

Comparing Science Learning Among 4th-, 5th-, and 6th-Grade Students: STS Versus Textbook-Based Instruction

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Abstract

Fifteen 4th-, 5th-, and 6th-grade teachers from five school districts each taught two sections of science—one with a Science-Technology-Society (STS) approach and the other with a more traditional textbook approach in which basic science concepts were the major organizers. Local, current, and personally relevant issues provided the context and organizational scheme for the STS section. The two approaches were evaluated using six different domains: (1) Concept, (2) Process, (3) Application, (4) Creativity, (5) Attitude, and (6) Worldview. The results indicate no difference in results at any grade level in the Concept domain. However, significant differences in terms of learning with large effect sizes were found in the other five domains. STS provided an impressive teaching approach utilizing the features of the National Science Teachers Association's (NSTA) (2006) position paper regarding STS in all assessment domains.

A unique model for encouraging more use of the Science-Technology-Society (STS) teaching approaches has been developed at the University of Iowa. This model, known as the Iowa Chautauqua Model, has operated since its inception in 1983. It was one of the efforts in five states selected by the National Science Teachers Association (NSTA) (2006) as part of a National Science Foundation (NSF) grant. It was designed to match the long-standing NSF projects developed by the American Association for the Advancement of Science (AAAS) to assist and update college science faculty. The original project called the "National Chautauqua Workshop Program" was funded for a three-year period to determine its effectiveness as an efficient professional development program for improving school science programs and teaching. The program basically included a two-to four-week summer institute followed by a short course in the fall and a second one in the spring. The original project supported 30 teachers for each of the three years (1983 to 1986). With an increase in numbers and sites following renewed support from NSF funding, the Iowa Chautauqua Program has enrolled over 5,000 K-12 teachers during its 25 years of operation (as indicated in annual reports to NSF). For the past decade, the program has enrolled about 225 teachers each year ending with the 2006 academic year.

The Iowa Chautauqua Model includes several specific features, including the following:

- A two-week leadership conference for 25 of the most successful teachers from previous years who are invited and who agree to become a part of the instructional team for future workshops—All 15 teachers involved in this study

participated in numerous leadership workshops and were involved in over a dozen workshops over the past years.

- A two- to four-week summer workshop at each new site for 30 new teachers electing to develop and try STS modules and strategies—The workshop provides experience with STS (teachers as students) and time to plan five-day STS modules to be used in the classrooms of all summer participants during the early fall.
- A three-day, short fall course for 30 to 50 teachers, including the 30 enrolled during the summer—The focus is upon sharing results of the five-day trial and developing a month-long STS module and extensive assessment plans.
- Interim communication with central staff, lead teachers, and fellow participants, including a newsletter, special memoranda, monthly telephone contacts, and school/classroom visits
- A three-day, short spring course for the same 30 to 50 teachers who participated in the fall courses—This session focuses on reports by participants concerning their STS experiences and the results of the associated assessment efforts. Plans for continued efforts for the next two years were also established. (Blunck & Yager, 1990)

Ideally, the program continues in some form at each site in terms of continued teaching, data collection, action research projects, and collegiality over a three-year period.

The work with the teachers is aimed at helping them improve learning in the following six domains: (1) Concepts, (2) Processes, (3) Applications, (4) Creativity, (5) Attitude, and (6) Worldview. These domains have been conceptualized by Yager and McCormack (1989) as a way of broadening the nature of science (NOS) content in schools and as ways of assessing student learning and changing the traditional focus to that of concept mastery. Table 1 provides a contrast between the Iowa STS model and more typical approaches to science teaching.

Table 1. Defining Characteristics of STS and Non-STS Science Instructional Approaches

STS*	Non-STS
Student centered	Teacher centered
Individualized and personalized; recognizing student diversity	Group instruction geared for the average student
Use of a variety of resources	Directed by the chapters in a textbook
Cooperative work on problems and issues	Some group work, primarily in laboratories with directions to be carefully followed
Students considered as active contributors to instruction	Students seen as recipients of instruction
Teachers build on student experiences, assuming that students learn best from their own experiences	Teachers do not build on individual student experiences; it is assumed that students learn more efficiently by being presented with organized, easy-to-grasp information
Teachers and students plan instruction around problems and current issues	Teachers plan their instruction using prescribed curriculum guides and textbooks
Teachers and students are involved with structuring goals and associated assessment strategies	Goals are not discussed nor used to assess learning

*As defined by NSTA (2006) and utilized in the Iowa Chautauqua Program

The contrasts listed in Table 1 concerning the Iowa Chautauqua Program effort utilized the official position statement of NSTA (2006) for defining specific features of STS. The following 11 features of such teaching were offered and unanimously adopted by NSTA as official policy in 1990:

1. Student identification of problems with local interests 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
4. The extension of learning beyond the class period, the classroom, and the school
5. A focus upon the impact of science and technology on individual students
6. A view that science content is more than an elaboration of specific concepts, which are identified for students to master on tests
7. An emphasis upon process skills, which students can use for 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 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 pursued by students (p. 242)

These 11 features described the instruction in the STS section; the school curriculum and textbooks chosen for the course indicate the non-STS instructional mode—almost the opposite of each of the 11 defining features of the STS classroom.

Methods

This study is an action research effort by 15 teachers who had participated in earlier workshops and who have served as lead teachers in helping others move to an STS approach. As part of the study, each of the 15 teachers (five for 4th grade, five for 5th grade, and five for 6th grade) needed to teach two sections of science—one with an STS approach and one with a non-STS approach—for the semester-long research project. To make this work, teacher colleagues not involved in the study taught two social studies courses to the students, thus allowing the teacher participants to teach the science units. This process assured that differences in teaching styles were controlled.

Each teacher worked with two classes in which there were no observed differences between the students in either section. Information from school records verified no differences in terms of gender, ability level, and socioeconomic background of the homes of the students in the two sections in each building included in this study. The building principals randomly assigned the classes as either STS or non-STS classes. All five teachers in a single district at each grade level agreed to follow the contrasting descriptions indicated in Table 1 and to produce all these features defining STS in the STS section and the opposite strategies in the non-STS traditional section. In the non-STS classes, the textbook (and laboratory manual) were used exclusively. As Weiss (1978, 1987) indicated,

dependence upon text materials is by far the most common situation in most K-12 science classrooms and laboratories. This was also the major finding of the Project Synthesis research report (Harms & Yager, 1981). The teachers in the non-STS sections rarely extended learning, suggested sources for new information, and/or provided ideas for activities beyond the textbook. Instead, student questions; prior experiences; ideas for sources of information; investigations; personal and group projects; and follow-up actions in homes, the schools, and the community all came from students in the STS sections. The teaching approaches used in the two classes were reported constant regarding all other variables such as instructional time, homework, subject matter, topics, and teacher enthusiasm.

The instruments used for each of the six domains were those commonly used in the Iowa Chautauqua Project as described in annual assessment handbooks (Enger & Yager, 1998, 2001; Liu, Veronesi, Lieu, & Yager, 1994; Yager, Kellerman, Liu, Blunck, & Veronesi, 1993; Yager, Liu, & Varrella, 1993). Teacher-developed pre- and posttests were used to measure learning the Concept domain for each unit, each grading period, and at other points determined by each teacher. There was no attempt to keep all teachers on the same schedule, topic, or testing pattern. A separate 30-item test that had been used in preceding years was administered at each grade level at the end of the semester. The Concept domain test varied for each grade level and for each of the schools. The instrument used for the Process domain was a common test used across grade levels as a posttest with items taken directly from the *Iowa Assessment Handbook* (Enger & Yager, 1998). In the Attitude domain, a 30-item survey was administered using the examples from the third National Assessment of Educational Progress (NAEP) in 1978, which was the first time Attitude domain information was collected. Creativity was measured by the use of a discrepant event during which students were asked for questions it raised, possible answers, suggested tests to determine the accuracy of proposed answers, and a listing of consequences that each solution suggested. Both quantities of responses in each of the four areas as well as the quality of each (from a 20-point rubric) were used to secure final scores. The Application domain was measured by using student suggestions for analogies; use of the constructs and skills in new settings; and information about the use of the concepts at home, in other courses in the school, and in the wider community. There were several in terms of number, data source, and degree of impact made. The Worldview domain was measured with items developed from the *Views on Science-Technology Society (VOSTS)* instrument (Aikenhead, Ryan, & Fleming, 1989). The measure involved using a rubric concerning various constructs to define the NOS. The information was collected initially during the first two weeks of the course, and a final instrument was used again at the end of the semester. It was not considered a formal test, but, rather, it was a request for examples of perceptions based on early ideas and those after a semester of work in science classes with both an STS approach and a non-STS approach.

A variety of lessons characterized the programs in the five different school districts in terms of the Concept and Application domains. This means that the topics characterizing the courses, books, learning materials, and the curriculum structure varied among the districts. Many school districts used a unit approach—often three for each nine-week grading period. This contributed to the necessity for different assessments, their frequency, and their focus on understanding rather than ability to define and/or paraphrase content and record their uses by students. The instruments and procedures regarding the four other domains were identical across grade levels and school districts.

Results

Each of the 15 4th-, 5th-, and 6th-grade teachers taught an STS section and a non-STS section. Comparisons were made on the average scores between the two groups or for each grade level using the *t*-statistic. The averages across sections were reported. The effect size for each teacher was determined, finding the difference between the STS average score and the non-STS average. The difference was then divided by the square root of the pooled estimate of the common variance. The average effect sizes are shown in Tables 2, 3, and 4.

On average, the STS sections differed significantly from the non-STS sections on all but the Concept domain. The average effect size indicates large differences between the two types of sections, and the *t*-test comparisons were also highly significant.

Table 2 indicates student scores in all six domains for 4th-grade teachers and students. For the five domains other than Concept, the average scores reported more than doubled across the domains. There were significant differences in the average scores for Process, Application, Creativity, and Attitude. The difference in average scores in the Worldview domain was quite shocking, especially since some studies indicate little growth and change regarding the NOS. More study is needed on the varying tools used to teach the NOS and on previous work performed in this area. For this study, the NOS constructs used provided examples of how students worked, especially with respect to their own STS experiences. Sometimes students in STS classes were in direct contact with practicing scientists. Students helped define problems, worked on their own projects, shared experiences, offered interpretations, and suggested related ideas.

Table 2. Average Posttest Scores, SD, and Effect Sizes for Non-STS and STS Students in Six Domains for 4th-Grade Students

Domain	Non-STS		STS		Average <i>t</i>	Average Effect Size	Average SE
	M	SD	M	SD			
Concept	10.62	2.64	11.34	2.94	0.58	0.07	0.05
Process	5.36	1.89	11.24	3.01	8.44*	3.21	0.09
Application	3.86	1.84	9.48	2.90	11.38*	4.01	0.11
Creativity	48.24	16.41	98.62	61.32	10.84*	2.81	0.12
Attitude	16.02	3.81	32.21	4.18	51.41*	1.71	0.09
Worldview	13.61	4.11	48.30	5.13	5.38*	2.34	0.11

Data from five teachers, each with a non-STS and an STS section

Average number of students per class: Non-STS = 23; STS = 24 (Total 235)

**p* < 0.001

Table 3 is a report of results from 5th graders. In a sense, the results are very similar. In fact, this similarity encourages the possibility of extending the studies for an entire year in order to look at the same students who were studied as 4th graders to see if similar results were achieved after two or three years.

Table 3. Average Posttest Scores, SD, and Effect Sizes for Non-STS and STS Students in Six Domains for 5th-Grade Students

Domain	Non-STS		STS		Average <i>t</i>	Average	
	M	SD	M	SD		Effect Size	Average SE
Concept	12.08	2.67	11.73	2.90	0.58	0.13	0.05
Process	5.34	2.03	6.02	2.03	7.48*	2.32	0.09
Application	4.84	2.01	10.62	3.61	8.18*	3.11	0.11
Creativity	58.31	18.21	97.38	2.19	7.03*	2.84	0.13
Attitude	14.20	3.84	24.50	4.11	6.84*	1.84	0.10
Worldview	40.81	2.89	51.20	3.10	6.11*	1.58	0.12

Data from five teachers, each with a non-STS and an STS section

Average number of students per class: Non-STS = 19; STS = 21 (Total 200)

* $p < 0.001$

Table 4 focuses on the results of 6th-grade students. The findings are again very similar, with significant results in the same five domains and with no significant differences found in the Concept domain. The results certainly invite research/study across similar grade levels and investigations of how students perform in middle schools where there are more often teachers with stronger backgrounds in science disciplines. It is reassuring to find similar results across the three elementary grade levels for the 15 teachers involved. It has been interesting to share the results indicated in the three tables with other lead teachers, many of whom are anxious to try similar studies with slightly different research instruments and protocols.

Table 4. Average Posttest Scores, SD, and Effect Sizes for Non-STS and STS Students in Six Domains for 6th-Grade Students

Domain	Non-STS		STS		Average <i>t</i>	Average	
	M	SD	M	SD		Effect Size	Average SE
Concept	11.80	3.00	11.71	3.00	0.61	0.03	0.07
Process	4.20	1.97	8.83	2.43	6.90*	2.20	0.10
Application	4.30	1.99	11.20	2.89	9.38*	3.21	0.12
Creativity	61.47	23.27	103.43	30.43	6.21*	2.12	0.10
Attitude	13.42	4.02	20.00	3.90	5.75*	1.62	0.09
Worldview	43.21	3.63	64.20	2.73	6.03*	2.71	0.11

Data from five teachers, each with a non-STS and an STS section

Average number of students per class: Non-STS = 23; STS = 25 (Total 240)

* $p < 0.001$

The results in the Concept domain indicate that with the kind of teachers who participated in the study, there were no statistically significant differences in student performance between STS and non-STS sections. Concept mastery (the primary focus for evaluating learning in traditional teaching) was not hindered when the typical textbook or curriculum framework was not followed rigidly. The consistency of the results is impressive if one notes that different teachers administered different test items related to the topics they taught (e.g., weather, radioactivity, forces and motion, and electric circuitry). Even though the STS approach follows the local interests and preferences of students, is much less structured, and is not centered around textbook materials, learning in the Concept domain is as high as that found in non-STS situations. The student-centered STS

activities result in meaningful learning that is reflected in the performance on typical tests, focusing mostly on concept mastery. However, it is not better than that found in non-STS classrooms where concept mastery is the only focus.

Discussion

Many studies arising from the Iowa Chautauqua Model have included pre- and posttests in the six domains. Rarely, however, have such tests in all domains for all teachers been collected over a full semester for both an STS and a non-STS section. The intensive effort to collect information was not possible in all cases (teachers and schools) in all of the five school districts involved in this study. This is a report of the use of STS strategies for one group of students and one parallel group of students where the STS approach was not used over the course of a full semester. Tests were administered to determine the effects of the two approaches in regards to student learning in the six domains listed previously. Teachers from 4th, 5th, and 6th grades utilized their existing curriculum guides but tried to discern differences when the STS features were used with one group and not in a control group. There was an attempt to measure the success of the approach in all six instructional and assessment domains. It should be emphasized that the study was not one set by university professors where the teachers were doing favors for the researchers. In a real sense, the teachers were long-time partners and researchers themselves. The NSTA (2006) has long advocated that science teachers should be researchers because that typifies the nature of the scientific enterprise. It was an action research effort conceived and generated by 15 teachers who had also acted as key leaders over multiple years with the Iowa Chautauqua Model.

The findings of this study indicate that with experienced, high-quality teachers, the STS approach yields neither better nor worse student attainment in the Concept domain. As shown in Tables 2, 3, and 4, it is striking to note that the trends across the grade levels are remarkably similar. Without a focus on concept mastery for predetermined concepts in a given textbook at a given grade level, it may be surprising that students in STS classrooms performed as well as they did in non-STS sections. It can only be hoped that the less direct teaching means that more meaningful learning occurred—an idea yet to be tested. Meaningful learning is personalized, and, hence, it is unlikely that differences will appear on typical concept tests, including norm-referenced ones.

With respect to process skills, creativity skills, application of concepts and processes in new situations, the nature of the scientific enterprise, and the attainment of more positive student attitudes about school science, the STS approach was found to be significantly better than a textbook/curriculum-centered approach. The effect size differences between STS and non-STS sections were found to be high for all these domains, except Concept mastery. Nonetheless, the very positive results in terms of producing more positive student attitudes concerning science are exciting. Most studies of student attitudes about science decline with more typical instruction across the elementary, middle, and high school years (NAEP, 1978; Penick & Yager, 1993; Yager & Yager, 1985). In view of other studies, it is remarkable that the attitudes of students in this study improved significantly with all STS classes, resulting in more positive changes in student attitudes.

The NAEP studies (1978, 1988) as well as other national studies (Harms & Yager, 1981; Weiss, 1978, 1987) have generally reported school science to result in more negative changes regarding student attitude and creativity skills as students advance through grade levels. Most studies have revealed that students who seem

to know given concepts have no ability to use them in other contexts (Champagne & Klopfer, 1984; Mestre & Lockhead, 1990; Weiss, 1978, 1987; Yager & Akcay, 2008; Yager & Penick, 1986; Yager & Weld, 1999; Yager & Yager, 1985). Typical results of studies of learning in school science reveal that few can do anything with the skills and concepts taught outside of the classroom/laboratory. The results of this study reveal a major contrast to this general situation when STS strategies are employed. The successes reported in this study are no doubt related to the experience of all 15 teachers who have been in leadership roles with Iowa Chautauqua Program for more than ten years. The 15 teachers remained in contact as the semester-long project continued. Several administrators were also involved with the research/study and were anxious to share the results with other teachers in their buildings.

The significant ability to apply results and skills in new contexts for students in the STS classroom is noteworthy, and it illustrates the most important advantage for the STS approach. This ability is also one of the best indicators that real learning with understanding has resulted, ensuring that students can meet all the general goals for science education as envisioned in the *National Science Education Standards (NSES)* (National Research Council [NRC], 1996). Questions concerning how long such "learning" is retained with each of the two instructional models are of interest and will be the subject of further research. It would be interesting to follow the study further to see if the 8th-grade students who also had STS experiences in multiple grades would continue to improve.

Implications

The study indicates that when students are in more control of the science classroom and when science concepts and processes are unified and approaches are presented in real-world contexts, students learn more. They are more creative, they have more positive attitudes about science classes/teachers, they see the usefulness of science in their daily lives, and they are more interested in scientific careers in science and technology. The implications suggested in this study of 4th-, 5th-, and 6th-grade classrooms is for more learning, better attitudes, and progress toward meeting all four goals of the *NSES* (NRC, 1996).

Conclusions

The STS approach is well-suited to elementary schools where so many teachers are minimally prepared in formal science. Many teachers have been unsuccessful with their own experiences in science classrooms, especially in high schools and colleges. They are quite ready for assistance in improving instruction and are quick to admit to not knowing what to do. These are important assets when trying to get students to actively participate in science rather than to merely accept information that appears in textbooks, kits, curriculum guides, and teacher pronouncements and to test to what degree students remember what they read or are told. Teachers must teach differently, involving students directly in questioning, proposing answers, considering implications, and taking corrective actions.

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