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Effectiveness of Science-Technology-Society (STS) Instruction on Student Understanding of the Nature of Science and Attitudes toward Science

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Abstract

The study reports on an investigation about the impact of science-technology-society (STS) instruction on middle school student understanding of the nature of science (NOS) and attitudes toward science compared to students taught by the same teacher using traditional textbook-oriented instruction. Eight lead teachers used STS instruction an attempt to improve student understanding of NOS concepts. The major findings of the study suggest that students experiencing STS instruction improve their understanding of the nature of science and attitudes toward science significantly more than do students who were instructed with traditional instruction. Analysis of the data indicates that students in STS classrooms attain more positive changes in their views about the NOS. Specifically, the STS students displayed powerful changes in their understanding of the ways in scientific theories and the scientist. Implications for improving teacher professional development programs are suggested.

Key words: Attitude toward science, Nature of science, Science-Technology-Society (STS), Science education.

Introduction

Creating a scientifically literate society has been a major goal of science education all over the world since the late 1950's when Paul DeHart Hurd defined scientific literacy as a new goal of science education (DeBoer, 2000). After Hurd expressed how important it is to develop a curriculum to address scientific, social, and economic needs of society, in the 1980's the understanding of science as a social enterprise became a strand of scientific literacy. Scientifically literate person understand and be aware of needs of the community to be able to participate technological oriented economy (Sofowora & Adekomi, 2012). Science, technology, and society (STS) was a term indicating reform teaching to provide these needs (Driver, Leach, Miller & Scott, 2000).

Scientifically literate individuals can be defined as someone who can understand (a) science as a way of knowing (including nature of science [NOS]) (Zeidler et al., 2004; Yager, 1996) and (b) science in a societal context of how science, technology, and society effect one another as well as applying knowledge and skills in their everyday lives (National Research Council [NRC], 1996). Realizing the importance of scientific literacy for future citizens, new perspectives regarding professional development programs now focus on science educators who can help their students to promote meaningful learning which includes addressing discussion, argumentation, social negotiation, cooperative learning, NOS, problem solving skills and then applying these skills to real life situations (Tsai, 2002). Features of STS instruction address all these descriptive indicated above.

Understanding the NOS is a critical objective according to current reform documents in science education (e.g., American Association for the Advancement of Science [AAAS], 1990). NOS refers mostly to "the values and assumptions inherent to the development of scientific knowledge" (Lederman, 1992, p. 331). The *National Science Education Standards (NSES)* (NRC, 1996) state that teacher understanding of the nature of science is a component of Science-Technology-Society (STS) that is essential for developing student understanding of science content and the processes through which science develops. Unfortunately, it has been shown that many

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teachers do not have an adequate understanding of the NOS, and that this shortcoming is often passed on to their students (Abd El Khalick, 2005; Nworgu & Yager, 2004).

Tsai (2002) has argued that teachers need to understand the NOS as major aspects in order to implement STS instruction and to enhance student interest in science (Gwimbi & Monk, 2003). Additionally, other researchers have argued that teachers' conceptions regarding NOS affect student understandings of the NOS (Brickhouse 1990; Palmquist & Finley, 1997; Jones & Beeth, 1995). Rubba and Harkness (1993) argue that helping students to develop informed views of NOS, technology and their interaction in society is a central goal of science education. According to McShane and Yager (1996), STS instruction helps students to develop positive attitudes toward science. Therefore, students have opportunity to meet their personal needs, see how science works, solve local problems and pursue science as a career (Driver et al., 2000).

Iowa Chautauqua Professional Development Program

The Iowa Chautauqua Professional Development (ICPD) program was first selected as a model for science teachers following a National Science Teacher Association (NSTA) grant in 1983. One of the central goals of this program was to focus on developing the understanding of science teachers regarding NOS as well as that of their students' conceptions of NOS resulting from STS instruction. The purpose of this study was to investigate whether or not the ICPD program affected student understanding of the major features of NOS.

Program Description

The ICPD program was an in-service professional development project coordinated by the NSTA and sponsored by American Association for the Advancement of Science (AAAS). ICPD Program was a year-long effort for K-12 science teachers. The following description indicates the three essential features of the Iowa Chautauqua PD Program for PreK-12 science teachers in terms of its year-long organization and specific anticipated learning outcomes (Singh et al., 2012). The ICPD Program has three phases including leadership conference in early June for 14 days, new teacher conferences in June and July for three to five month long, Fall Short Course in October and Spring Short Course in April for 3 days.

Leadership Conference participants are the most successful teachers for meeting NSES reform goals of past ICPD programs. Thirty teachers attend the leadership conference. During the conference participants' review of NSES Less and More Emphasis conditions, work on differences of approaches used in PreK-4, 5-8, 9-12 classes and discuss the importance of adding investigations that indicate degrees of success.

New Teacher Conferences are organized three to five month long Chautauqua workshops across Iowa annually for teaching at three grade levels for each site. Teacher Leaders are major staff for elementary; middle school, and high school groups. During this conference participants plan a 5-10 day lesson to match the NSES recommendations for the More Emphasis for teaching and assessment of specific plans for use and assessment in the fall. During the Fall Short Course, participants report on successes and failures with students in the planned 5-10 day trials. They plan for a 4-9 week New Module using the most successful features that were discussed in planning a 5-10 day lesson plans developed in the summer as well as plan for assessing results with data indicating successes.

During the Spring Short Course, participants report on teaching/learning results with the larger unit. They plan for additional changes needed, especially as planned for further instruction. They discuss post-test data indicating successes in all Six Domains (Akcay & Yager, 2010). At the end of the program, new Teacher Leaders are selected for the following summer Leadership Conference. Fall and Spring Short Courses (October and April) are important because they were designed to indicate what happens in classrooms with students after role-playing experiences, planning, and specific accomplishments during the summer workshops without students. For this study, the focus is on the students involved at the beginning and ending of the fall short courses where use of the summer experiences and ideas were tried and evaluated with students.

Features of Iowa Chautauqua Professional Development Program

Throughout the three phases of ICPD, STS approach was used. STS is an approach to stimulate learning, which is grounded on constructivist theory (Yager, 1996; Aldridge et al., 2004). Students are center in STS approach. Students generate their own questions rather than purely relying on the questions provided by others (Duffy, & Cunningham, 1996). Based on their own questions, students view their previous understanding of the problem, and phenomena. Student-directed questions further serve to define problems, potential solutions, and other points of view. This enables students to see/do science in a way known to scientist. This makes science more meaningful, exciting, and appropriate (Wilson &Livingston, 1996; Nworgu & Yager, 2004).

Duffy and Cunningham (1996) argue that the student must see the problem as important and personally relevant, feel that his/her action is valuable and not just an exercise, and have decision-making responsibility. According to Grabinger (1996), when students take ownership of the situation and their own learning, they develop deeper and richer knowledge structures leading to a higher likelihood of transfer to novel situations. In short, students see a problem, take ownership, and act on it. Choosing real world issues as problems requires them to use basic concepts and process skills such as observing, classifying, communicating, measuring, using space/time relations, using numbers, and inferring and predicting are used in conjunction with the integrated skills of controlling variables, interpretation data, formulating hypothesis, defining operationally, and experimenting (AAAS, 1990).

Blunck and Yager (1990) described features of ICPD program to explain how to apply STS module in the classroom. These features are (1) students identify the problems which have local interest and impact, (2) students use local resources to solve the problem, (3) students actually involve in seeking information to solve real life problems, (4) learning goes beyond the classroom, (5) teaching methodology focus on the impact of science and technology on individual students, (6) an emphasize on science process skills which students can use to solve real life problems, (7) an emphasize on career awareness related to science and technology. Table 1 defines the outcomes of a Chautauqua PD. The nine features in the U.S. National Standards provide a way to visualize how teachers experience science in the two settings (Singh et al., 2012).

Table 1. Outcomes of Iowa Chautauqua Professional Development Program

Teachers without Chautauqua Experiences	**Teachers with Chautauqua Experiences**
Class activities are set and controlled by the teacher	Class activities are student-centered
Group instruction geared for the average student	Classes are individualized and personalized, recognizing student diversity
Context directed by the textbook	Classrooms directed by student questions and experiences
Use of basic textbook almost exclusively	Students and teachers use a variety of resources
Some group work, primarily in laboratory where procedures and directions are provided	Cooperative work is encouraged regarding problems and issues
Students are seen as recipients of instruction	Students are considered active contributors to instruction
Teachers do not build on students' experiences, assuming that students learn more effectively by being involved with easily grasped information	Teachers build on student experiences assuming that students learn best from their own experiences
Teachers plan their teaching from the prescribed curriculum guide and textbook	Teachers plan their teaching around problems and current issues – often those planned by students
Students are "receivers" of information; they are not expected to use what they are taught	Teachers encourage students to question and to respond to possible answers

Purpose of the Research

STS is being increasingly implemented in K-12 science education programs around the world because its impact on preparing lifelong learners who can participate effectively on technologically orientated economy. STS addresses emerging questions about effective strategies for improving student understanding of the nature of science. Several studies have been undertaken to evaluate effectiveness of ICPD program or student outcomes from use of STS instruction however few have explicitly sought to identify that if in-service teachers have a satisfactorily level of STS instruction, would it be an advantage in promoting their students' understanding of NOS concepts and improving their attitudes toward science.

For this reason, two research questions were outlined as follows:

1. Are there any significant differences in development of NOS views when middle school students are taught with an STS approach than when taught by the same teacher using a more traditional textbook-oriented approach?

2. Are there any significant differences in middle school students' attitudes toward science when students are taught with an STS approach than when taught by the same teacher using a more traditional textbook-oriented approach?

Method

Sample

Eight lead middle school teachers and their 356 students were involved in Iowa Chautauqua Program summer workshop at the University of Iowa. Among thirty lead teachers, only eight lead middle school teachers were voluntarily participated the study. All eight were previous participants and familiar and experienced with the STS philosophy. They all had bachelor's degrees with some graduate credits and had taught for 5 to 12 years. Each teacher had two sections of science, one of which served as the treatment group taught with STS instructional method; the other section served as a control group taught with traditional textbook-oriented instruction (Table 2).

Table 2. Number of students in traditional textbook-oriented classrooms and STS classrooms

Teacher	# of students Traditional Classrooms	# of students STS Classrooms
1	24	26
2	18	19
3	22	23
4	21	21
5	27	22
6	24	20
7	23	26
8	18	22

Content of the Iowa Chautauqua Professional Development Workshop

During the three-week summer workshop, eight lead teachers assumed the role of students to explore issue-based questions. Teachers were helped their students to understand and experience STS teaching with focusing on nature of science concepts. Moreover, they explicitly discussed each nature of science concepts, i.e., how science change over time, role of social and cultural features in development of scientific knowledge, role of scientific theories and importance of creativity and imagination on scientific knowledge as well as how to implement and embed these ideas in their lesson plans. They developed 5-day modules for using in teaching in their own classrooms addressing nature of science concepts where school offered for the next academic year.

During the fall semester, they taught the units, and then shared their experiences and problems with each other via e-mail exchanges. During the fall short course, the eight teachers developed nine-week long STS module to implement during the spring. The goal of the module was to improve teachers' instructional strategies using STS approaches that would lead to the improvement of their students' understanding of NOS concepts in terms student understanding of scientists and scientific theories as well as to develop positive attitude toward science, science teacher and science career. At the spring short course they discuss the Reporting on STS experience, assessment efforts, planning for involvement in professional meetings, planning for next-step STS initiatives (Table 3).

Table 3. Overview of the ICPD workshop

Summer workshop	**Fall short courses**	**Spring short courses**
➢ Three-week workshop ➢ 5-day lesson plan for fall	➢ 3 days short course ➢ Nine-week long module as an action research project for spring	➢ 3 day short course ➢ Reporting on STS experiences ➢ Reporting on assessment efforts ➢ Interactions concerning new information about STS ➢ Planning for involvement in professional meetings ➢ Planning for next-step STS initiatives

Instruments

The Worldview Domain instrument was used and outlined in the Assessing Student Understanding in Science: A Standards-Based K-12 Handbook (Enger, & Yager, 2009). World View domain is used to assess "how efforts in schools can assist students in understanding the nature of science (Akcay, et al., 2010, p. 5). The instrument designed as a Likert-type five point scale from strongly agree to strongly disagree administered on a pre-/post-test basis in order to measure student understanding of the NOS.

Information about validity and reliability issues are reported in Enger and Yager (2009). The reliability coefficient is obtained by using the test-retest method with students in the classes taught by teachers. The reliability regarding the domains ranged from 0,76-0,96 (test-retest two weeks later) (Yager et al., 2009). The nature of science questionnaire focused on student understanding of scientists and scientific theories.

The Attitude toward science instrument (Enger & Yager, 2009) designed as a Likert-type five point scale from strongly agree to strongly disagree. It used to assess students' attitudes toward science in terms of science, science class and science career.

Data Analysis

Differences between STS and traditional instruction were considered as separate groups (i.e., class sections) for each of the eight teachers. The independent variable was the teaching method used; the dependent variable was the learning outcome, i.e., student understanding of the nature of scientific theories and scientists and students' attitudes toward science.

During the fall semester, the pre-tests were given to students prior to the beginning of instruction. The teachers taught for nine weeks using the STS approaches in the experimental classrooms and the typical traditional textbook-oriented approaches with the control groups. Post-tests were administered to students at the end of the nine-week module in the April. The major objective of the study was to compare changes in student understanding of NOS concepts and attitudes toward science between the control groups and the experimental groups.

Analyses of covariance with repeated measures were used to compute pre- and post-test results. F values were obtained by analysis of covariance. These values were used to compute differences statistically using the pre-test scores as the covariate.

Results

Analysis of Student Understanding the Nature of Science

Statistical analyses were carried out to compute the mean differences between pre- and post-test responses. The changes in student perceptions about the NOS are displayed in Table 4. It shows that there is a significant increase of estimated mean for the STS sections in terms of student understanding of NOS.

Table 4. Comparisons of traditional textbook-oriented and STS classrooms mean and mean differences about students' perception of nature of science

Teacher	# of students	Traditional Classrooms Mean scores		Mean Dif.	# of students	STS Classrooms Mean scores		Mean Dif.
		Pre-test	Post-test			Pre-test	Post-test	
1	24	34	37	3	26	33	42	9
2	18	26	29	3	19	21	39	18
3	22	17	24	7	23	18	41	23
4	21	23	27	4	21	21	60	39
5	27	18	21	3	22	17	53	36
6	24	16	22	6	20	19	33	14
7	23	23	27	4	26	27	59	32
8	18	12	14	2	22	13	47	34

The changes in student perceptions about the nature of science are shown in Figure 1.

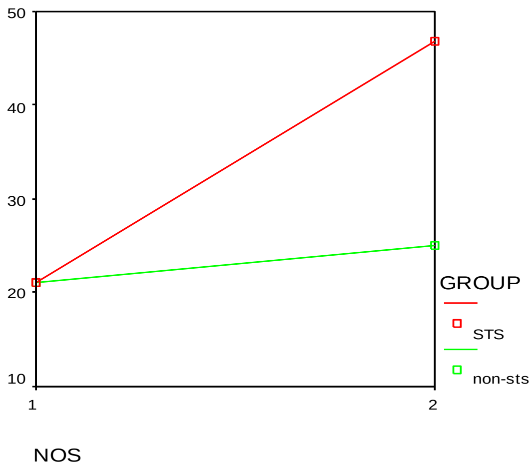

Figure 1. Changes in student perceptions about the nature of science

Table 5 indicated that there are significant differences (P<0.05) for all items on posttest for students in STS and traditional textbook-oriented classrooms, when using the pretest scores as the covariate. The STS instruction is more effective in helping students understand the nature of science than traditional instruction.

Table 5. Differences between STS and traditional instruction with respect to student understanding of the nature of science

		Mean		*ST.D.*			
Group	*N*	*Pre*	*Post*	*Pre*	*Post*	*F*	*p*
STS	179	21.125	46.750	6.243	9.779	26.604	.000*
Textbook	177	21.125	25.125	6.895	6.706		

*F, p: F- and p- Values of analysis of variance with repeated measures between posttest scores in the STS group and Textbook group.

After finding significant results with the overall NOS questionnaire, the statistical tests were analyzed for each of two subcategories of the survey. The NOS questionnaire includes two aspects of the NOS, namely student views of scientists and scientific theories. The results from statistical analysis showed that significant differences were found for both subcategories (see Table 6 and Table 7). Students who experienced the STS learning methods resulted in significant differences than the students enrolled in traditional textbook-oriented classrooms.

Table 6. Differences between STS and traditional instruction with respect to student understanding of scientists

		Mean		*ST.D.*			
Group	*N*	*Pre*	*Post*	*Pre*	*Post*	*F*	*P*
STS	179	10.25	37.125	3.058	11.102	42.342	.000*
Traditional	177	11.875	13.25	4.051	3.575		

*F, P: F- and P- Values of analysis of variance with repeated measures between posttest scores in the STS group and Traditional group.

Table 7. Differences between STS and traditional textbook-oriented instruction with respect to student understanding of scientific theories

		Mean		*ST.D.*			
Group	*N*	*Pre*	*Post*	*Pre*	*Post*	*F*	*P*
STS	179	6.875	13.375	2.474	4.565	29.297	.000*
Traditional	177	9.375	11.75	3.662	3.770		

*F, P: F- and P- Values of analysis of variance with repeated measures between posttest scores in the STS group and Traditional group.

To assess effectiveness of STS instruction students' attitudes toward science, analysis of variance with repeated measures was used. The results indicated that there are significant differences on post-test scores for students from STS classrooms and those from traditional textbook-oriented classrooms (see Table 8).

Table 8. Differences between STS and textbook approaches with respect to student attitudes

		Mean		ST.D.			
Group	*N*	*Pre*	*Post*	*Pre*	*Post*	*F*	*P*
STS	179	9.25	11.875	2.964	3.563	16.989	.001*
Traditional	177	9.625	11.5	3.378	3.891		

*F, P: F- and P- Values of analysis of variance with repeated measures between posttest scores in the STS group and Traditional group.

Discussion and Conclusion

The results of the study show that ICPD program with STS instruction helps students to understand nature of science concepts and provide positive attitudes towards science, science class and science teacher than traditional textbook-oriented classrooms. The results are consistent with what has been previously reported by researchers (Yager, 1996; Liu, 1992; Rubba & Wiesenmayer, 1990; Lochhead & Yager, 1996). However the results of this study are quite different from the Mackinnu (1991) study. Mackinnu (1991) reported no statistically significant differences either pre-test or post-test scores on student understanding of nature of science.

Teachers have a critical role in teaching and learning because they are responsible for preparing scientifically literate citizens for the 21st century. Scientifically literate person is a lifelong learner who can participate the national socio-economic targets. ICPD program helps in-service teachers to change their philosophy of teaching and learning by proving them a new perspective of science education (Jones & Beeth, 1995; Nworgu & Yager, 2004). However, the change takes time. This is not a miracle method to change everything in one workshop or two. Therefore, in this study the experienced lead teachers from previous ICPD program were chosen.

STS instruction encourages teachers to use more explicit methodologies than traditional textbook-oriented classrooms. Students had opportunity to chose a problem or issue from real life to investigate. They were encouraged to seek out their problem as well as to apply their concepts to new situations (Akcay & Yager, 2010). ICPD program help teachers to realize how to create a student-centered environment to increase their students' creativity, critical thinking and problem solving skills as well as to develop more positive attitude toward science to encourage student to choose or think science as a profession because middle school is an important state for students to think science as a profession or even just to decide taking science courses for their education. However, especially female students, develop negative attitude toward science courses during middle school years (Grabinger, 1996; Liu, 1992; Singh et al., 2012). In this study, results showed that ICPD program with STS instruction improved middle school students' attitudes toward science.

In traditional textbook-oriented classrooms, teacher used more implicit teaching methodologies. They become director of the course instead of being a facilitator. Teachers only focus on textbooks and had no flexibility over the course. Students work on a given problem has no connection with students' lives or local societal problems (Singh et al., 2012).

According to Tsai (2006), "teachers do not have adequate knowledge to implement Science-Technology and Society (STS) instruction if they lack the instruction regarding the epistemological and sociological nature of science in their former science education, especially in teacher education programs." (p.365). Teachers who completed the ICPD Program increase their confidence to teach science, their understanding of the nature of scientific knowledge, their understanding of basic concepts and processes of science, and their abilities to use STS teaching modules. Therefore, the ICPD program empowers in-service science teachers to make science more meaningful and useful for their students. Their students gained better concept mastery, better use of science processing skills, more applications of scientific concepts in their lives, more positive attitudes toward curricular science and careers, and enhanced creativity skills, as well as a greater understanding of the nature of science.

Although there are many professional development programs designed to improve teachers conceptions of NOS and their teaching practices, professional development programs should include the following factors: (1) a month long workshops in the summer and follow-up short courses that emphasize explicit teaching activities, (2) demonstrate how to teach NOS concepts effectively as a features of STS instruction, (3) provide a method through which teachers keep in touch and share their experiences implementing with STS techniques while also providing feedback with one another, and (4) explicit NOS instruction. It is also recommended that the program take place over multiple school years, so that long-term effects of professional development on instructional practice are dependent on the length of the program. Even though the positive changes on student understanding of NOS concepts can be detected shortly after implementation, the conceptual change takes time. It is necessary to provide meaningful reinforcement in order to promote retention of the improved understanding of NOS that can be achieved using STS strategies.

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