Implementing Science-Technology-Society Approaches in Middle School Science Teaching

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Abstract

The National Science Education Standards emphasize a goal that students should achieve scientific literacy, which is defined as the knowledge and understanding of scientific concepts needed in daily living. 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. Understanding scientific knowledge and processes contributes in an essential way to these skills. The economic productivity of society is related to the scientific and technological skills of the people. The results of this study indicate that students in the student-centered STS sections achieved significantly better than students in the teacher-directed STS sections in terms of understanding and use of process skills, use of creativity skills, development of more positive attitudes; and the ability to apply science concepts in new contexts. (This paper is a summary of Akcay & Yager, 2010)

The reform movement characterizing Science, Technology, and Society (STS) contributes to the goal of scientific literacy (National Science Teachers Association [NSTA], 2007; Yager, 1996). STS provides direction 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 both components. The National Science Teachers Association defines the STS approach as the teaching and learning of science and technology in the context of human experiences (NSTA, 2007).

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 that address them, and moving to actions designed to resolve the issues investigated. STS is meant to provide 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 both important components. Technology is of more interest to most people than is pure science. Technology is a focus on the human-made world where the designs are aimed at providing observable products that directly affect humans (e.g., air travel, refrigeration, T.V., cell phones, transportation, machines, and buildings). To be considered STS, the reforms envisioned and characterized include eleven basic features that are central to 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;
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 on 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;
11. some autonomy in the learning process as individual issues are identified and used to frame instruction.

(NSTA, 2007, p. 242)

The Chautauqua Professional Development Program

The Chautauqua Professional Development Program was conceived in 1983 as a way to introduce changes in teaching that exemplify the STS approach for teaching science. It is an in-service model for improving science teachers and science education programs that has developed over the past three decades. The staff development model was designed to assist teachers in changing their goals, curricula, and teaching strategies. The model has been singularly successful in meeting basic goals advanced by STS efforts and later identified as new directions in the National Science Education Standards (NSES) (National Research Council [NRC], 1996). The Standards recommend the collection of assessment data over time, a practice designed to change teaching, assessment strategies, and inquiry-oriented methods. Specific program goals include:

1. improving teacher confidence for teaching science;
2. changing the focus of teachers to make their teaching more congruent with the features of basic science, and those more specifically envisioned in the National Science Education Standards; and
3. preparing science teachers as leaders who can help their own students improve in five domains of learning science.

These domains comprise:

1. *Concept domain* (mastering basic content constructs): 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.
2. *Process domain* (learning skills scientists use as they seek answers to their questions about the natural world): Scientists use certain identifiable processes (skills). 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, communicating with others, predicting and inferring, hypothesizing, hypothesis testing, identifying and controlling variables, interpreting data, and constructing instruments, simple devices, and physical models.
3. *Creativity domain* (improving the quantity and quality of questions, explanations, and tests for the validity of personally generated explanations): Most science programs view a science program 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 the development of students' imagination 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 (i.e., 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.

4. *Attitude domain* (developing more positive feelings concerning the usefulness of science, science study, science teachers, and science careers): 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, 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 a constructive way, making decisions about personal values, and making decisions about social and environmental issues.
5. *Application domain* (using concepts and processes in new situations): It seems pointless to have any science program if the program does not include some substantial amount of information, skills, and attitudes that can be transferred and used in students' everyday lives. Also, it seems inappropriate to divorce "pure" or "academic" science from technology. Students need to become sensitized to those experiences they encounter that reflect ideas they have learned in school science. Some dimensions of this domain 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, nutrition, 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 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 indicating reform in K-12 classrooms.

(Enger & Yager, 2001, 2009; Yager & Akcay, 2007)

The Chautauqua Program operates on a continuing basis and an annual sequence of events describes its basic features that have been validated by the National Diffusion Network as a model for use elsewhere. These features can be abbreviated as follows:

1. A 2-week leadership conference for some of the most successful teachers from previous years who want to become a part of the instructional team for future workshops.
2. A 3- to 4-week summer workshop at each new site for 30 new teachers electing to try inquiry teaching and learning strategies. The workshop provides experience with inquiry (teachers as students) and time to plan a 5-day inquiry unit to be used as a pilot with students in the fall.

3. A 3-day fall short course for 30-50 teachers (including the 30 enrolled during the summer) focusing on developing a month-long inquiry module and an extensive assessment plan.
4. Interim communications with central staff, lead teachers, and fellow participants via a newsletter, special memoranda, monthly telephone contacts, and school/classroom visits.
5. A 3-day spring short course for the same 30-50 teachers who participated in the fall. This session focuses on reports by participants about their inquiry experiences and the results of the assessment program. The emphasis is on sharing successes and failures while also planning more fall inquiry courses. Every attempt is made to model inquiry teaching techniques by all staff members for the workshop. Action research projects are encouraged by staff members, teacher participants, and students in the classrooms of participants.

The Chautauqua Program is an example of teachers helping teachers with new curriculum modules and especially new approaches to instruction. The new directions are exemplified by cutting-edge science curricula developed around the world. The Chautauqua Program requires a commitment on the part of participants to try, assess, and experiment with instruction often suggested by the most innovative new curricula. Every participant becomes a part of the effort and adds to the information and experience base of the total group. Unlike many other in-service programs, information has been amassed over a 28-year period concerning the successes of the program. It is a program that produces changes in the perceptions of teachers about science teaching.

This study was to examine the effectiveness of the Chautauqua Professional Development Program in terms of improving student: 1) concept mastery, 2) ability to define and use process skills, 3) development of more positive attitudes regarding science, 4) development of specific creativity skills, and 5) ability to use major concepts in new situations. Differences between student successes in teacher-centered STS sections and those in largely student-centered sections were sought among the 12 teachers involved, each with one regular STS section and the other with an almost complete focus on students identifying their own issues, their own proposed solutions, their own search for validity of their hypotheses, and their own solutions to the issues they identified.

Overview of Data Set

Our study involved 12 teachers who agreed to collect pre- and post-assessment information in the five assessment domains for students in one section where the teacher guided instruction, prepared daily lesson plans, and structured the STS modules for the 9-week grading period, the semester, and/or the entire academic year. Another section was established as the experimental one where the STS teaching consistently focused on student-centered teaching and learning methods. A total of 724 students were involved from Grades 6 through 9. The Assessment Handbook for the Chautauqua Program provided the instruments and procedures used to collect data (Enger & Yager, 2001, 2009). The assessment handbook includes samples, test features, and scoring directions with new samples added each Chautauqua year--all developed and used by the enrolled teachers. A quasi-experimental design was used. The same instruments were used as pre-tests and post-tests. The pre-tests were given at the beginning of the semester. The teachers involved were active mentors for new teachers enrolled in Chautauqua sites designed to help teachers use more student-centered STS strategies in their daily teaching. The post-tests were given at the end of the semester. The data were analyzed quantitatively by reporting means and standard deviations. The differences in mean values were tested using a t-test for determining significances. The mean differences, standard deviations, and t- values were calculated and used to assess differences between pre- and post-test scores in the five domains for all students in both class sections for each of the 12 teachers. A 5% level of significance ($P \leq 0.05$) was used to assess statistical differences.

Findings

In order to evaluate the effects of more student-centered STS instruction, comparisons were made between students taught using teacher-guided STS and those in classes where the primary focus was on student-centeredness with respect to the five domains. The findings of our study can be summarized as follows:

- Students experiencing the student-centered STS instructional approach were as successful as students in sections where the focus was almost totally on concept mastery (and to a lesser degree on process skills used in laboratories).
- Students experiencing student-centered STS instruction were significantly better in terms of use of science process skills in new situations and understanding of the nature and importance of such skills.
- The students who experienced science in the student-centered STS sections were able to demonstrate greater creativity in terms of questioning and hypothesizing skills than students in the teacher-directed sections for all grade levels. This included creativity in asking questions, proposing answers, testing for validity of hypotheses offered, use of the ideas and skills, and conceptualizing consequences for specific corrective actions.
- Students in the student-centered STS sections proved to be the more successful in improving attitudes, while those in the teacher-centered sections largely remained the same. In some cases, student attitudes actually worsened significantly in the teacher-directed sections.
- The application items illustrate student use of the major concepts and process skills characterizing the science concepts used at each of the four grade levels. The greatest success of students in student-centered STS sections occurred in the use of the concepts and skills in completely new situations as chosen and proposed by students. Information was collected via teacher tests where students had to recognize appropriate use of the concepts and skills in new situations. In addition, students were asked in an open format to identify and prepare such applications and discuss them as an indicator of the learning of all students enrolled in a particular section.

Discussion and Implications

James Rutherford was one of the first to recognize that real change in the instructional procedures in schools, as well as the curriculum structure, require time. His thinking is exemplified by *Project 2061: Science for all Americans* (American Association for the Advancement of Science [AAAS], 1989), which notes the next appearance of Haley's Comet from Earth as being a more realistic expectation than educational change. He argued that real change in school science will take 75 years--the likely lifetime of humans. *Science for all Americans* was the most comprehensive view of needed reform in the U.S. during the past 18 years. Its use impacted the development of the NSES. One major change has been the reunion of science and technology (i.e., considerations of the natural world and the human-made world). Involving engineers in school science program was a welcomed change that has enjoyed significant National Science Foundation (NSF) support. But, these programs retained the focus on curriculum, both in terms of textbooks and shorter modules. Most did not focus primarily on teaching as a new approach and/or as an important ingredient for successful learning. Some of the programs enjoyed support, trial use, and success with needed reforms. Some were involved with collecting evidence about the advantages of STS teaching in general. Being focused on the design world and headed by engineers are important changes, but also result in setbacks from lack of support and leverage gained by more typical reform projects and only small changes were adopted by major textbooks that tend to depend almost completely on the traditional course content found in typical textbooks. They did not fit well with existing curricula, leadership strategies, standard assessments, state frameworks, or features required by textbook adoption states (about 17). It is probably fair to note that the most innovative programs are seldom in general demand and the publishing companies they attract are not "main stream."

The following are five examples of new STS and design-world programs where student-centeredness for reforms can easily be added:

1. The Man-Made World (ECCP), Polytechnic Institute of Brooklyn (1971)
2. Integrated Mathematics, Science, and Technology (IMaST), Illinois State University (1994)
3. Teaching Science Through Science/Technology/Society (S-STS), Pennsylvania State University (1984)
4. Material World Modules (MWM), College of Engineering Northwestern University (1996)
5. Science and Technology for Children (STC), Smithsonian Institution (1996).

Further, study designs also improve when ideas emerge from individuals or small groups of students. Their voices and actions may be more important than curricular frameworks provided by others.

These programs all indicate STS initiatives and changes yet to be commonly found in schools. Although all wanted to be student-centered, none were so described fully. None of these STS reform programs succeeded in changing actual teaching in school programs. They reported progress that openly included technology and science while suggesting new teaching approaches that encouraged use of constructivist perspectives. Such a perspective when emphasized led to more student-centered efforts.

STS efforts have been criticized for not advancing specific curriculum structures (such as the "design world" examples of STS indicated above). But they indicate the problems of curricula that are offered as "teacher-proof" pathways to reform. It is impossible to conceive of any STS effort in a textbook without use of contemporary problems that are personally relevant, current in terms of importance, and experienced and found locally. Some have called such STS approaches to be concerned with "me, here, and now." Such efforts by definition tend to be student-centered. Few curriculum reforms are personally relevant, deal with local issues, and exemplify current concerns. Few have taken seriously the eight facets of content spelled out in the NSES: 1) Unifying concepts and processes in science, 2) Science as inquiry, 3) Physical science, 4) Life science, 5) Earth and space science, 6) Science and technology, 7) Science in personal and social perspective, and 8) History and nature of science. Few focus primarily on instruction and a truly student-centered curriculum. And yet these are attributes that are necessary ingredients for achieving the reforms--and possibly in less than the 75 years Rutherford foretold. The question concerning the degree of student versus teacher centeredness remains.

More attention may need to be paid to teachers and their teaching, as exemplified in the NSTA Exemplary Science Program series. Present titles comprise *Exemplary Science in Grades PreK-4* (Yager & Enger, 2006), *Exemplary Science in Grades 5-8* (Yager, 2006), *Exemplary Science in Grades 9-12* (Yager, 2005b), *Exemplary Science Best Practices in Professional Development*

(Yager, 2005a), *Exemplary Science in Informal Educational Settings* (Yager & Falk, 2008), *Inquiry: The Key to Exemplary Science* (Yager, 2009), and *Exemplary Science for Resolving Societal Challenges* (Yager, 2010).

What have been found to be exemplary in meeting the visions of the NSES prove to be exciting examples of the implemented reforms. The data reported in this study provide real evidence that the reforms have been successful with students and provide pathways that have been used by over 200 teachers who have shared evidence of successes for their teaching ideas and descriptions of the associated effects with student learners. This study indicates the power of student-centered instruction over teacher-centeredness in five domains advanced for assessment.

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