What Results Indicate Concerning the Successes with STS Instruction

This study investigates the effectiveness of the Iowa Chautauqua Professional Development Program.

The National Science Education Standards emphasize a goal that all students should achieve scientific literacy which is defined as the knowledge and understanding of scientific concepts needed in daily living (NRC, 1996). The National Science Teachers Association has declared that a scientifically literate person is one who can ask and determine answers to questions derived from curiosity about everyday life experiences (NSTA, 1996).

Several NSTA reports and position papers illustrate the meaning and importance of scientific literacy as a way of improving K-12 science (NSTA, 1991; Harms & Yager, 1981). Scientific literacy enables people to not only use scientific principles and processes in making personal decisions but also to participate in discussions of scientific issues that affect society. Scientific literacy increases many skills that people use in everyday life, like being able to solve problems creatively, thinking critically, working cooperatively in teams, and using technology effectively. An understanding of scientific knowledge and processes contributes in essential ways to attaining these skills. The economic productivity of society is related to the scientific and technological skills of the people which is another reason for encouraging a more scientifically literate citizenry.

Achieving the goal of scientific literacy for all will take time. The National Science Education Standards call for dramatic changes in what students are taught, how student performances are assessed, and how teachers are educated and remain current (NRC, 1996). Understanding the relationship among science, technology, and society is essential for achieving basic science literacy. Students, the next generation, need to be able to analyze evidence, to understand the relevance of science-based issues in their everyday lives, and to understand that scientific endeavors are governed by social values (NRC, 1996; AAAS, 1990). The National Science Standards urge specific changes in the way teachers teach, the way they continue to grow as teachers, the way content is defined, how learning

Table 1: Changing Emphases for Teaching Science as Advocated in the NSES

Less Emphasis on :	More Emphasis on:
Treating all students alike and responding to the group as a whole	Understanding and respo nding to individual student's interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquire d knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

* could also be assumed to apply to students working alone vs in groups

(NRC, 1996, p52)

is assessed, how science programs are built, and how the entire school system supports the needed reforms. But the needed changes in teachers are seen as a first requisite for reforms to succeed. Table 1 is a summary of the changes in science teaching envisioned by the Standards. These recommended changes were the least controversial as the standards were developed but remain a major challenge to achieve.

The Iowa Chautauqua Program was developed in 1983 with support from National Science Foundation (NSF) which awarded the National Science Teachers Association (NSTA) a major grant to study an inexpensive in-service model for stimulating reform in K-12 science classrooms. Iowa was one of the six Chautauqua sites which were modeled after a program for teachers from small colleges and operated by the American Association for the Advancement of Science. In Iowa this new Chautauqua effort focused upon STS materials and teaching strategies with primary attention directed to teachers in grades 4 through 9. The program began with 30 teachers enrolled in a program in one center and increased annually to number 230 teachers enrolled in five centers across the state. The program was expanded with funds from various of private industries and Title

Figure 1: **Iowa Chautaqua Model**

Leadership Conference

A Two Week Long Conference Designed To

1. Prepare staff team for conducting a workshop series which follows for 30 new teachers.
   a) One lead teacher per ten new teachers
   b) Scientist from a variety of disciplines
   c) Scientists from industry
   d) Administrators
   e) Science Supervisors/Coordinators as chair of staff teams
2. Organization and scheduling for each workshop
3. Publicity and reporting
4. Assessment strategies
   a) Six domains
   b) Use of reports

c) Active Research (Every teacher as researcher)
   d) New research plans for Lead Teachers

Three or Four Week Summer Workshop

STS Experiences

1. Includes special activities and field experiences that relate specific content within the disciplines of biology, chemistry, earth science, and physics.
2. Makes connections between science, technology, society within the context of real world issues.
3. Issues such as air quality, water quality, land use/management are used as the context for concept and process skills development.
4. Every staff member and every teacher participant selects an action and completes at least one Action Research Project.
5. Plan for continuing Action Research in the classroom over the next academic year.
6. Complete several videotapes of teaching experiences with both self and group analyses.

Academic Year Workshop Series

Fall Short Course ➜ (3 days)	Interim Projects ➜	Spring Short Course (3 days)
Awareness Workshop	Three Month Interim Project	Final Workshop
20 hr Instructional Block (Thursday pm. Friday, & Saturday)	**The STS Module**	**20 hr Instructional Block** (Thursday pm. Friday, & Saturday)
Activities Include: 1. Review problems with traditional views of science and science teaching 2. Outline essence of STS 3. Define techniques for developing STS modules and assessing their effectiveness 4. Select a tentative module topic 5. Practice with specific assessment tools in each STS Domain. 6. Use Lesson Study designs 7. Analysis one videotape of Middle Class	Activities Include: 1. Developing instructional plan for minimum of twenty days 2. Administer pretests in five domains 3. Teach STS module 4. Collect posttest information 5. Communicate with regional staff, Lead Teachers, and central Chautauqua staff 6. Complete and analysis one class videotape with colleagues from given sites	Activities Include: 1. Report on STS experience 2. Report on assessment efforts 3. Interact on new information concerning STS 4. Show one videotape of classes 5. Analyze changes from summer, fall, and spring 6. Plan for involvement in professional meetings 7. Plan for next-step STS initiatives (including complete reorganizing of existing courses)

II projects. Over 15,000 teachers have been enrolled during last two decades. The focus and unique feature was the Science-Technology-Society (STS) teaching approach as reform in science education. Figure 1 illustrates the features of the Iowa Chautauqua model.

The National Science Teachers Association (NSTA) defines Science- Technology-Society (STS) as the teaching and learning of science in the context of human experiences (NSTA, 1991). STS means focusing upon current issues and attempts at their resolution as the best way of preparing students for current and future citizenship roles. This means identifying local, regional, national, and international problems with students, planning for individual and group activities which address them, and moving to actions designed to resolve the issues investigated. The emphasis is on responsible decision-making in the real world of the student. STS provides a means for achieving scientific and technological literacy for all. The emphasis is on responsible decision-making in the real world of the student where science and technology are components. To be considered STS, the reforms envisioned and characterized include ten basic features that are central to those in the NSTA policy statement regarding STS. These include:

1. student identification of problems with local interest and impact;
2. the use of local resources (human and material) to locate information that can be used in problem resolution;
3. the active involvement of students in seeking information that can be applied to solve real- life problems;

A major component of the Iowa Chautauqua Program is assessment, just as it is in science itself.

4. the extension of learning beyond the class period, the classroom, the school;
5. a focus upon the impact of science and technology on each individual student;
6. a view that science content is not something that exists merely for students to master for tests;
7. a de-emphasis upon process skills *per se* just because they represent glamorized skills used by practicing scientists;
8. an emphasis upon career awareness—especially careers related to science and technology;
9. opportunities for students to perform in citizenship roles as they attempt to resolve issues they have identified;
10. identification of ways that science and technology are likely to impact the future. (NSTA 1990;Bybee and Yager 1982; Blunck and Yager 1990; Yager 1992)

A major component of the Iowa Chautauqua Program is assessment, just as it is in science itself. There must be evidence that others can see before explanations are accepted by the community of experts (scientists). One aspect of the assessment efforts of the Chautauqua program focuses on the effect of STS on students. Six domains of science education proposed by Yager and McCormack (1989) are used to assess student growth over a period of time of at least one full calendar year with the use of a variety of assessment instruments in each domain. These assessments arise from published instruments as well as from instruments and techniques devised by teachers as a means of collecting evidence of the validity and successes their instruction has achieved. Frequently, pre-assessments are involved as a part of the study successes, especially related to the concept and attitude domains. The decision concerning the other domains was left the preferred of the twelve teachers involved.

The first domain is the concept domain. Science aims to categorize the observable universe into manageable units for study and to describe physical and biological relationships. Ultimately, science aims to provide reasonable explanations for observed relationships. Part of any science instruction may involve learning by students in terms of the information developed over time through scientific pursuits of the past. The concept domain includes: facts, concepts, laws (principles), and existing hypotheses and theories being used by scientists. This vast amount of information is usually classified into such manageable topics as: matter, energy, motion, animal behavior, and plant development (Enger & Yager, 2001; Myers, 1996).

The second domain is processes. Scientists use certain identifiable processes (skills) in their inquiry efforts. Being familiar with these processes concerning how scientists think and work is an important part of learning science. Some processes of science are: observing and describing, classifying and organizing, measuring and charting, communicating and understanding communications of others, predicting and inferring, hypothesizing, hypothesis testing, identifying and controlling variables, interpreting data, and constructing instruments, simple devices, and physical models (Enger & Yager, 2001; Wilson & Livingston, 1996).

The third domain is creativity. Most science programs view science instruction as something to be done to students to help them learn a given body of information. Little formal attention has been given in science programs to development of students' imaginations and creative thinking. Little has been done to encourage curiosity, questioning, explaining, and testing – all the basic ingredients of science. Some of the specific human abilities important in this domain are: visualizing: producing mental images, combining objects and ideas in new ways, producing alternative or unusual uses for objects, solving problems and puzzles, designing devices and machines, and producing unusual ideas. Much research and development has been done on developing students' abilities in this creative domain, but little of what has been learned about creativity has been purposely incorporated into science programs (Enger & Yager, 2001; Penick, 1996).

The fourth domain is attitude. In these times of increasingly complex social and political institutions, environmental and energy problems, and general worry about the future, scientific content, processes, and even attention to imagination are not sufficient parameters for science programs. Human feelings, values, and decision-making skills need to be addressed. This domain includes: developing positive attitudes toward science in general including both science in school and science teachers, developing positive attitudes toward oneself (an "I can do it" attitude), exploring human emotions, developing sensitivity to and respect for the feelings of other people, expressing personal feelings in constructive ways, making decisions about personal values, and making decisions about social and environmental issues (Enger & Yager, 2001; McComas, 1996).

Many in education are looking to technology (the application of science concepts) or the applications domain as a starting point for initiating reform in the K-12 classroom.

The fifth domain is applications and connections. A successful program must include information, skills, and attitudes that can be transferred and used in students' everyday lives. Many would question if real learning had occurred unless there is evidence of the use of it in new contexts. Also, many now argue against a divorce between "pure" science from technology. The National Standards include technology as one of eight facets of content standards for school science and thereby note the interdependence of the two disciplines (NRC, 1996). Students need to become sensitized to these experiences they encounter which reflect ideas they have learned in school science. Some dimensions of this domains are: seeing instances of scientific concepts in everyday life experiences, applying learned science concepts and skills to everyday technological problems, understanding scientific and technological principles involved in household technological devices, using scientific processes in solving problems that occur in everyday life, understanding and evaluating mass media reports of scientific developments, making decisions related to personal health and life-style based on knowledge of scientific concepts rather than on "hear-say" or emotions, and integrating science with other subjects. For many, the applications of science can provide the entry to the knowledge and process domains. For others (probably a definite minority) applications represent moves to the use of the science known and developed over time. Many in education are looking to technology (the application of science concepts) or the applications domain as a starting point for initiating reform in the K-12 classroom (Enger & Yager, 2001; Varrella, 1996).

The sixth domain is world view. Science should portray the nature of the discipline – not just a study of the current views that comprise the current understanding of the various disciplines. Often scientists themselves are poor students of what they do, how they do it, and how their discipline changes (and has changed). Many, however, feel a primary justification for science in the general education of all students, kindergarten through college, is to portray the nature of science as a major intellectual pursuit of all humankind. Once again the National Standard includes the history and philosophy of science as one of the eight facets of science content for school science (NRC, 1996). This domain is concerned with: ways in which scientific knowledge is created, the nature of research processes; the meaning of basic concepts of scientific research (e.g., hypothesis, assumption, control, replication), the history of scientific ideas; the ways scientists work, and the interactions among science and the economy, politics, history, sociology, and philosophy (Enger & Yager, 2001; Kellerman & Liu, 1996).

Experienced STS teachers have always been major parts of the instructional team for the Iowa Chautauqua Program. These are the teachers who were excited with their own STS initiatives, who spend most of their time in their courses with STS instruction, who were anxious to complete assessment projects, and who were willing to be a part of the annual leadership conferences as a new Chautauqua cycle was planned.

As one might expect, some of the most exciting assessment results are provided by the most successful STS teachers. As assessment instruments were developed, twelve of the most successful teachers with STS volunteered to help. Many assessment strategies and instruments developed have been published as new ideas were developed and publicized in the workshop series. Some of them were adaptations of other published instruments. Most of these have now been published for all to use (Enger &Yager, 2001).

Methods

This study involved twelve teachers who agreed to share assessment information from their students regarding the six domains previously described. One section for each teacher utilized traditional instructional methods while a second section utilized STS teaching strategies. Instruments used were included in annual publications of assessment tools. The same instruments were used with students in both sections. The teachers selected similar class sections and times of the day for the section experiencing the STS approach and the one relying almost fully on a textbook. Students in the two sections were almost identical in terms of gender, socio-economic levels, class size, student grade point averages, educational and career aspirations, extra-curricular activities, previous success with science courses, variations with interest in other aspects of the school program. The administrative and counseling staff in each of the twelve schools reported that they could find no significant differences between the make-up of the students in two sections who were selected for the study. In most instances the teachers involved planned similar instruction in the other 2 or 3 sections which comprised their teaching load. The instruments were given near the end of the school year. A comparison of learning results between STS and non-STS sections were noted and recorded and represent the results of this report. Although not collected in all domains and by all teachers, pre-assessments were collected, especially those concerned with concept mastery and student attitude.

The ability of students to utilize information and processes in new situations is greater for STS students than it is for non-STS students.

Results of the Study

All twelve teacher leaders taught in grades 6 through 9. They were interested in the degree to which concepts were mastered as well as student ability to use them in new contexts. Some were especially interested in stimulating and measuring growth with respect to process skills; others were more interested in the development of creativity skills, and encouraging changes in student attitudes.

When teachers express interest in such areas and expect students to grow, more positive results emerge regarding all domains. Teacher ownership and their expectations of student achievement may be more important than a specific STS format and/or the exclusive focus on more typical textbook topics. Nonetheless, the Iowa Chautauqua program and the twelve teachers agreeing to collect the evidence for the study obtained the following results. Tables 2 through 7 show the comparisons of results regarding student successes in STS and typical science classes for a variety of aspects for each of the six assessment domains. This means reporting the percentage of all students from all 12 sections who report or demonstrate certain abilities or attitudes.

The data from Table 2 indicate percentages of students who recognize the meaning of selected basic concepts. None of the differences between treatments is significant between STS and non-STS science classes. STS students perform just as well regarding concept mastery for the sample concepts used as did students enrolled in more typical courses which emphasize such mastery as the main instructional goal.

Table 2: Percentages of Students Recognizing the Meaning of Eight Basic Science Concepts

Concepts	STS	Traditional
Volume	65	75
Organism	71	67
Motion	62	65
Energy	45	54
Molecule	48	54
Cell	43	46
Enzyme	31	24
Fossil	48	54

Table 3 indicates the comparisons of students demonstrating effective use of specific science process skills for students in both sections. STS students outperform non-STS students in their mastery of fourteen process skills.

Table 3: Percentages of Students who Can Demonstrate their Abilities to Use Fourteen Process Skills

	Skill	STS	Traditional
1	Using Space/Time Relations	51	12
2	Observing	84	30
3	Classifying	87	26
4	Interpreting Data	88	31
5	Inferring	74	19
6	Communicating	88	38
7	Controlling Variables	63	21
8	Drawing Conclusions	82	24
9	Predicting	71	19
10	Using Numbers	89	40
11	Measuring	91	33
12	Comparing & Differentiating	84	31
13	Hypothesizing	63	18
14	Selecting Best Experiment Procedure	52	24

In Table 4 the differences in use of various creativity skills are indicated between students enrolled in the STS and typical science classrooms. The data indicate the percentage of students demonstrating specific creativity skills. Student creativity, as observed in terms of quantity of questions generated, predictions of certain consequences, and ideas about possible causes for given phenomena increased more for students in STS sections. Student creativity in terms of quality/unique questions, prediction of consequences, and ideas about possible causes are much greater for STS students than for students in non-STS sections.

Table 4: Percentages of Students Demonstrating Their Abilities to Use Various Creative Thinking Skills

		STS	Traditional
1	Devise Unique Tests	94	6
2	An unique Explanations	87	13
3	A distinguish Between Cause and Effect	75	25
4	Prepare Unique Questions	83	17
5	Number of Student Questions Raised Per Class Period	67	33

The data in Table 5 indicate the percentages of students enrolled in all twelve sections who reported given attitudes. Results show that attitudes are more positive for STS students than they are for non-STS students. The results were similar regarding science as a field, science courses, relative usefulness of science, and effectiveness of science teaching.

Table 5: Percentages of Students with More Positive Attitudes Toward Classes, and Science Teachers

		STS	Traditional
1	Science is least favorite course	6	19
2	Science is favorite course	22	11
3	Information from science classes is useful	81	69
4	Science teachers admit to not knowing	74	22
5	Science teachers like my questions	88	48
6	Science teachers help me make decisions	63	31
7	Science classes make me curious	71	24
8	Science classes are boring	14	31
9	Science classes are fun	81	40

The results included in Table 6 report on the percentage of students who demonstrate that they can apply information to completely new situations. The ability of students to utilize information and processes in new situations is greater for STS students than it is for non-STS students. The "application" of the concepts and skills encountered in the classrooms were encouraged for all students with the teachers reacting to the applications proposed and the relative differences in the complexity of the various proposed applications and use. Often this became a next assessment and resulted in active student discussions of the various applications proposed by other students.

Table 6: Percentages of Students in STS and Non-STS Sections Concerning Their Abilities to Apply Information and Skills

		STS	Traditional
1	Use Information in new settings	81	25
2	Relate Phenomena in new settings	66	18
3	Identify questions used for discussions	83	17
4	Choose information to solve problems	91	26
5	Choose appropriate action based on new information	89	35

The results from Table 7 indicate that the STS approach produces students who better understand the nature and history of science. Students in STS classrooms improved in their understanding of the nature and history of science more so than did students in non-STS classrooms.

Table 7: Percentages of Students Concerning Their Understanding of the Nature and History of Science

Samples Features of Science	STS	Traditional
Questioning, Exploring & Testing	46	19
Tentativeness of Science Constructs	65	12
Nature of Science Theories	33	24
Science Changes over Time	44	16
Creative and Imaginative Nature of Science	80	8.3
Social and Cultural Features	20	12
Over-all Scores	66	22

Discussion

The data from this study certainly indicate the power of STS instruction and what happens when the organization of the content for instruction arises from local issues, current examples, and personally relevant situations. Of course the data reported are dependent on the information provided by the assessments in each of the assessment domains. Further, the effectiveness of the twelve teachers in their use of the teaching strategies could produce another variable. The results obtained merely report what happened with students in two sections taught by the twelve experienced STS teachers. This could provide unfair advantages for students in the STS sections since the teachers by definition preferred this teaching approach.

The data also help define factors useful in defining student achievement. Too often a single test score is used as the primary indicator that students have learned and allows a relative rating resulting from performance on one examination. Too often traditional achievement is simplistically defined by students checking the most accurate definitions for major terms (often italicized in textbooks).

The results indicate the importance of specific teaching strategies in developing the differences reported in the six tables. Significance would be added if more teachers were to report similar data and if additional instruments and different procedures were used for data collection. The teachers involved with this study were special teachers who were helping others move to STS teaching approaches. It is important to mention that the teachers involved with the study helped develop and evaluate the research instruments. Some were more involved and interested in some of the domains than were others. Several were actively involved with helping shape the National Standards; many assisted new teachers to move to STS approaches. Many used the differences in their own teaching in two sections (video taping) to illustrate the approach for new teachers. Some became involved in staff development efforts with pre-service programs. Of special interest is the degree that desired teaching practices correspond to the visions for change needed in teaching that are central to the National Science Education Standards as included as Table 1 (NRC, 1996, p.52).

The development of more positive attitudes concerning science, science teachers, and science careers for students in STS sections is extremely exciting. Most results reported since 1978 as part of the National Assessment of Educational Progress (NAEP), which first included assessment of students' attitudes, have indicated a decline in positive attitudes each year that students are enrolled in science classes K through 12. It is said that so few are concerned that student attitudes become more negative the longer students study science, including college. One of key benefits of STS is that the classrooms become more student-centered and the study more related to daily life. Perhaps this explains the increase in more positive attitudes.

The results concerning student ability to use the basic science concepts and skills on their own in completely new situations is of utmost importance. This is possibly the best evidence that real learning has occurred instead of the ability to remember and/or to repeat what textbooks and teachers say. The focus on student projects and real problems provides the way for many STS teachers to illustrate the importance of the concepts and processes that too often are taught directly with no apparent use and too often with no efforts to encourage students to find such uses. Again, the National Standards provide an important rationale for STS with the four goals that should frame school science. These include assuming that all students:

1. Experience the richness and excitement of knowing about and understanding the natural world;
2. Use appropriate scientific processes and principles in making personal decisions;
3. Engage intelligently in public discourse and debate about matters of scientific and technological concern; and
4. Increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers (NRC, 1996, page 13).

The results reported in this paper illustrate how these goals can be more effectively met with an STS approach to instruction.

Conclusions

More evidence and more ideas regarding student growth as a result of STS efforts in K-12 science classrooms are needed. Admittedly the results reported in this study are from students who were in schools taught by experienced STS teachers and who were also staff members in the Iowa Chautauqua Program assisting as new teachers became involved. They were not drawn from a random sample of teachers nor do they represent an unbiased group concerning the power and value of STS instruction.

The Iowa Chautauqua Program has enrolled 15,000 K-12 teachers during its twenty-five year history. Assessment information from classrooms taught by twelve key teachers permits some statements regarding the advantages of STS instruction as it is defined and practiced in Iowa and as defined by an NSTA policy statement. However, there are limitations to studies that include lack of pre-assessment data in all domains and the use of instruments constructed by teachers and Chautauqua staff over the course of several decades. With these limitations in mind the following statements are offered as summary conclusions from pooling the results from twelve teachers-each with an STS and a non-STS section of students.

1. There is little or no differences between student achievement in STS and non-STS sections with the development of conceptual knowledge among the 724 students involved with the study.
2. Students who experience their science courses taught with the STS approach achieved more process skills than did students in the non-STS sections.
3. Student in STS sections were able to demonstrate their creativity skills better than students in the non-STS sections.
4. Student experiencing their science with an STS approach developed more positive attitudes concerning science, science teachers, and science classes than did students in non-STS sections.
5. Students experiencing their science with an STS approach were better able to apply science concepts and process skills in new contexts than were students who experienced science with a non-STS approach.
6. Students experiencing their science with an STS approach developed more accurate views of the history and philosophy of science than did students who experienced science with a non-STS approach.

Generally the study, even with some limitations of design and lack of fully validated and reliable instruments, indicates advantages of the STS approach in many different domains. All of these can be defined as achievement areas in characterizing the Iowa Chautauqua model and the reforms in teaching as envisioned in the National Science Education Standards.

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