticipate new sources of risk is essential if losses are to be minimized or avoided.

Discussions of risk have some pitfalls that can usually be avoided in the classroom, given proper planning, execution, and follow-up. Hertz and Thomas (1983) mention a few such pitfalls. A different problem from the one intended may be solved due to inadequate structuring of the question. People may be reluctant to face uncertainty and confront events of the long-term future. The students' processes of identification and assessment may be interfered with if the control of the manager (in our case, the teacher) is too strong. The task may strike the novice as too sophisticated and complex. In addition, risk analysis may produce "tunnel vision" in participants who cling too closely to their desired end product and forget the importance of the process.

Finally, there is the question of what issues are appropriate for risk analysis. Virtually any STS issue is fair game for risk analysis. Acid rain is a good topic, because there are many sources of risk and also multiple alternatives for risk treatment (Bybee, 1983). Excellent case studies are available on subjects such as saccharin, nuclear power plants, automobile

safety features, radiation exposure, nuclear copper mining, mass chest radiography, skull fracture diagnosis, coronary artery surgery, and swine influenza immunization (Crouch & Wilson, 1982).

Cost-Benefit Analysis

Any consideration of risk leads inexorably to mention of benefit. One may be willing to take substantial risk if the potential of massive gain is high. Conversely, even the most foolhardy are likely to avoid a risk where the possibility of triumph is miniscule. Risk analysis asks, "What do we have to lose?" Risk-benefit analysis asks another question: "What do we have to gain?" Although cost-benefit and risk-benefit analysis differ in some important ways in their use in the economic world, these differences need not concern teachers and pupils. In both kinds of analysis, risks and benefits are considered and evaluated in both pecuniary and nonpecuniary terms.

Cost-benefit analysis is defined by Berry (1982) as "a conceptual, systematic framework for evaluating alternative means of satisfying a specified set of objectives" (p. 38). The methodology of cost-benefit analysis consists of a fairly standard series of steps:

- Identify alternatives for solving the problem being considered.
- Estimate relevant costs for each alternative.
- Estimate the results of expending these costs.
- Evaluate and compare the alternatives.
- Identify and consider nonquantifiable factors.
- Select the most feasible alternative.

The ease of listing these steps belies the difficulties of cost-benefit analysis, which are many. Perhaps the greatest difficulty is to decide which costs and benefits to include and how to value each of them (Prest & Turvey, 1972). Although economists have developed elaborate procedures for answering these questions, the mere attempt to identify all the possibilities may provide sufficient challenge for a high school class. As for the determination of value of each alternative, students may be relieved to learn that even experts recognize that "the 'objective' data of the economist is, in the final reckoning, nothing other than the subjective valuation of all the individuals affected" (Mishan, 1982, p. 29). The easiest way to look at the net cost of an alternative is to weigh the value accrued by all those positively affected against the losses of all those negatively affected.

Another caveat may be in order. Mishan (1982) warns against confusing the estimation of worth that may be placed on some consequence according to the ethics and values of a particular society, and the weights assigned by individuals possessing power in the political or administrative hierarchy. In some cultures, for example, the elderly are treated with greater respect than in the United States. Those cultures, then, would place a higher value on the lives of the aged than ours would. In the televised debate aired in October, 1984, President Ronald Reagan and his Democratic challenger Walter Mondale expressed sharply divergent views on abortion. Reagan said that, so long as there is any doubt about when life begins, the law should grant the same rights to the fetus that it would to any citizen. Mondale stated his belief that 'ifficult matters of personal choice should be left to the judgment of the individual and that interference on the part of the state is wrong It is not difficult to imagine how abortion and its related issues would be treated differently in executive branches of government depending on which of these men were in power. The trick in dealing with the two kinds of weights is, first of all, to recognize them for what they are. Then values may be assigned and justified on either basis.

The similarity of cost-benefit analysis to the decision making process is obvious. Furthermore, it is clear that cost-benefit is an extension of risk assessment. In application, cost-benefit analysis is more comprehensive than either decision making or risk assessment, and in most classrooms, may require a longer period of time. It may also require heavier reliance on outside sources of information (books, newspapers, expert opinion, environmental impact statements, and so on). A class project requiring a semester or even a year may be built around the six steps of the cost-benefit approach.

In Conclusion

There is nothing magic about decision making, conflict management, risk assessment, and cost-benefit analysis as subjects of study in the classroom. If treated as nothing more than topics to be covered, these constructs will no more likely command attention than the study of the parts of the crayfish or the laws of motion would, except perhaps on the grounds of contemporary relevance. But when presented as intellectual tools and as a means of acquiring important life skills, these four themes outstrip many other pretenders to the throne of highest-priority classroom time and attention. If students can learn to use these tools effectively through experience, then much is to be gained, especially toward achieving the goals of scientific and technological literacy.

I have heard school administrators complain that it is not yet possible

to include science-related social issues in the curriculum because of the current dearth of instructional materials. Such materials are not as scarce as is generally perceived. Several articles in this yearbook provide information on available STS course materials and modules. (See also Bybee, 1984.) To be sure, much additional curriculum development is needed to augment the pool of resources from which educators may draw But today's science teacher need not wait for the time-consuming and expensive process of curriculum development to run its course. Appropriate issues are presented in the newspaper and on the nightly news. The data are available in the library and elsewhere. The issues are already in the minds of the the people in the community. The techniques of decision making, conflict management, risk assessment, and cost-benefit analysis are easily adaptable to classroom discussions The challenge that remains is for the creative science teacher to fit together the pieces of the puzzle in meaningful ways. The outcome will prove rewarding to all students and teachers who choose to collaborate in examining the significant issues of science and society.

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