A Comparison of Student Learning in STS vs Those in Directed Inquiry Classes

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Abstract

Fifteen experienced grade 5-10 teachers each taught two sections of students – one with an STS approach and one following closely the curriculum with a "directed inquiry" approach. Data were collected from five teaching and assessment domains from the two classes. These include: science concepts, science process skills; creativity, attitudes, applications of concept and processes in new contexts. There was no difference found in assessing in the concept domain. In all the other four domains student outcomes were significantly higher for students in the STS sections.

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Introduction

There has been little actual reform in American science education for the past several decades. Educational policies and new science courses and programs have recommended significant changes, but actual classroom practices have not changed. It is apparent that the practice and theory of reform do not coincide (Bybee, 1991; Abell & Lederman, 2007; Weiss, 1993, 1994, Tillotson, 2005). When teacher beliefs are incompatible with the philosophy of science education reform, a gap develops between the intended and the implemented principles of reform (Levitt 2002). Certainly, the teaching advocated by the National Science Education Standards (NRC, 1996) and that advocated in Science for All Americans (AAAS, 1990) have both identified the need for different forms of teaching. Both indicate that the focus on teaching and learning of science must go far beyond the simple transmittal of scientific facts, concepts, and process skills directly to students. But, the interpretations of the needed changes often result in continuation of the status quo in actual classrooms.

Interestingly, inquiry (a new reform focus proposed in the late 50s) is now accepted as a desired focus for teaching as well as a form of content in the NSES. A follow-up publication from NRC entitled "Inquiry and the NSES" elaborates more focus on inquiry and indicates that there are four levels of student inquiry and five distinct features (NRC, 2000, p. 29). These same levels vary from very "open" inquiry to very "directed" inquiry. Too many are quick to adapt "directed" inquiry with little more than superficial changes with no firsthand experiences with students doing their own inquiry! Instruction described in most state standards and most textbooks remain directive. To STS enthusiasts, inquiry is uniquely student-centered and centered on problem situations identified by students. (Some science educators maintain that open-inquiry – student inquiry – is not really possible (Abell & Lederman, 2007). This study provides data for comparing student outcomes in highly student-centered classrooms (i.e., often open inquiry) that characterizes the teaching central to Science/Technology/Society (STS) (NSTA, 2008-09, p. 242) reforms with student outcomes in classrooms that are taught by the same teacher in a much more directed inquiry fashion.

Much previous research has reported solely on teacher perceptions of their own implementation of recommended teaching practices associated with specific reforms (Bybee & Bonnstetter, 1985; Mitchener &Anderson, 1989; Rubba, 1989; Tillotson, 1996, 2005; Luft, 2001; Luft, Roehrig, Patterson, 2003). The majority of teachers in these studies displayed positive perceptions of their teaching and supported the idea of the use of real world contexts for their teaching. Few studies have focused exclusively on teacher use of the teaching strategies that characterize the nine "more emphasis" conditions recommended in the National Science Education Standards (NSES) – (NRC, 1996, p. 52) as specific ways teaching should change. These nine changes indicate that teachers should: 1) understand and respond to individual student's interests, strengths, experiences, and needs; 2) select and adapt curriculum; 3) focus on student understanding and use of scientific knowledge, ideas, and inquiry processes; 4) guide students in active and extended scientific inquiry; 5) provide opportunities for scientific discussion and debate among students; 6) continuously assess student understanding; 7) share responsibility for learning with students; 8) support a classroom community where cooperation, shared responsibility, and mutual respect occurs; 9) work with other teachers to enhance the entire science program (NRC, 1996).

Science-Technology-Society efforts were underway in the U.S. by 1980 and superseded the National Science Teachers Association (1996) and Project 2061 (AAAS, 1990) with its inclusion as a form of science for Project Synthesis funded by NSF in 1978 (Harms & Yager, 1981). After many extensive efforts to implement STS programs, NSTA appointed a Task Force to define STS. This work resulted in a Position Paper unanimously approved by the NSTA Board of Directors in 1990 after four years of debate. STS was defined in the official NSTA position as "the teaching and learning of science <u>and technology</u> in the context of human experiences. Eleven features of STS were identified in the Position Statement to describe needed change in teaching. These essential features characterizing STS include: 1) student identification of problems with local interest and impact; 2) the use of local resources (human and material) to locate information with can be used in problem resolution; 3) the active involvement of students in seeking information that can be applied to solve real-life problems; 4) the extension of learning beyond the class period, the classroom, the school; 5) a focus on the impact of science and technology on individual students; 6) a view that science content is more than concepts which exist for students to master on tests; 7) an emphasis upon process skills which students can use in their own problem resolution; 8) an emphasis upon career awareness – especially careers related to science and technology; 9) opportunities for students to experience citizenship roles as they attempt to resolve societal issues they have identified; 10) identification of ways that science and technology are likely to impact the future; 11) some autonomy in the learning process as individual issues are identified and used as the basis for science study (NSTA, 2008-09, p. 242). This study is an examination of learning outcomes for students enrolled in STS classrooms versus those following a curriculum closely and using mostly "directed" inquiry.

But there is little evidence that the teaching approaches urged by NSES or those characterizing STS are being employed in schools generally (Mitman, Mergendoller, Marchman & Parker, 1987; Rubba, 1989; Weiss, 1993, 1994). The level of success with STS depends on several factors, such as prior experiences of teachers with STS, the level of "inquiry" they are willing and able to try, their attitudes, the extent of cooperation and communication with their colleagues, and the level to which their instruction focuses on student constructions of concepts (Wilsman, 1991; Williams, 1994). Massenzio (2001) has reported that most teachers are not implementing STS approaches because they are very familiar and comfortable with traditional approaches to science teaching. Most teachers still retain the beliefs that learning occurs as a result of direct teaching. This means that most teachers and state mandated reforms are merely a matter of transmitting what they know and what textbooks and other materials include. Mitchener and Anderson (1989) identified five factors that influence teacher perceptions that keep them from implementing an STS approach. These include: concerns over the dilution of science content, discomfort with cooperative learning, difficulty assessing student work, frustrations regarding varying student ability levels, traditional conceptions of the role of the teacher, and unwillingness to deal with issues not part of their own science preparation. Unfortunately, there are few teachers who have learned science with an STS approach as part of their own preparation. One exception can be found in Iowa where there have been continuous efforts and financial support for moves to STS teaching since 1983 and the Project Synthesis conception of needed changes and the research supporting them.

Features of Iowa Chautauqua and the Scope, Sequence, and Coordination Projects as Sponsored by NSTA

The Iowa Chautauqua Program (like the later SS&C effort involving all science teachers in the 20 Iowa middle school districts) has emphasized constructivist teaching practices with an STS philosophy of learning in classrooms. The SS&C project sought to energize <u>all</u> science teachers in the twenty participating districts in the effort. It was one of six state efforts that comprised the NSTA Scope, Sequence, and Coordination Project. The STS efforts associated with SS&C were funded in Iowa with three major grants totaling over four million dollars over a seven year period (1990-1997) not including local funds from industry and other local support. One major feature of Iowa SS&C was the fact that it followed six years of NSF funding ($2.5 million) as the Iowa Chautauqua

Project which was first funded in 1983 and involved interested teachers from across the state. Both projects utilized successful teachers as instructional "partners" who were actively involved with reforms in Iowa where the model was developed and used. Basically these teacher partners were identified because of their understanding of science and reform teaching pedagogies which characterized the "Desired State" of Harms' Project Synthesis (1977). The first report of this major research effort was first published as a part of the NSTA "What Research Says" series (Harms & Yager, 1981).

The Iowa Chautauqua Model provided the framework for working with Iowa teachers and their implementation of SS&C during the 1990-97 funding interim and continued for four more years with State funding. The Iowa effort provided the framework for the Staff Development efforts for both the funded Chautauqua series and for the Iowa SS&C project. Both were ultimately validated as exemplary by the U.S. Department of Education's Program Effectiveness Panel, precursor for funding by the National Diffusion Network. The major facets of the professional development projects included a leadership conference, three-week summer workshop, 5 to 10 day trial use of the materials and approaches planned during the summer, a 3-day fall short course, interim interactions with other teachers in the study, and a Spring 3-day short course to report on all the efforts for the entire academic year. Some of the goals and products typically collected and evaluated at each stage are also indicated in Figure I. All of the efforts were offered with six teaching and assessment domains central to STS teaching and learning. The STS efforts were found to be superior to more traditional textbook-dominated courses in all domains – sometimes, however, no significant advantages were found for the STS in the Concept Domain (Yager & Tamir, 1992; Yager & Weld, 1999).

Previous studies of the Iowa SS&C Project pertaining to student achievement show that all aspects of the learning of students in STS/Constructivist classrooms increase, especially related to process skills, thinking and designing skills, achievement test scores, ability to apply concepts and skills to new situations, creativity skills, and the development of more positive attitudes concerning science, science study, and science careers (Yager & Weld, 1999; Yager & Tamir, 1992; Harms &Yager, 1981; Yager, 1982; Yager, 1993; Yager & Yager, 2007; Varrella, 1997; Enger, 1997; Yutakom, 1997). This means that typical content (organized around major science concepts) is but one form of content and often the only one aspect used traditionally to assess learning. A broader view of content was developed in Iowa where teachers helped urge such language and focus for the National Science Education Standards (NSES) which were conceived and funded in 1992; they were published in final form in 1996 (NRC, 1996).

Leadership Conference

A Two Week Long Conference Designed To

1. Prepare staff teams for conducting a workshop series which enrolled up to 30 new teachers.
   a) One lead teacher per ten new teachers
   b) Scientists from a variety of disciplines
   c) Scientists from industry
   d) School Administrators
   e) Science Supervisors/Coordinators
2. Organization and scheduling for each workshop
3. Publicity and reporting
4. Assessment strategies
   a) Five domains for assessing students for teaching effectiveness
   b) Use of past reports and sample instruments and techniques
   c) Action Research (Every teacher as researcher)
   d) New research plans for the successful teachers that were instructional partners

Three Week Summer Workshop

Learning 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 and in terms of meeting the four goals elaborated in the NSES, p. 13..
3. Issues such as air quality, water quality, land use/management are used as the contexts for concept and process skills development.
4. Focuses on problems/issues in the school and local communities.
5. Enrollees develop materials for use in peer teaching as well as specific plans for teaching a 5-10 day mini-module prior to the fall short course.
6. Decisions regarding specific evidence needed to assure that each goal was achieved.

Academic Year Workshop Series

Fall Short Course (3 days) → Interim Projects → Spring Short Course (3 days)

Awareness Workshop

<u>20 hr Instructional Block</u>
(Thursday pm. Friday, & Saturday)

Activities Include:

1. Review problems with traditional views of science and science teaching
2. Outline essence of new instructional strategies
3. Define techniques for developing new modules and assessing their effectiveness
4. Select a tentative module topic
5. Practice with specific assessment tools in each Domain.
6. Use Lesson Study designs
7. Analyze one videotape of one class prepared for use in the Short course to be Shared with total group

Three Month Interim Projects

<u>Developing More Modules</u>

Activities Include:

1. Developing instructional plans for minimum of twenty days
2. Administer pre-tests in six domains
3. Teach one complete module (3-4 weeks)
4. Collect posttest information
5. Communicate with regional staff, Partner Teachers, and central Chautauqua staff
6. Complete and analyze one class videotape with colleagues from given sites
7. Decide on other modules to be tried

Final Workshop

<u>20 hr Instructional Block</u>
(Thursday pm. Friday, & Saturday)

Activities Include:

1. Report on new instructional experiences
2. Report on all assessment efforts
3. Interact with new information concerning the new teaching strategies elaborated in the NSES, p. 52
4. Show and discuss one videotape of teaching in one class
5. Analyze changes from summer, fall, and spring
6. Plan for involvement in professional meetings
7. Plan for next-step initiatives (including complete reorganizing of existing courses and helping with new workshop series)

Figure I. The IOWA CHAUTAQUA MODEL: A Professional Development Model Approved by the National Diffusion Network

How SS&C Relates to the Visions Included in the National Science Education Standards

The NSES include eight facets of content including: 1) unifying concepts and processes; 2) science as inquiry; 3) physical science; 4) life science; 5) earth /space science; 6) science and technology; 7) science for meeting personal and societal challenges; and 8) history and nature of science. Unfortunately, many state standards, and most textbooks, focus only on the concept facets (i.e., physical, life, earth/space) and on inquiry (too often at the “teacher directed level”) while the other four facets are not commonly pursued by teachers or even acknowledged in some state standards. The Iowa reform efforts have focused on all eight facets of content in addition to concern for attitude and creativity, which have been called the enabling domains.

Assessment efforts in Iowa have utilized the design proposed by Wiggins and McTighe (1998) called “Understanding by Design” which calls for teachers and staff development leaders to develop protocols for assessing evidence that the specific goals advanced have been met before considering any curriculum materials. The stated goals for K-12 science included in the NSES include only four for determining student learning, namely students should: 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, p. 13)

These goals are very similar to the Project Synthesis goals used in the 1980 research project mentioned earlier. Again, there were but four goals. These Synthesis four are: 1) science as preparation for further study; 2) science for dealing with personal problems; 3) science for resolving current societal issues; and 4) science for preparing for science careers (NSTA, Vol. 3 of What Research Says to the Science Teacher). The Synthesis research team reported that the only goal that was identified to plan the curriculum and used to justify science programs was the first one, i.e., preparing students for further study of science across grade levels and for college. It is extremely interesting to note that this goal was omitted completely from the NSES, especially since it was the only goal acclaimed by 95% of the K-12 science teachers. In its place was the new first goal for science in the NSES which indicated that all students must Do Science. Some argue that this first goal is the over-arching one which makes inquiry basic – and a form of content as well as a teaching approach. This is certainly central to STS efforts and to the Iowa SS&C efforts over the seven years it was funded and continues today with Title IIa funding.

With the faculty and focus of the Iowa Staff development efforts during the funding, 1983-1997, it is interesting to see what occurred in the classrooms of the most successful teachers of Iowa SS&C who served as important partners in the continuing professional development efforts. Further, it is of interest to determine what they do in their classrooms that can affect learning in multiple domains.

Changes in Constructivist Teaching Practices

The study of teacher perceptions, teaching practices, and the relationship between them is considered important for understanding new problem teaching situations and for encouraging even more successes with the current reform efforts (Anderson & Mitchener, 1994). The thinking by teachers about their own teaching as well as their implementation of innovative teaching methods provide a basis for understanding the process for accomplishing even more changes. Clark and Peterson (1986) have asserted that teacher behavior is influenced substantially by the thought processes of teachers. Studies of teaching practices are important for enhancing student understanding and improving teaching (Good & Brophy, 2000; Rosenshine, 1971). More importantly, such studies support the fact that effective teaching practices can be developed when teachers are provided with appropriate experiences as a part of continuing staff development projects (Yager & Penick, 1990; Yeany & Padilla, 1986; Kimble, 1999). Teaching practices exhibited by successful teachers serve as guides and inspiration for other teachers to emulate.

Yager and McCormack (1989) have identified six domains for use in science teaching and assessment of teaching success that correspond to the changes advocated in the NSES. These were developed further and used with both Iowa Chautauqua and Iowa SS&C. They were used by the teacher leaders as well as new teachers enrolled in subsequent years. Obviously the teacher leaders provided great role models and the most significant results with new students over subsequent years. These domains include: 1) Concept Domain: mastering basic content constructs; 2) Science Process Domain: learning and using the skills scientists use in "sciencing"; 3) Creativity Domain: improving in quantity and quality of questions, possible explanations, and predicted consequences; 4) Attitude Domain: developing more positive feelings concerning the usefulness of science, science study, science teachers, and science careers; 5) Application and Connection Domain: using concepts and processes in new situations; 6) Worldview Domain: focusing on the whole science enterprise for learning with respect to philosophy, history, and sociology.

Figure 2 illustrates the relationship of the domains identified for assessing successes with the STS approach. The typical domains are concept and process mastery – often the primary foci for typical instruction -- almost always giving more attention to the mastery of given concepts. STS demands attention to the two "enabling" domains that surround the "bulls eye" of the diagram. Biologists like to think of creativity and attitude as symbolizing the cell membrane -- controlling what gets in and out of the world of professional scientists, estimated to be the 0.004 percent of the population of the world who are practicing research scientists. The large Applications and Connections domain is where most people live and work – where the concepts and processes can affect their living. This domain is even larger than indicated in Figure II. Few who even start in college science courses actually operate in the central region (i.e., new concepts and process skills). The sixth domain was not a focus for this study (the Worldview Domain) – where less focus was given to it. Further, the attention to it varied and many instruments that were used were inappropriate for the grade level span. Interest and focus among the instruments and the data collection in the Worldview domain varied widely – both in terms of quantity and quality.

It is also important to emphasize that STS focuses on technology (the design world) as well as on pure science. It connects the world of science to the whole of society. STS efforts also illustrate the importance of society and its affect on people, including scientists. Science and even more so – technology -- focus on human problems and their possible resolution when STS approaches are used. In spite of the call for unification of science and technology, relatively few mergers have occurred in the U.S. nor in Iowa in spite of the major STS focus.

Specific research questions for the study include how students taught by the same teacher in an STS section compare to students in a Non-STS section related to: 1) learning of basic science concepts? 2) learning of science process skills? 3) learning of creativity skills? 4) student attitudes concerning science? 5) ability of students to apply concepts and process skills in new situations? In all fifteen schools each teacher taught one section with an STS approach and one which did not utilize any of the defining characteristics of STS. Hence the results reported in the tables indicate the differences found in STS and Non-STS sections. All 30 classes (15 STS and 15 Non-STS) were taught involving teachers who had been active partners in the Iowa Chautauqua and Iowa SS&C projects – both with major NSF funding. The study involved a total of 310 students in the 15 STS classes and 302 in the Non-STS sections.

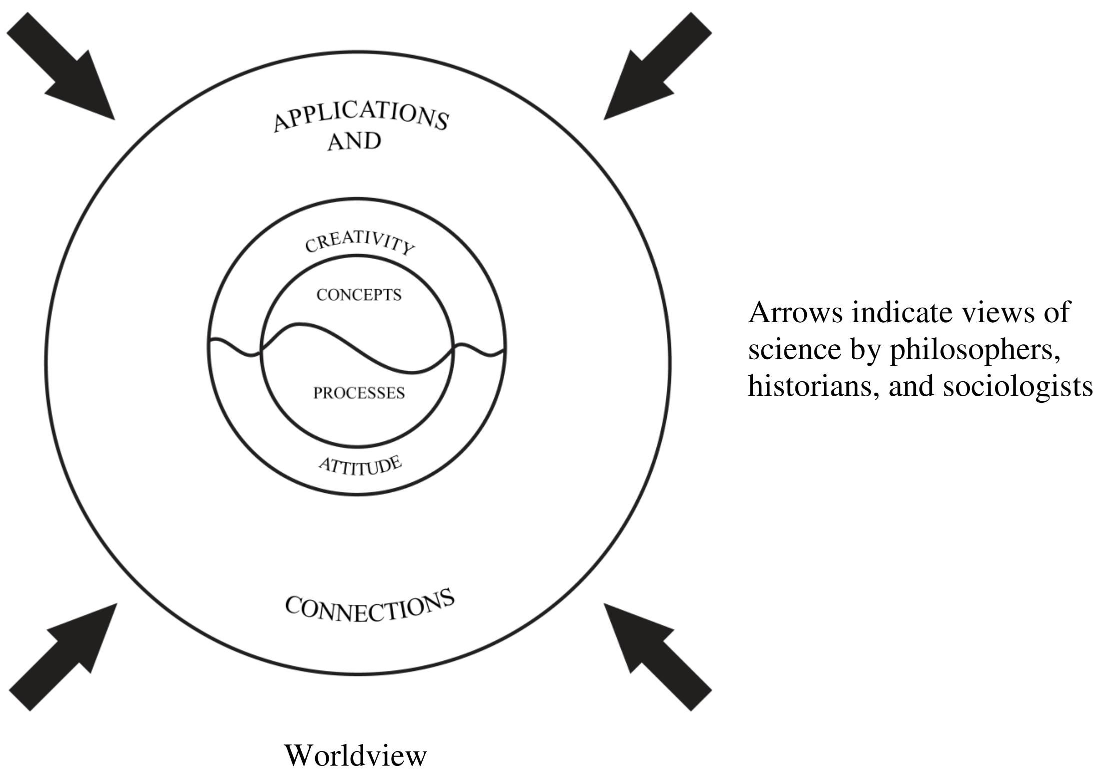

Figure II. Domains for Teaching and Assessing Science Learning

Procedures

This is a report of the use of STS teaching approaches and its effects on student learning in five of the six teaching and assessment domains indicated. Fifteen teachers were identified as the most effective partners involved with STS reforms over the thirty year interim. These teachers served as instructional partners for at least ten years. Most were selected from a follow-up study conducted by Yutakom (1997) —all were recommended by the program staff, school administrators, enrolled teachers, and students who provided feedback that illustrated the advantages of STS teaching. It was part of the information used to gain approval from the Program Effectiveness Panel (PEP, 1992)) and ultimately to gain recognition and funding as part of the National Diffusion Network.

Each of the 15 teachers agreed to select one class session where STS would be implemented fully and one class where traditional procedures would be utilized but recognizing the importance of inquiry. The science topics for both sections were the same from the various Standards and science curricula developed and used in the fifteen schools and involved teachers across grades 5 through 10. The differences were the degrees of understanding of the basic science and technology content. In the STS sections students were asked to identify problem questions that framed their study; in the traditional section teachers merely outlined the content that would frame the studies without input from students. Data were collected over two 9-week grading periods which occurred as a part of a whole semester in grades 5-9 middle schools where the selected fifteen teachers taught across Iowa. Data consisted of weekly quizzes as well as unit and semester exams for noting differences in the concept domain.

Other instruments consisted of a process skills instrument used with SS&C and published in “Assessing Student Understanding in Science” (Enger & Yager, 2001). It was given as a pre-test prior to beginning the semester long study and again at the end of the semester.

The attitude instrument was taken from the affective battery characterizing the 1978 administration of National Assessment of Educational Progress (NAEP, 1978) which was the first year that such items were included other than those assessing Concept Mastery. Thirty items were selected where students were asked to indicate their feelings using a scale of: strongly agree, agree, not sure, disagree, strongly disagree. This scale was used as a pre-test before instruction and again at the end of the semester long course.

The creativity scale was used and outlined in the Iowa Assessment Handbook (Yager, Kellerman, & Blunck, 1992). It consists of describing a discrepant event and then recording student questions, suggestions for possible answers, evidence for validity, and predictions of possible consequences, and finally the uniqueness of each on a ten point scale. Each was evaluated in terms of quantity and later for degree of uniqueness. A five point scale was used and rated as follows: response is “irrelevant”, i.e., not related to the question (0 score), “pertinent” question related but not creative (2 points), and “unique” difficult to see the connection and not frequently cited by others (5 points). The entire exercise was undertaken as a pre-test, repeated at the end of each unit over the semester, and again as the post-test for the study. Two research assistants (some included as co-authors of this report) reviewed the information – mainly from sample videotapes of at least three class periods at the end of each nine week assessment.

The instruments for assessing student growth in each of the domains are all illustrative of the samples from Enger & Yager (2009). No specific measures were used in the Worldview Domain for all teachers (hence no data are reported or used by all teachers in all thirty classrooms involved with this study). There were consistent directions for using each instrument. Information about validity and reliability issues are reported in Enger & Yager (2009). These domains were defined as a goal of science education in the Iowa Chautauqua Program. The reliability coefficients for assessment items in each of the domains are obtained by using the test-retest method with students in classes taught by all lead teachers for a given year. Specific information reported for this study did not involve the teachers and students in the sample. In other Action Research efforts instrument reliability and/or validity were studied. The reliability regarding the domains ranged from 0.76-0.96 (test-retest two weeks later).

The specific instruments for the five assessment domains are summarized as follows: 1) Concept – The pre-test for the content for the instructional units for the semester and as a final each 9 weeks and an end-of-semester grading). These examples were different for each teacher and grade level. 2) Process – The process test included in Enger and Yager used as a pre-instructional test and a final semester measure. 3) Creativity – Pre and post scores on a discrepant event where students were asked to provide questions, possible-explanations, evidence for the validity of an expert, and an indication of uniqueness for each. Points were given for number and relative quality of each of the four areas. 4) Attitude – Thirty items from the 1978 NAEP were selected and used as a pre-instruction and semester end instrument. 5) Applications – The teachers were assisted in providing application items for each major concept from each unit – these were completed prior to and following each instructional unit and as a final semester survey. Teachers were also active in urging use of the skills and concepts taught in new situations as a feature of STS teaching and an activity to encourage <u>use</u> of the information in ways students could evaluate their own work and that of others in the class. These procedures were great in illustrating assessment as a basic ingredient of science itself – not something that only teachers do to grade student performances. The application domain consisted of items concerning each of the concepts encountered where students were asked to apply them in new situations. Some of these were used to indicate the degree of creativity as well. The "Assessing Student Understanding" monograph (Enger & Yager 2001) details how teachers were asked to provide application items to measure a sampling of content in each of the instructional units and to get experience with use of a multiple choice format. Teachers provided the researchers with examples of their concept items and matched application items for each instructional unit included for each nine-week grading period (often three units involved with each grading period). Teachers in STS sections frequently asked students to suggest their own applications in the classroom, the school, and the wider community.

Results

Tables I through V include the pre and post scores for students in both the STS and Non-STS sections for all fifteen teacher participants who had been partners in professional development efforts for at least ten years with the Iowa Chautauqua and SS&C projects.. They were leaders in terms of work on a variety of Action Research projects and well known in other districts where the STS approach was used. They typically used STS approaches in their own classrooms. All were considered leaders for science teaching in grades 5 through 9 for the Iowa SS&C project. School administrators and counselors were positive and helpful with the research, especially the ones involved with this study. The students involved were typical for both sections for each of the teachers. School counselors reported finding no differences in terms of gender, socio-economic factors, and ability levels. One concern was related to the teaching in Non-STS sections which was not the typical style for the 15 teachers; they did try hard not to make students in the Non-STS classrooms to feel disadvantaged. Nonetheless, this could be a factor that was not standard nor observable even after analysis of classroom observations and/or via video-tapes. School counselors did report that there were no complaints from students nor parents for student not experiencing the STS approach.

The tables show clearly that there were no differences in terms of pre-test scores in all five domains in terms of the STS and Non-STS students for the fifteen teachers. On the other hand, the post test scores illustrate mostly positive changes in all five domains for students enrolled in the STS sections for each of the fifteen teachers.

As indicated in Table I student growth in terms of Concept Mastery with the post-tests was not different for the students enrolled in the two sections for each teacher. This is important since the Non-STS students focused largely on Concept Mastery while the students in the STS sections learned concepts that were needed as they worked on problems with personal and local concerns. Some teachers generally are often concerned that students will learn fewer concepts since they are not the driving forces for the lessons or unit studies. The lack of any differences is encouraging and a positive result showing that STS does not limit Concept Mastery – just because they are not used as instructional organizers.

Table I
Summary of the ANCOVA for Comparisons of Student Performances in Fifteen STS and Non-STS Classrooms Concerning the Concept Domain

Teacher	Group		Mean		S.D.		t	p	F	p
		n	Pre	Post	Pre	Post				
1	STS	21	8.36	16.72	2.76	3.53	23.52	0.00	341.98	0.000
	Non-STS	19	8.69	17.69	2.61	4.79	15.33	0.00		
2	STS	14	3.03	6.55	1.37	1.94	22.68	0.00	407.70	0.000
	Non-STS	17	2.57	6.80	1.10	1.69	16.81	0.00		
3	STS	21	6.00	13.00	2.35	3.44	22.35	0.00	1241.39	0.000
	Non-STS	24	5.70	12.40	2.20	3.21	22.33	0.00		
4	STS	29	1.68	6.59	0.89	1.84	17.15	0.00	135.58	0.000
	Non-STS	32	1.56	6.30	0.84	2.03	15.31	0.00		
5	STS	16	2.42	6.50	1.41	2.38	15.35	0.00	391.64	0.000
	Non-STS	14	2.24	6.60	1.50	2.56	14.56	0.00		
6	STS	26	2.85	9.09	1.52	3.01	14.88	0.00	245.68	0.000
	Non-STS	21	2.95	9.54	1.25	2.66	17.80	0.00		
7	STS	16	2.42	7.46	1.41	2.40	18.74	0.00	287.26	0.000
	Non-STS	18	2.66	6.79	1.49	2.76	11.07	0.00		
8	STS	28	4.18	11.81	2.01	3.36	13.35	0.00	186.45	0.000
	Non-STS	27	4.20	13.37	2.32	2.76	31.98	0.00		
9	STS	15	5.30	12.87	2.49	3.20	20.98	0.00	324.73	0.000
	Non-STS	16	5.54	12.83	2.68	3.47	16.88	0.00		
10	STS	23	6.48	13.29	2.35	3.36	24.55	0.00	990.08	0.000
	Non-STS	21	6.34	12.69	2.41	3.71	19.08	0.00		
11	STS	18	3.88	12.52	1.65	2.64	23.80	0.00	200.92	0.000
	Non-STS	19	4.25	12.62	1.57	2.21	23.78	0.00		
12	STS	22	4.66	13.51	2.10	3.13	28.69	0.00	571.34	0.000
	Non-STS	20	4.67	14.60	2.10	2.42	45.58	0.00		
13	STS	23	5.96	17.12	2.83	3.57	23.15	0.00	271.24	0.000
	Non-STS	21	5.29	15.51	2.09	3.90	23.00	0.00		
14	STS	21	6.04	12.68	2.97	3.79	21.14	0.00	722.36	0.000
	Non-STS	19	5.96	12.65	2.64	3.69	18.66	0.00		
15	STS	17	9.00	16.22	3.78	3.75	27.43	0.00	1424.38	0.000
	Non-STS	14	9.96	15.96	3.58	3.70	22.67	0.00		

Table II reports on the results focusing on the learning of general Process Skills. A focus on such mastery is not often a primary goal, especially at the middle school or early high school levels. Of particular importance is the fact that student learning of process skills is enhanced in the STS sections. Apparently thinking and analogies, (as well as experience with the specific fourteen processes basic to the Science-A Process Approach (SAPA) (AAAS, 1965) are realized to a greater extent in STS sections over those in Non-STS classrooms. SAPA was a K-8 program for pre-K through grade 8 classrooms in the late 60s. Significant increases for students in the STS sections could be caused by the fact that Concept Mastery is the major focus of traditional teaching and in the Non-STS classrooms of the STS teacher leaders. Typical teacher and textbook examinations focus on Process Skill Mastery per se. Similarly, typical laboratories do not focus on processes as foci for learning. Hence the results indicated in Table II are not unexpected.

Table II
Summary of the ANCOVA for Comparisons of Student Performances in Fifteen STS and Non-STS Classrooms Concerning the Process Domain

Teacher	Group		Mean		S.D.		t	p	F	p
		n	Pre	Post	Pre	Post				
1	STS	21	4.36	9.28	1.18	2.45	15.84	0.000	276.00	0.000
	Non-STS	19	4.19	4.34	1.35	1.54	0.84	0.404		
2	STS	14	2.18	5.40	0.96	1.86	13.38	0.000	293.24	0.000
	Non-STS	17	1.84	2.80	0.92	1.23	8.18	0.000		
3	STS	21	4.22	7.66	1.70	1.78	18.64	0.000	715.37	0.000
	Non-STS	24	3.50	4.10	1.60	1.83	3.94	0.000		
4	STS	29	2.09	5.72	1.06	1.83	15.60	0.000	297.08	0.000
	Non-STS	32	1.69	2.87	0.82	1.32	7.24	0.000		
5	STS	16	2.42	7.38	1.03	2.33	17.38	0.000	305.10	0.000
	Non-STS	14	2.20	3.08	1.32	1.25	6.60	0.000		
6	STS	26	2.57	8.61	1.24	2.90	14.51	0.000	308.06	0.000
	Non-STS	21	2.59	3.40	1.05	1.62	5.23	0.000		
7	STS	16	2.42	7.76	1.36	2.59	13.24	0.000	134.73	0.000
	Non-STS	18	2.62	3.95	1.24	2.07	4.87	0.000		
8	STS	28	2.90	9.09	1.37	2.36	21.20	0.000	358.26	0.000
	Non-STS	27	2.79	4.04	1.17	2.01	5.31	0.000		
9	STS	15	6.52	11.82	2.60	3.18	16.10	0.000	618.68	0.000
	Non-STS	16	6.75	7.66	2.78	3.19	3.25	0.004		
10	STS	23	3.14	9.77	1.61	2.48	27.00	0.000	729.10	0.000
	Non-STS	21	3.42	5.75	1.81	2.39	6.32	0.000		
11	STS	18	5.11	10.64	1.76	2.52	8.05	0.000	352.37	0.000
	Non-STS	19	4.81	5.68	1.90	2.30	4.34	0.001		
12	STS	22	2.72	10.03	1.30	2.59	21.23	0.000	290.63	0.000
	Non-STS	20	3.00	3.92	1.24	1.69	41.00	0.000		
13	STS	23	3.40	4.77	1.55	2.15	21.04	0.000	373.29	0.000
	Non-STS	21	3.40	4.77	1.55	2.15	7.36	0.000		
14	STS	21	5.08	9.12	2.13	2.81	12.67	0.000	553.62	0.000
	Non-STS	19	4.50	5.76	1.98	2.38	7.04	0.000		
15	STS	17	4.88	10.22	2.02	2.34	26.70	0.000	956.08	0.000
	Non-STS	14	4.76	5.92	2.14	2.44	6.45	0.000		

Table III reports on the differences in terms of student outcomes in the Application/Connection Domain. The results again clearly indicate the superiority of the STS approach in terms of applying concerns (and process skills) in new situations. Not surprisingly, the students in the Non-STS classes do not excel in applying and/or connecting their learning to anything else in their lives. They are not expected to do more than taking notes, remembering, and repeating what they are told or what they have read. One of the key advantages of the STS approach is the ability to apply information and skills in new situations. To many this is the ultimate proof of learning and something that every teacher (and pupil) should accomplish. And yet, it rarely occurs – even in classrooms where experienced and enthused STS teachers elect not to focus on any applications which are required and central to the STS approach. STS starts with problems – often related to the environment or energy needs. Non-STS situations are usually devoid of issues, problems, applications or actions in school or the lives of students outside of school.

Table III
Summary of the ANCOVA for Comparisons of Student Performances in Fifteen STS and Non-STS Classrooms Concerning the Applications Domain

Teacher	Group	n	Mean Pre	Mean Post	S.D. Pre	S.D. Post	t	p	F	p
1	STS	21	6.32	18.32	2.01	3.80	22.54	0.000	383.03	0.000
	Non-STS	19	6.46	8.03	2.42	3.37	6.49	0.000		
2	STS	14	1.37	7.29	1.37	7.29	18.27	0.000	155.74	0.000
	Non-STS	17	1.19	2.23	0.74	1.33	8.18	0.000		
3	STS	21	5.33	13.00	2.30	3.71	19.35	0.000	632.33	0.000
	Non-STS	24	4.30	6.00	1.62	2.47	6.03	0.000		
4	STS	29	1.31	6.27	0.94	1.51	25.86	0.000	243.50	0.000
	Non-STS	32	1.34	3.52	0.88	1.44	11.13	0.000		
5	STS	16	0.76	6.00	0.71	2.24	14.16	0.000	94.76	0.000
	Non-STS	14	1.04	2.12	0.20	0.21	8.43	0.000		
6	STS	26	1.90	8.38	1.33	2.69	17.85	0.000	294.23	0.000
	Non-STS	21	1.68	2.50	1.32	1.53	5.23	0.000		
7	STS	16	1.92	6.84	1.44	2.14	18.53	0.000	278.08	0.000
	Non-STS	18	1.54	2.16	1.10	1.16	4.30	0.000		
8	STS	28	1.81	10.63	1.25	3.87	11.95	0.000	53.34	0.000
	Non-STS	27	1.95	2.54	0.99	1.50	3.44	0.002		
9	STS	15	2.21	12.04	1.78	3.02	20.58	0.000	116.07	0.000
	Non-STS	16	1.66	5.79	1.09	2.46	10.93	0.000		
10	STS	23	2.55	10.18	1.15	2.60	24.55	0.000	181.40	0.000
	Non-STS	21	2.53	4.84	1.27	2.24	7.50	0.000		
11	STS	18	2.41	11.41	1.12	3.00	16.80	0.000	101.23	0.000
	Non-STS	19	2.31	3.56	1.07	1.59	4.69	0.000		
12	STS	22	2.13	12.31	1.62	3.21	23.34	0.000	192.09	0.000
	Non-STS	20	1.78	3.00	1.10	1.36	8.70	0.000		
13	STS	23	3.12	15.12	1.61	3.19	25.02	0.000	214.39	0.000
	Non-STS	21	3.25	5.70	1.48	2.63	8.76	0.000		
14	STS	21	3.40	13.72	1.65	2.71	29.49	0.000	396.46	0.000
	Non-STS	19	3.57	6.19	1.96	2.85	9.81	0.000		
15	STS	17	4.74	15.92	2.04	3.38	31.57	0.000	643.71	0.000
	Non-STS	14	4.64	6.32	1.84	2.73	7.11	0.000		

Table IV indicates the results regarding the Creativity Domain. Although most recognize the importance of creativity and its role in scientific pursuits, it is not a facet for assessing student performance; it typically has little or no role in typical classrooms – again where Concept Mastery is the major focus. In all fifteen STS sections enhanced creativity was found to be significantly better. Students experiencing the STS approach asked more questions, raised more unique questions, offered more ideas about possible explanations for the objects and event studies – and more often they offered more unique explanations. The students in the STS sections also were able to provide evidence of the validity of some of their explanations; they were also quick to discuss their evidence with others, and to enter into debates and arguments. The STS students were also better able to suggest consequences for some predictions. In every case the STS students were better in all aspects of creativity than students in Non-STS sections where they were the receivers of information from teachers or textbooks – merely to be remembered and/or replicated.

Table IV

Summary of the ANCOVA for Comparisons of Student Performances in Fifteen STS and Non-STS Classrooms Concerning the Creativity Domain

Teacher	Group		Mean		S.D.		t	p	F	p
		n	Pre	Post	Pre	Post				
1	STS	21	23.04	52.72	8.75	16.96	15.29	0.000	450.46	0.000
	Non-STS	19	23.11	23.96	6.43	5.76	2.14	0.042		
2	STS	14	87.66	163.96	33.37	50.98	18.06	0.000	1326.39	0.000
	Non-STS	17	83.96	79.42	33.01	33.93	3.36	0.002		
3	STS	21	76.61	163.33	25.97	39.68	23.07	0.000	843.45	0.000
	Non-STS	24	76.00	74.90	23.71	20.06	0.87	0.391		
4	STS	29	54.90	115.59	20.94	36.65	17.56	0.000	1261.70	0.000
	Non-STS	32	55.65	63.43	22.07	22.40	9.05	0.000		
5	STS	16	68.42	135.76	26.20	47.66	15.33	0.000	1243.57	0.000
	Non-STS	14	65.72	72.00	28.44	32.96	15.35	0.000		
6	STS	26	76.71	133.95	25.58	34.07	20.04	0.000	1113.20	0.000
	Non-STS	21	68.50	75.59	25.70	29.28	3.52	0.002		
7	STS	16	25.30	46.92	9.78	15.59	17.60	0.000	987.44	0.000
	Non-STS	18	24.37	25.04	9.09	10.08	0.69	0.495		
8	STS	28	60.18	106.77	23.34	27.76	21.78	0.000	1669.32	0.000
	Non-STS	27	61.41	65.91	22.90	25.76	3.37	0.003		
9	STS	15	68.04	115.08	21.05	31.35	15.79	0.000	940.57	0.000
	Non-STS	16	67.37	68.20	21.18	22.64	0.67	0.509		
10	STS	23	70.33	127.96	25.31	38.78	19.36	0.000	431.21	0.000
	Non-STS	21	65.00	69.57	26.65	33.28	2.61	0.015		
11	STS	18	76.00	125.70	24.37	36.14	15.76	0.000	757.97	0.000
	Non-STS	19	71.68	72.75	24.31	23.98	0.43	0.672		
12	STS	22	24.00	41.48	8.99	12.83	20.52	0.000	1287.70	0.000
	Non-STS	20	24.39	24.42	8.16	8.82	0.05	0.962		
13	STS	23	72.36	125.76	24.11	37.23	17.56	0.000	1429.06	0.000
	Non-STS	21	69.63	74.59	26.16	29.18	2.92	0.007		
14	STS	21	66.12	113.04	21.03	27.54	24.15	0.000	1335.92	0.000
	Non-STS	19	61.57	69.23	22.35	27.61	3.76	0.001		
15	STS	17	64.92	117.14	22.57	31.88	22.83	0.000	1463.69	0.000
	Non-STS	14	63.24	62.96	23.15	23.28	0.20	0.839		

Table V is a report of the differences between students in the STS and Non-STS sections in terms of their attitudes about science study, science classes, science teachers, science concerns, and their views of science versus technology (the "natural" world vs the "design" world). Once again there is a clear difference in terms of positive attitudes concerning the whole experience with STS teaching versus a more traditional focus on Concept Mastery. Too often teachers remain unconcerned about the negative reactions of most students K-16 concerning their attitudes toward/about science study. In fact, attitudes traditionally become more negative as students progress across the years of their schooling (Yager, Akcay, Choi, Yager, 2009). The STS approach engages students in doing science and technology and depends on their ideas, their actions, their questions – as well as the interactions among their peers in a given classroom. In the Non-STS sections there was less collegiately and more of a competitive atmosphere.

Table V
Summary of the ANCOVA for Comparisons of Student Performances in Fifteen STS and Non-STS Classrooms Concerning the Attitude Domain

Teacher	Group		Mean		S.D.		t	p	F	p
		n	Pre	Post	Pre	Post				
1	STS	21	8.36	15.08	3.08	4.49	12.23	0.000	437.27	0.000
	Non-STS	19	8.69	9.07	3.27	3.74	1.13	0.266		
2	STS	14	16.77	24.77	5.32	4.40	12.32	0.000	714.67	0.000
	Non-STS	17	17.84	17.34	5.19	5.36	1.42	0.168		
3	STS	21	10.05	15.38	2.30	2.76	12.25	0.000	261.94	0.000
	Non-STS	24	10.60	10.50	2.11	2.23	0.38	0.705		
4	STS	29	9.72	15.18	2.93	2.78	11.64	0.000	281.68	0.000
	Non-STS	32	10.47	9.95	2.50	2.73	1.47	0.156		
5	STS	16	11.80	20.42	4.60	4.87	13.36	0.000	526.43	0.000
	Non-STS	14	13.96	13.76	4.95	4.78	0.48	0.635		
6	STS	26	12.47	21.09	4.19	4.71	10.32	0.000	241.50	0.000
	Non-STS	21	14.18	13.36	3.72	3.83	2.00	0.059		
7	STS	16	14.15	20.73	3.90	4.15	10.27	0.000	272.11	0.000
	Non-STS	18	14.50	14.12	3.41	4.84	0.711	0.484		
8	STS	28	14.50	21.81	4.61	4.83	11.63	0.000	490.73	0.000
	Non-STS	27	14.58	13.95	4.14	4.39	1.53	0.139		
9	STS	15	13.04	21.60	3.90	4.74	9.38	0.000	133.17	0.000
	Non-STS	16	12.25	13.25	2.55	3.61	2.26	0.034		
10	STS	23	14.63	21.55	4.17	3.96	15.09	0.000	438.52	0.000
	Non-STS	21	15.11	14.38	3.93	4.85	1.30	0.203		
11	STS	18	14.52	20.05	3.62	3.19	8.05	0.000	256.85	0.000
	Non-STS	19	14.25	14.81	3.33	3.58	1.59	0.132		
12	STS	22	14.44	19.58	3.68	3.54	12.96	0.000	465.80	0.000
	Non-STS	20	14.92	14.35	3.18	4.02	1.27	0.212		
13	STS	23	14.16	20.00	3.98	4.07	7.36	0.000	276.49	0.000
	Non-STS	21	15.55	14.37	4.30	4.36	2.63	0.014		
14	STS	21	14.12	22.04	3.77	3.43	15.15	0.000	334.96	0.000
	Non-STS	19	15.00	13.61	3.82	3.92	2.54	0.017		
15	STS	17	15.29	20.70	3.40	3.11	15.05	0.000	687.04	0.000
	Non-STS	14	14.56	14.48	3.21	4.04	0.25	0.802		

Discussion

A Look at the Results and the Meaning They Suggest for Teaching Science

Too often achievement in science is based on the conceptual information students seem to possess as measured by standard instruments or those provided in teacher editions of standard textbooks. Although inquiry is often espoused, it is rarely tested as a form of content and/or used to indicate learning per se. Also, it is important to note the four levels of inquiry in the NRC, 2000, (p. 29) monograph. It is remarkable that many science educators maintain that open inquiry cannot be approached even in college classrooms. However, it occurred in all STS sections of the teachers in this study. The results of the study using results from assessments and learning in five of the six domains indicate considerable advantage for STS (as defined by NSTA) in all domains except Concept Mastery. As indicated no data are reported in this study concerning the 6th Domain (Worldview) because of the differences in grade levels and varying research protocols to collect such information. In terms of concepts, however, there is no advantage over direct teaching and the added time that could be spent on Concept Mastery which probably resulted in more time practicing definitions and concepts directly by teacher actions/lectures and/or textbook reliance and teacher directed laboratories and demonstrations.

The results indicate that there are significant advantages for STS teaching while uncovering no disadvantages. More teachers need the assurance that nothing is lost and that it is actually easier and more fun to involve students more in planning lessons, selecting projects, identifying topics and problems to pursue. It is also possible to actually use science projects for improving and/or resolving problems identified in schools and the local communities. STS provides pathways for the use of concepts and skills instead of merely promising that they will be useful at some point in the future.

STS seems to provide a way for students to remain curious – something they have had prior to attending school as well as to having fun and working on problems they identify and about which they are concerned. It is too bad that parents, administrators, state agencies, and many funding groups continue to argue about identifying concepts and needed skills (often merely focusing on terms claimed to be needed for future endeavors). These are seen as boring practices <u>before</u> working on real problems that are local, personally relevant, and of current importance. The starting point for science as it is for scientists themselves is not a new vocabulary or a listing of Key Concepts to be learned without a real context on any past or current student related experiences.

Conclusions

The results of the semester long teaching, which is the focus of this study, permit the following conclusions: 1) Students learn as many (occasionally more) basic concepts when approached via an STS pathway. 2) Students learn more and more useful science process skills with STS approaches than occur generally in more traditional classrooms and hence one might expect it to favor the students in Non-STS classrooms. 3) Students become even more creative as they study in an STS mode. Creativity can be defined as asking questions about the objects and events in the natural world as opposed to "going through" a textbook or required curriculum. 4) Students develop more positive attitudes about science the more they study science with an STS approach. (In typical classrooms attitudes become more negative the longer science is studied in schools!). 5) Students learn better how to apply science concepts and skills in new contexts than when science is experienced with an STS teaching approach.

When considering the broadened view of science content as outlined in the National Standards, the STS approach is easier to use while also illustrating the visions for the reforms of teaching which are central to the standards. Once again it is apparent from the results of this study that <u>how</u> teachers teach is more important than <u>what</u> they teach. Perhaps there is still too much focus in too many schools on the "What"!

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