

Incluimos aquí dos trabajos más presentados en el marco del simposio "Science Technology-Society Reform in High School Chemistry in Mexico-USA-Canada" durante el Quinto Congreso de Química de América del Norte (Fifth Chemical Congress of North America).

## Designing and Developing Science-Technology-Society (STS) Video Resources for High School Chemistry Students in Alberta, Canada

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### Abstract

Efforts to incorporate a Science, Technology and Society (STS) emphasis into curriculum frameworks are becoming increasingly common. More challenging is the development of resources to match and support the curriculum framework. In Alberta, Canada, several resources have been, or are in development to support the Science Programs of Study. These include textbooks, videos and classroom assessment materials. Most interesting and comprehensive are telecourses consisting of 50 videos with print guides to instruct the entire Grade 12 Chemistry program. The development of these materials posed a design and development challenge as examples of such resources were non-existent. This paper describes the adaptation of the learning cycle to the development process.

### Introduction

One of the difficulties in planning resources for the next millennium is trying to predict what the future learning environment might look like. Will there be the traditional teacher with 30 students sitting in desks in a classroom setting, or might there be students sitting at computers each in their own homes working at an individual pace with an instructor waiting on-line to provide assistance? In 1995, at the inception of the high school chemistry instructional video project, there were rapid developments occurring in the area of multimedia. Predictions were that students of the near future would largely be independent learners with instruction delivered via the internet perhaps by the year 2000. Many institutions, including private educational publishers, had begun to place entire textbooks on CD-ROM that included animation to increase interest. Others were investi-

gating multimedia options. Such was the context within which funding was allocated by the Alberta government to develop resources for distance and independent learners of science. Already in place was an attractive print component consisting of 7 student modules for distance learning (Alberta Education, 1994). It was colorful, interactive and linked to textual and video resources. The Ministry of Education investigated the possibility of a multimedia chemistry project. This soon was downsized to a prototype project when the costs were calculated. The reality was that the technology needed to develop multimedia was still in its infancy and difficult to use; and the expertise to develop it limited to very few individuals, most of whom had little or no background in classroom instruction, or chemistry particularly. Nor could the product be tested in a classroom situation with actual students because access to the necessary computer technology was limited. A decision was made to develop a video resource to accompany the print component for distance and independent learning students. This medium was chosen for several reasons:

- Classroom teachers, who would be the developers of the content, are very familiar with the video medium and have a strong sense of what constitutes good video, as well as having the pedagogical expertise in science instruction.
- The VCR technology is accessible to students studying independently, even in remote locations.
- The STS connections to science that are found in the community are available to the camera through site visitations and interviews with experts.

### The Vision in the Program of Studies for Chemistry

The program of studies for all of the senior high school programs in Alberta, including Chemistry, was revised between 1991 and 1994. The vision statement in the programs of study clearly states that there are two major goals for the senior high

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school science programs: to “help all students attain the scientific awareness to function as effective members of society... and to pursue further studies and careers in science”. The dual goals of scientific literacy and preparation for the next level of study in science can be in opposition, and indeed, this dichotomy has led to some discomfort for teachers and administrators. In the vision statement of each program of studies, it is also stated that “students will focus on learning the big interconnecting ideas and principles of science... major themes... that transcend and unify the natural science disciplines” (Alberta Education, 1995, p. 1). Clearly, the aim is to foster integration of the science disciplines through the unifying concepts of change, diversity, energy, equilibrium, matter, and systems. These are prominent in the titles, overviews and major concepts for each unit, a prominence that strongly suggests that this is an integrated science program.

An objective stated in the Chemistry 20-30 program of studies is to help students “understand the nature of science and the relationship of science to technology and to society”. That is, the chemistry program has an STS dimension in which it is stated that students are “expected to demonstrate an understanding of the processes by which scientific knowledge is developed, and of the interrelationships among science, technology and society” (Alberta Education, 1995 p. 5). Furthermore, the program states that this goal is to be accomplished using contexts chosen from the STS connections listed with each unit, or by choosing “other relevant contexts”. Therefore, the STS context chosen can be entirely up to the individual teacher to decide. Most proponents of STS programs recommend that contexts be largely student driven, and that option is encouraged in the Alberta program of studies.

Several sources describe the changes in classroom practice suggested by an STS, integrated approach to science (Bybee, 1987; Yager, 1993; BSCS, 1993), based on the premises of constructivism. Yager (1992) states that STS programs require teaching techniques that “help students formulate meaning for themselves”, by encouraging students to do the following:

- identify questions and problems that they see as important;
- invent or plan activities;
- express their views, discuss, and take action on them;

- prepare products that result from learning activities that can illustrate student “expertness” as a result of lessons (rather than giving a test of memory as a closure activity to lessons and instructional units);
- take actions and displays outside of school to create a feeling of importance for the study, for example, community improvement projects.

(Yager, 1992, p. 227)

Accordingly, he describes the STS classroom as follows:

- student centered and directed by students’ questions and experiences;
- individualized and personalized approaches that recognize student diversity;
- using a variety of resources;
- valuing cooperative work on problems and issues;
- planned around problems and current issues.

(Yager, 1993, p. 77)

#### Program Rationale and Philosophy

Many of the vision statements are reemphasized in the program rationale and philosophy: for example, there are references to “scientific awareness essential for all citizens in... society”, “key concepts and principles”, “unified view of sciences... and the connections among them”, “methods of inquiry”, “positive attitudes”, “relevant contexts”, and “increased responsibility for... learning” (Alberta Education, 1995, p. 1). In addition, the philosophy and rationale emphasize other goals not specifically mentioned in the vision: here it is stated that students are to “exercise their creativity and develop their critical thinking skills;” the program is “to provide students with opportunities for acquiring knowledge, skills and attitudes that contribute to personal development” and “help them become capable of, and committed to, setting goals, making informed choices and acting in ways that will improve their own lives and life in their communities” (Alberta Education, 1995, p. 2). These statements tie this particular program to the larger goals of basic education related to personal development and citizenship.

In the introduction to the specific learner expectations for all the Alberta senior high science programs, including Chemistry 20-30, there is an explicit message about the preferred teaching strategy in the form of the learning cycle. This description is intended as a guideline for incorporating the STS connections into lesson planning. Programs of study

are narrowly defined by Alberta Education as comprehensive listings of what students are expected to know and be able to do at the completion of a course. The accompanying resource manuals for teachers describe appropriate pedagogical approaches. The two together replace the curriculum guides, previously produced for all Alberta programs.

### Organization

The course of studies for Chemistry 20-30 consists of two major sections in which the learner expectations are arranged into four categories: attitudes, knowledge, skills, and STS connections. In the general learner expectations section are listed the program expectations common to all the senior high school science courses intended for students planning to pursue further studies in chemistry. The program expectations for knowledge define six scientific themes for development: change, diversity, energy, equilibrium, matter, and systems. The purpose of the themes is to “transcend the discipline boundaries, and show unity among the natural sciences”. The program expectations for skills outline a comprehensive framework of skills that can be applied in a variety of problem-solving contexts. These skills are organized into several categories: “initiating and planning”, “collecting and recording”, “organizing and communicating”, “analyzing”, “connecting, synthesizing, and integrating”, and “evaluating the process or outcomes” (Alberta Education, 1995, p. 4-5). The program expectations for STS connections identify eight dimensions encompassing the nature of science, the nature of technology, the interrelationships between science and technology, and the interrelationships among science, technology, and society. The listing of program general learner expectations is linear and consecutive, but in the course’s general learner expectations, the various categories of learnings, that is, knowledge, skills, and STS connections, are brought together into summary expectations for Chemistry 30. In the section of the course called specific learner expectations, unity is provided among the categories through the way they are displayed across the page. Each category of

learner expectation is formatted as a column and the four columns are placed next to one another across two facing pages (Table 1).

This format allows the expectations to be read either from left to right or right to left across the pages. Read from left, the major concepts and themes are the focus, and the skills and STS connections are simply associated with, and supportive of, them. Read from the right-hand side, the STS connections become the focus, particularly because of the summary statement that appears at the top of this column in which the expectation is that the knowledge and skills on the left are to be addressed within the context of the STS connections listed. This statement and format makes the Alberta programs unique among mainstream science programs from other jurisdictions, because of this focus on using science, technology, and society connections as organizers for instruction and learning.

There are three units of study in Chemistry 30, each with a major emphasis on the science themes chosen as conceptual foundations for the senior high school science programs. In Unit 1, “Thermochemical Changes”, students investigate changes in matter, viewing models of matter as systems in which energy plays a role in change. The specific learner expectations for knowledge, skills, and STS connections are arranged across the page such that the reader can see at the glance how each component supports and relates to the others (Table 2).

Quickly, the reader can see the laboratory activity and the STS activity that students can do to better understand and see the relevance of the knowledge statement, eventually coming to an understanding of the major concept. Each specific learner expectation can also be traced back to a general statement in the front part of the document, resulting in a consistent message throughout the document. For example, the section above is derived from the following general learner expectation:

- Explain the interrelationship between energy and physical, chemical and nuclear changes to matter by describing how the rearrangement of bonds

Table 1. Format of the Chemistry 20-30 program of studies (1995).

Left Hand Page		Right Hand Page	
MAJOR CONCEPT	KNOWLEDGE	SKILLS	STS CONNECTIONS

**Table 2.** Sample Components of the Specific Learner Expectations for Chemistry 30.

MAJOR CONCEPT	KNOWLEDGE	SKILLS	STS CONNECTIONS
There are energy changes associated with changes to matter.	<p><i>Students should be able to</i></p> <ul style="list-style-type: none"> <li>define molar enthalpy change, including the heats of phase, chemical and nuclear change</li> </ul>	<p><i>Students should be able to</i></p> <ul style="list-style-type: none"> <li>perform and evaluate experiments to determine the molar enthalpy change of physical and chemical changes to matter</li> </ul>	<p><i>Students should be able to</i></p> <ul style="list-style-type: none"> <li>provide examples of personal reliance on the chemical potential energy of matter; e.g., of fuels, and identifying and evaluating ways of using energy more efficiently in the home and the community in order to use natural resources judiciously to ensure adequate supplies for future generations</li> </ul>

(Alberta Education, 1995, p. 35-37).

results in the release or absorption of energy; and evaluate society's production and use of energy from fossil fuels and nuclear fission.

(Alberta Education, 1995, p. 8)

In Unit 2, "Electrochemical Changes", students investigate electrochemical systems, analyzing the matter and energy changes within them. In Unit 3, "Equilibrium, Acids and Bases in Chemical Changes", students investigate chemical change from the perspective of equilibrium.

The STS monograph, *STS Science Education: Unifying the Goals of Science Education*, (Alberta Education, 1990) describes STS programs as taking the step of merging the front matter of programs of study and curriculum guides, where the philosophical statements regarding STS objectives are listed with the specific learner expectations for students. "This integration of STS components is the main challenge to teachers presenting a curriculum that tries to meet all the objectives of science education." (Alberta Education, *STS Science Education*, 1990, p. 4). In the Chemistry 30 course of studies, similar statements in the general learner expectations are supported by specific learner expectations. Although the choices provided in the STS connections column can result in an uneven emphasis on particular aspects of STS, it is still clear that this is an important dimension of the program.

In the chemistry program general learner expectations provide a framework for the course learner expectations, which describe the essential attitudes, knowledge, skills, and STS connections for each course. The course general learner expectations for Chemistry 30 clearly indicate that this is an integrated program and that themes play a prominent role in providing the unity among the concepts

chosen from the subdisciplines of chemistry and that an STS focus will be present. This is illustrated by the following course expectation:

- apply the principles of energy and matter conservation to chemical systems undergoing change; and use direct and indirect evidence and theoretical knowledge to predict the outcomes of chemical change; and relate chemical change to a broad range of reaction applications.

(Alberta Education, 1995, p. 7)

### The Learning Cycle

Beyond a change in content and organization, the Alberta chemistry curriculum suggests a shift in pedagogy. Within the Philosophy and Rationale section of the program is implied a constructivist viewpoint by the statement: "Learning is facilitated by relating the study of science to what the learners already know", and students "will take varying amounts of time to acquire...science learnings" (Alberta Education, 1995, p. 1). An inquiry method for learning is emphasized. For example, it is stated that: "students will further their ability to ask questions, investigate and experiment; gather, analyze and assess scientific information; and test scientific principles and their applications" (Alberta Education, 1995, p. 1). Students are described as "active learners" who "will assume increased responsibility for their learning" (Alberta Education, 1995, p. 1). In the vision, there are also several statements that emphasize the fostering in students of positive attitudes to learning science and the importance of relevance to student learning.

In the Alberta science curricula, the learning cycle is described in each of the senior high school programs of study and is considered as an important

means of incorporating STS into the curriculum while making learning meaningful to students through an inquiry-oriented and student-centered approach. The active role of the student in his or her learning is seen as the key to the learning cycle (Odom and Kelly, 1996).

While the learning cycle was introduced as a pedagogical tool some 20 years ago, the Biological Sciences Curriculum Study (1993) provides one of the better descriptions of an instructional model based on a learning cycle. It consists of the following five stages: (a) engagement, (b) exploration, (c) explanation, (d) elaboration, and (e) evaluation. Teachers acting consistently with this model would, at the beginning of a lesson or topic, create interest and curiosity and discover what students already know about the concepts. In the second stage, the teacher would encourage group effort and provide students with time to work through problems as the instructor observes and acts as a consultant. For example, the teacher could encourage students to explain the concept in their own words and ask for justification and clarification from students while formally providing definitions and explanations. In the later stages, the teacher would expect students to use the definitions and explanations previously provided while encouraging them to apply and extend their knowledge to new situations. Evaluation would ideally involve teacher observations that sought evidence of changes in student behavior and thinking. Self-assessment by students would be used to supplement the teacher assessments. Broadened means of assessment would include projects and open-ended questions (BSCS, 1993).

The stages of the learning cycle in the Alberta science curriculum and in other sources, including the draft of the Pan Canadian science project common framework of learning outcomes K-12 (1995) can be summarized in three major phases: Explore, Develop, Apply. A fourth phase is sometimes mentioned: the Overview, which consists of the learner expectations to be addressed. In planning a set of lessons using the learning cycle, the teacher first decides on the knowledge, skills, attitudes and STS connections to address. This overview of the lesson plan is the goal of all planned activities. Any activities that do not address these learner expectations should be discarded. Generally the STS connections provide the context for learning, but most particularly in the exploratory and application phases which open and close the cycle.

The *exploration phase* of the learning cycle serves as the lead in to the set of lessons that makes a connection to previous learning as well as anticipating planned activities. It provides the “hook” that draws the student into the collaborative learning process. The teacher engages the student by presenting an interesting piece of information preferably an STS connection, perhaps drawn from a media story. Another approach is to demonstrate a discrepant event and pose appropriate probing questions, in the manner of the POE. Students can be immediately engaged by having them do a simple laboratory activity and then asking for a description and explanation of the results. Another technique is to present a question that requires students to do some library or internet research. The posing of problems and questions of an STS nature to engage students is the major goal of the exploration phase of the learning cycle.

#### *Learning Cycle:*

##### *Summary of the Exploration Phase*

- frames the lesson in a manner relevant to the student; ideally based on an STS Connection;
- purpose is to motivate and answer the question “why am I learning this?”;
- connections are made to past learning experiences;
- questions are posed to pique interest and to encourage critical thinking;
- students explore a new idea through an activity-based experience.

The *development stage* of the learning cycle is sometimes referred to as the hypothesis-building phase as the initial experiences provide a common base upon which to build understanding. The teacher may engage in direct instruction to explain particularly difficult concepts. She/he may use audiovisual aids, present demonstrations or, in some similar manner, show students how to unravel the meaning of the concepts. However, the greatest amount of time is devoted to assisting students to uncover meaning for themselves through independent and group activities. It is in this concept development phase of the learning cycle that students take part in many traditional science classroom activities including laboratory investigations, problem solving and writing. The teacher assesses the students understanding and use of appropriate terminology and explanations through short assignments and tests consisting of selected response and short answer questions. The

goal of this phase is concept development and retention, therefore students are provided with opportunities to develop and practise skills, then apply them to new situations.

*Learning Cycle:*

*Summary of the Development Phase*

- Concepts, skills and attitudes are developed to explain the results of the initial exploration and to answer the questions;
- hypotheses, vocabulary and concepts are related to previous learning and to key ideas and principles of science;
- learnings are applied to new situations;
- assessment tends to be quantitative in nature.

In the *application phase* of the learning cycle concepts are elaborated upon, extended and evaluated through longer term projects and group discussions. The STS context introduced in the Exploration phase is explored in greater depth, now that students have a firm background in science to fully explain and understand the implications and applications. Learning is ideally linked to key concepts and principles of science. This phase provides an opportunity for students to make ventures into the community by interviewing experts, visiting chemical plants, or simply by gathering information at the library or in the newspaper. In some ways it is a reflective time for students as they are led to deeper understandings of concepts and ideas. Typical assessment techniques might include investigative papers, projects and long answer examination questions.

*Learning Cycle:*

*Summary of the Application Phase*

- The significance of the learning is investigated in a new STS context;
- learning is extended through individual or group activities;
- deeper understandings and thoughtful reflection are encouraged;
- assessment tends to be holistic and qualitative in nature.

**Design features of the videos**

The design of the video series developed for Alberta's Grade 12 Chemistry program makes extensive use of the learning cycle as a means of bringing together all of the elements of the program of studies. Each video begins by posing a problem, asking the

viewer a question or by presenting an interesting STS connection, exemplifying the Exploration phase of the learning cycle. The STS connection serves to link past and present learning experiences, as well as to foreshadow activities that focus students on the learning outcomes of the current program.

A major feature of each video is the tutorial consisting of an interaction sequence between the facilitator; usually the teacher, but sometimes community members or other students, and the learner. The tutorial events exemplify the Development phase. A loose script allows for natural interactions between facilitator and learner that at times may seem to the viewer like listening in or eavesdropping on a personal conversation. Each tutorial event focuses on the development of a concept through mutual problem-solving, conversations and laboratory activities. A major aspect is an inquiry approach in which the facilitator poses questions or problems that require some time to answer. This encourages the learner to ask further questions which are sometimes answered by the facilitator, but may also be passed back to the student and to the viewing audience. A common occurrence is for the facilitator to suggest that the answer can be found in the broader community, so the pair go in search of a source or an expert to resolve a problem.

The video medium allows the facilitator to draw upon animated graphics and location scenes or even existing footage to elaborate upon an answer or embellish a point. The behavior and language used by the presenters and the contexts and examples chosen foster positive attitudes toward science, the role of science and technology and the contribution of science and technology to present and past societies. Authentic laboratory activities are incorporated to the fullest extent given the limitations of the medium. Demonstrations and activities modeling experimental procedures and skills are presented in a manner conducive to engaging viewers to take an active role. A balance between conventional and innovative procedures, simple and complex apparatus is maintained in demonstrations and experiments to reflect and enhance the realities of the science classroom.

The latter part of each video makes a link back to the STS connection introduced at the beginning by answering the problem or question posed and applying it to new situations. Activities and discussions at this stage (Application phase of the learning cycle) are of a higher level, or extensions of previous learning. Features such as career interviews or community

visits add depth to skill and problem-solving activities that preceded. Closure is achieved by reviewing the video content within the context of the STS connection that provides the fabric for the program.

Where appropriate, assessment criteria are built into the program with skills and achievement modeled by students. Assessment elements are designed to encourage viewer participation through responding to the questions or problems posed on camera. The participation of the independent learner is enhanced by practice and self-check activities and complementary learning activities provided in the print guide.

#### The Product

The finished product, *Chemistry Connections*, consists of 50 videos with associated print guides that link the videos to the curriculum and other resources, including the basic textbook and distance learning modules. The series is designed to deliver the entire provincial curriculum for Grade 12 Chemistry. The proposed audience for *Chemistry Connections* includes students learning at a distance, classroom students requesting enhanced instruction, teachers desiring professional development, independent learners, as well as the general public. The series is broadcast on the provincial television station, called ACCESS, the Education Station. Learners view the videos in conjunction with the print guide which provides extra information and directs the student to readings, exercises and projects in associated resources to assist in their understanding of the concepts presented.

#### Project Partners

Chemistry Connections is a joint project of Alberta Education and ACCESS—the Education Station.

Team members consisted of seconded classroom teachers, curriculum leaders from the Ministry of Education, professional script writers, experts in tolerance and understanding experts, commercial video producers, students as non-professional actors, and community members who donated time and expertise. ▣

#### Availability

If you are interested in previewing the Chemistry Connections series, contact:

ACCESS, the Education Station  
3720-76 Avenue NW  
Edmonton, Alberta  
Canada T6B 2N9  
Toll Free: 1-888-440-4640

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