Comparison of Science-Technology-Society Approach and Textbook Oriented Instruction on Students' Abilities to Apply Science Concepts

Hasan Ozgur Kapici [i]
Yildiz Technical University

Hakan Akcay [ii]
Yildiz Technical University

Robert E. Yager [iii]
University of Iowa

Abstract
It is important for students to learn concepts and using them for solving problems and further learning. Within this respect, the purpose of this study is to investigate students' abilities to apply science concepts that they have learned from Science-Technology-Society based approach or textbook oriented instruction. Current study is based on quantitative research methodology. The participants of the study are 609 students. Science classes were designed based on STS approach curriculum for 301 students, which is called as experimental group and textbook oriented instruction was followed with 308 students as a control group. The students were from sixth grade to ninth grade (age 12-15). The Iowa Assessment Handbook for the Chautauqua Program was used to collect data. The mean differences, standard divisions and t-values were calculated and used to assess pre- and post-test results. The results indicate that students, who experienced STS based curriculum through one full semester, are able to apply basic science concepts to new situations meaningfully better than students who exposed to textbook oriented instruction.

Keywords: Science-Technology-Society, textbooks oriented instruction, middle school students, science concepts

---

[i] **Hasan Ozgur Kapici** Res. Asst., Faculty of Education, Yildiz Technical University, Istanbul, Turkey.

Correspondence: hokapici@yildiz.edu.tr

[iii] **Hakan Akcay** Assoc. Prof. Dr., Faculty of Education, Yildiz Technical University, Istanbul, Turkey, E-mail: hakcay@yildiz.edu.tr

[iii] **Robert E. Yager** Prof. Dr., College of Education, University of Iowa, USA, E-mail: robert-yager@uiowa.edu

Introduction

One of the central goals of science education is to enable individuals to be educated as scientifically literate people with an understanding of the nature of science and technology and their interconnectedness with the society (American Association for the Advancement of Science (AAAS), 1993; Ministry of National Education, 2013; National Research Council (NRC), 1996; Yalvac, Tekkaya, Cakiroglu, & Kahyaoglu, 2007). National Research Council (1996) explains scientific literacy as enabling people to use scientific principles and processes in making personal decisions and to participate in discussions of scientific issues that affect society (p. ix). In other words, scientific literacy improves many skills that people use in daily life such as being able to solve socio-scientific problems creatively, thinking critically, working cooperatively in teams and using technology effectively (Mbajiorgu & Ali, 2003).

There is a consensus among science educators that scientific literacy is a beneficial and useful concept which must be achieved. In the study by Laugksch (2000), it was investigated that why scientific literacy is so crucial. The benefits of it were categorized into two sections, which are macro and micro views. Whereas the macro view is introduced as the effects of scientific literacy on community, science and society, the micro view is defined as impacts of it on individuals. The first common view of macro effects of scientific literacy is about its impact on the economy of a nation. The economic productivity of a society is related to the scientific and technological skills of people. Only nations whose citizens possess an appropriate level of scientific literacy might be able to use science and technology in order to develop new high-technology products for contributing economic well-being of their nation. Another claim suggests that people with higher scientific literacy in the community enable science to be supported by most of people in that society. Public support for science is important since science, technology and society are interconnected with each other and developments in each of these depend on support among themselves. The more the public understands about the objectives, processes and capabilities of science, the less likely the public will be to acquire unrealistic and unrealizable expectations of science (Laugksch, 2000, p. 85). The other effect of scientific literate people is on science policymaking process with their qualified decision-making. Scientific literacy enables individuals to make better decisions than made in the absence of such an ability, that’s why successful science policies will be developed and supported in such a community. The last argument is the relation between science and culture. The isolation of science from culture of a society may cause people to understand science improperly and this process might finish with individuals’ negative feelings and attitudes toward science. In order to deal with this kind of a situation, scientific literacy of public can be supported since it might counteract such a perceived bad image of science among people generally.

However, achieving scientific literacy is not an easy task and requires time. Teaching more scientific facts or increasing the number of laboratory and hands-on activities in science classes are not enough to increase students’ scientific literacy (Glynn & Muth, 1994). The NRC (1996) and AAAS (1993) advocate that teaching and learning of science must be more than a simple transmittal of scientific facts, figures and processes. Science instruction should be multi dimensional. It should involve conceptual understanding and their applications in real life contexts, gaining skills like science process skills and also should emphasize nature science. The importance of being able to understand, comprehend and explain the fundamental scientific concepts in a meaningful way is the heart of science literacy (Glynn & Muth, 1994). In this respect, teachers have crucial roles because they are firstly responsible for developing their students’ such kind of skills. Teachers should be educated about how they can help their students to have such abilities. For this reason, several professional development programs were developed, one of them is the Iowa Chautauqua Program. The Chautauqua Program was supported by a National Science Foundation (NSF) grant to the National Science Teacher Association (NSTA), which was developed in 1983 to study a teacher education model for stimulating reform in science classrooms. The program began in Iowa with 30 teachers enrolled in the program at one center and up to 230 teachers enrolled in five centers across the State during 1980s and 1990s. Over 4,000 teachers were enrolled over the past three decades.

The Iowa Chautauqua program identified six important domains for developing instructional goals and assessing successes in meeting them. The first one is Concept Domain which is related with content knowledge and conceptual understanding. The second domain is Process Domain which is mainly related with science process skills. The third domain is Application Domain, in which students should apply the concepts and process that they gained in new contexts. The next domain is Creativity Domain that usually focuses on students' self-explanations and views, students initiated questions and their qualities. Another domain is Attitude Domain. In this one, it is aimed that developing more positive attitudes toward science, scientists and science teachers and science related careers. The last domain is World-View Domain which is related with schools' roles in order to assist students to understand the nature of science and practice the basic components such as questioning, explaining, and testing objects and events in the natural world (Enger & Yager 2001, 2009; Yager & Akcay, 2007).

In this study, instructional goals about Application Domain of the program were investigated. In this domain, it is crucial to determine in which extent students can transfer, use and apply effectively that they have learned in new contexts, especially in daily life events. Understanding the concepts or processes superficially is not enough in this domain, so students must show applications by applying the concepts into concrete and new situations. Problem solving or learning a new material based on the knowledge gained through previous courses are some examples of application domain at schools. Indeed, the Application Domain may be assumed as the most important one because it shows that students may use their knowledge to solve new problems and may apply the concepts in new contexts. This proves that if a student understands the concepts deeply, then s/he achieves these applications. Within this respect, some dimensions of the Application Domain can be summarized as using critical thinking skills, solving problems in daily life or in technological devices or technological problems through using conceptual understanding and skills, making meaningful decisions about personal health, nutrition and life style based on scientific concepts rather than on hearsay or emotions and understanding the relation between science, technology and society. Because the applications of science have impacts on developments in technology, it seems inappropriate to separate 'pure' or 'academic' science from technology. That's why; science and technology are interconnected and together has an effect on society.

1. Science -Technology - Society Approach

The National Science Teachers Association defines Science-Technology-Society (STS) as the teaching and learning of science and technology in the context of human experiences (NSTA, 1991). Mbajiorgu and Ali (2003) summarize the purposes of STS approach based on the studies in the literature (e.g. Bingle & Gasket, 1994; Fourez, 1995) as developing decision-making and problem solving skills of pupils in order to deal with socio-scientific issues, which they encounter. In STS perspective, teachers try to develop their students' ability to understand the events around them in a scientific perspective, its reflections on technological dimensions and the relation of these within society (Aikenhead, 1997). The central goal of STS education is to promote the development of an informed and responsible citizenry that is a requirement for human adaptation to the highly industrialized social life (Yalvac et al., 2007, p. 332). Aikenhead (1986) advocates that STS programs involve social issues related to scientific community's itself (e.g. history and nature of science, epistemology), other social topics which are not directly related to scientific community (e.g. socio-scientific issues) and science content knowledge (e.g. physics, chemistry and biology). These three aspects can be integrated with each other in different ways and in different degrees by science teachers in science classrooms (Mbajiorgu & Ali, 2003). Yager (1993) explains STS teaching as beginning with real world issues and concerns that are relevant to personal lives of students. Students focus on to analyze and to solve the problems by exploration of possible solutions. Students may work in groups or individually through the process in order to make meaningful decisions with the help of science and technology.

The STS effort is based on the constructivist learning theory (Brooks & Brooks, 1999; Yager, 1991) that emphasizes prior knowledge of students and their own previous interpretations of nature.

Constructivist teaching requires a learner-oriented environment where the teacher acts as a guide and co-learner. Due to the fact that STS uses the constructivist perspective for learning, students initiate questions, participate in discussions and research actions and practice decision making through social interactions (Yager, 1996, 2000). STS is also a major focus in other areas of the curriculum, especially the social studies, mathematics and the applied fields.

In related literature, there are many studies about STS approach. For example, Mbajiorgu and Ali (2003) investigated the relations between STS approach, scientific literacy and achievement. In another study done by Tsai (2000), he designed a research to examine the impacts of STS approach on high school students' cognitive outcomes. Similar study was done McClure and Bell (1990) in order to understand STS approach instruction on cognitive structure of pre-service teachers. Also there are studies which investigate the correlation between STS approach and constructivism such as Cho (2002) and Tsai (1999).

2. Aim of Research

There are several studies in literature which investigate the effects of STS teaching approach on students learning in some domains, change in students' beliefs about attitudes toward science (Akcay, Yager, Iskander & Turgut, 2010; Amirshokoohi, 2016; Vazquez-Alonso, Garcia-Carmona, Manassero-Mas, & Benassar-Roig, 2013), students' learning outcomes and successes (Akcay & Akcay, 2015; Akcay & Yager, 2010). The difference between current study and the others is that it is aimed to investigate students' abilities to apply science concepts learned through STS based or textbook oriented instructions in different contexts. The goal is to examine if there is any effect of the STS approach on using scientific knowledge in different situations. Another goal is to determine if there are any significant differences between STS and textbook oriented instructions with respect to students' genders, grade levels and successes in science classes.

Method

The study is based on quantitative research methodology which is used to explain phenomena, attitudes, opinions and behaviors or other defined variables by collecting numerical data that are analyzed using statistically based methods (Aliaga & Gunderson, 2000). Owing to the fact that questionnaires enable to reach large number of participants, they are one of the fundamental data collection instruments in this kind of research method.

1. Participants

A total of 609 students were participants of the study. 301 of students were in the experimental group in which the STS approach was used and the other 308 students were in a textbook oriented group as a control group. Table 1 shows the descriptive information about the participants of study. Participants are from six different public schools from Midwest part of the USA. The classes were assigned as experimental or control groups randomly. The teachers of the groups were their own teachers.

Table 1. *Descriptive information about participants*

Grade	Experimental Group		Control Group		Female		Male	
6	77	25,6%	81	26,3%	80	26%	78	25,8%
7	77	25,6%	76	24,7%	79	25,7%	74	24,5%
8	76	25,2%	75	24,3%	75	24,4%	76	25,1%
9	71	23,6%	76	24,7%	73	23,7%	74	24,5%
Total	301	49,5%	308	50,5%	307	50,4%	302	49,6%

2. Instruments

The part of application domain in assessing student understanding in science was used to collect data, which was developed by Enger and Yager (2009). The instruments involve student response sheets and teacher tabulation sheets. Directions about using the instruments were provided for teachers as they construct instruments suitable for the Application Domain. The study lasted for 9 weeks.

A quasi-experimental design was used in the study. Students in the experimental group followed STS approach and in control group, textbook-oriented approach was used. Table 2 indicates the differences between STS approach and textbook oriented science teaching program in terms of the Application Domain. The same student response sheet and teacher evaluation form were used for pre- and post-tests. While the pre-tests were given at the beginning of study, post-test were given at the end of the study.

Table 2. *Contrast between STS approach and textbook oriented programs in terms of application domain*

STS Approach	**Textbook Oriented Approach**
Students try to solve problems that are relevant to their daily lives	Teacher does not try to connect the topic with daily life
Students become involved in resolving social issues and see science as a way of fulfilling their responsibilities as citizens	Students feel no responsibility for resolving current societal problems
Students seek out information and use it in order to solve the problems	Students can recite information/concepts
Students are able to follow the developments in technology and able to see the relation between scientific concepts and technological progression.	Students cannot relate the science they study to any current technology
Teaching does not only take place at school but also supported with informal learning environments like science centers and science museums.	Learning is contained in a classroom for a series of periods over the school year
Students in science class wonder about what the future might be like.	Science class focuses on what has been previously known
Students are prompted to enjoy and gain experience through learning process.	There is little concern for the use of information beyond the classroom and performance on tests

3. Data Analysis

The data has been analyzed quantitatively by means and standard divisions. SPSS package program was used to analyze the data. The differences of mean values were tested by using dependent t-tests. The mean differences, standard divisions and t-values were calculated and used to assess pre-tests and post-tests results.

Results

Table 3 indicates comparisons of the differences for application of concepts and principles between students who were in the STS classrooms and those in textbook-oriented classrooms. According to the findings, there are no significant differences between STS oriented classes and textbook oriented classes on the pre-test scores except for the six grade students' pre-test result. Meaningful differences were found between the two teaching approaches on the post-test scores for applications of concepts from grade six to grade nine. Students in the STS classes showed significantly greater growth in terms of application of concepts. The data also indicates that students' abilities for application of science concepts are better in STS classrooms when compared to textbook-oriented classrooms.

Table 3. *Comparisons between STS and textbook-oriented students on their ability to apply science concepts*

		STS			Textbook-Oriented				
Grade	**Application**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**t**	**p**
6	Pre-test	77	1.69	.8	81	1.35	.8	6.64	.01*
	Post-test	77	5.89	2.7	81	2.23	1.0	133.22	.00*
7	Pre-test	77	2.12	.9	76	1.80	1.2	3.40	.06
	Post-test	77	6.23	2.3	76	2.56	1.3	148.84	.00*
8	Pre-test	76	2.03	1.0	75	1.97	1.1	4.21	.07
	Post-test	76	5.70	2.6	75	2.70	1.5	78.26	.00*
9	Pre-test	71	1.65	.7	76	1.66	.8	7.09	.08
	Post-test	71	5.25	2.2	76	2.32	1.0	111.00	.00*

Male students were compared based on before and after instruction involving application concepts with respect to the STS and textbook-oriented approaches. Table 4 indicates comparisons of the pre- and post-test average scores. No significant differences were found on the pre-test scores for the two groups except for six grade students. Male students showed significant differences between the two teaching approaches on the post-test scores for application of concepts from sixth grade through ninth grade. Male students at classes in which taught with an STS approach were able to apply more science concepts and principles when compared to students at classes where a textbook-oriented approach was used.

Table 4. *Comparisons between male STS students and their textbook-oriented counterparts and their ability to apply science concepts*

		STS (Males)			Textbook-Oriented (Males)				
Grade	**Application**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**t**	**p**
6	Pre-test	36	1.64	1.0	42	1.21	.8	4.20	.04*
	Post-test	36	5.97	2.8	42	2.10	1.0	70.84	.00*
7	Pre-test	37	2.03	1.0	37	1.68	1.2	1.98	.17
	Post-test	37	5.97	2.4	37	2.43	1.3	64.21	.00*
8	Pre-test	39	1.97	1.1	37	1.51	1.1	3.38	.07
	Post-test	39	5.38	2.6	37	2.46	1.5	35.52	.00*
9	Pre-test	35	1.60	.8	39	1.28	1.0	2.47	.12
	Post-test	35	5.03	2.0	39	2.08	1.1	61.63	.00*

Similarly, female students were compared based on before and after instruction of application concepts with respect to the STS and textbook-oriented approaches. Table 5 indicates comparisons of the pre- and post-test average scores. No significant differences were found on pre-test scores for the two groups regarding application concepts. Meaningful differences were found between the two teaching approaches on the post-test scores for application concepts across six grade through ninth grade. Female students in classes taught with an STS approach were able to apply scientific concepts in new situations when compared to students who were taught with a textbook-oriented approach.

Table 5. *Comparisons between female STS students and their textbook-oriented counterparts and their ability to apply science concepts*

		STS (Female)			Textbook-Oriented (Female)				
Grade	**Application**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**t**	**p**
6	Pre-test	41	1.73	.7	39	1.49	.8	2.13	.15
	Post-test	41	5.83	2.6	39	2.39	1.0	60.64	.00*

	Pre-test	40	2.20	.8	39	1.92	1.2	1.47	.23
7	Post-test	40	6.48	2.2	39	2.72	1.3	85.21	.00*
	Pre-test	37	2.08	.9	38	1.82	1.2	1.17	.28
8	Post-test	37	6.03	2.5	38	2.90	1.5	44.09	.00*
	Pre-test	36	1.69	.7	37	1.43	.7	2.56	.11
9	Post-test	36	5.47	2.3	37	2.57	.9	50.13	.00*

Table 6 indicates comparisons of pre- and post-test average scores for high achieving students concerning application of concepts in STS oriented classes and textbook oriented classes. High achieving students were defined as students who earned grades either of A or B in their coursework in both classes. There were no significant differences on pre-test scores involving all the groups except six grade. Significant differences were also found between the two teaching approaches on the post-test scores for application of concepts across six grade through ninth grade. High achieving students in classes taught with an STS approach could apply more science concepts when compared to students in classes taught with a textbook-oriented approach.

Table 6. *Comparisons between the STS high achieving students and their textbook oriented counterparts involving their ability to apply science concepts*

		STS			**Textbook-Oriented**				
Grade	**Application**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**t**	**p**
	Pre-test	33	2.36	.5	31	1.97	.6	9.35	.00*
6	Post-test	33	8.48	1.8	31	3.07	.7	234.60	.00*
	Pre-test	32	2.72	.7	31	2.55	1.1	.56	.46
7	Post-test	32	8.31	1.5	31	3.58	1.1	209.97	.00*
	Pre-test	30	2.77	.7	28	2.46	1.0	1.84	.18
8	Post-test	30	8.38	1.8	28	3.79	1.4	112.28	.00*
	Pre-test	27	2.19	.8	33	2.02	1.3	6.11	.06
9	Post-test	27	7.56	1.5	33	3.15	.6	242.43	.00*

Average scores for low achieving students were also compared in this study. Table 7 indicates comparisons of pre- and post-test average scores for low achieving students concerning application of concepts in STS oriented classes as well as textbook oriented classes. Students who earned a grade of C or lower in science classes or who were less interested and less motivated in a science classroom were defined as 'low ability'.

Table 7. *Comparisons between the STS low achieving students and their textbook-oriented counterparts and their ability to apply science concepts*

		STS			**Textbook-Oriented**				
Grade	**Application**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**t**	**p**
	Pre-test	44	1.18	.7	50	.96	.7	2.28	.13
6	Post-test	44	3.96	1.0	50	1.72	.8	145.31	.00*
	Pre-test	45	1.69	.8	45	1.29	.9	4.59	.03
7	Post-test	45	4.76	1.4	45	1.89	.9	128.37	.00*
	Pre-test	46	1.54	.9	47	1.19	1.0	3.42	.07
8	Post-test	46	3.98	1.1	47	2.02	1.1	76.46	.00*
	Pre-test	44	1.32	.6	43	1.24	1.2	4.11	.06
9	Post-test	44	3.84	1.1	43	1.67	.8	118.32	.00*

No significant differences were found on pre-test scores between the two low achieving groups. However, significant differences were found between the two teaching approaches on the post-test scores concerning application of concepts across six grade through ninth grade. Low ability students in classes taught with an STS approach were able to apply more science concepts and principles when compared to students in classes taught with a textbook-oriented approach.

Discussion

The comparisons of STS approach and textbook-oriented instruction for using scientific knowledge on solving problems and conceptual understanding were investigated in current study. Furthermore, in order to understand the effects of the STS approach in detail, analyzes were done with respect to students' genders, grade levels and successes.

The results from this study indicate that students, who experienced STS strategies in science classes from six grade to ninth grade through one full semester, are more successful about applying basic science concepts to new situations meaningfully better than students who were taught by a textbook-oriented approach. In another study done by Yager and Akcay (2008), fifty two middle school students were compared with respect to two different teaching approaches, one of which is STS and the other one is textbook based instruction. Students who exposed to STS approach learned basic concepts and applied science concepts in new situations better than the students who studies science in a more traditional way. Yager, Choi, Yager and Akcay (2009) also designed a study to investigate the impacts of STS approach in six domains, which are concept, process, application, creativity, attitude and wordview. According to the findings of study, no difference in results at any grade level in the concept domain was reached. On the other hand, significant differences were found in the other five domains. Using scientific knowledge in different contexts is also one of the important characteristics of a scientifically literate person since it requires an individual to apply scientific knowledge in life related problems (Bybee & McCrae, 2011). It is an indispensible fact that society creates needs and scientists seek to identify, prioritize and generate solutions for those needs (Sadler & Zeidler, 2005, p. 72). Applying science concepts to real-world problems helps students to gain deeper understanding of content and fosters critical thinking skills needed by them to become productive members of society (Jones, 2012, p. 69).

STS strategies involve student ideas and include consideration of multiple points of views, collaborative inquiry and problem solving. All these promote instruction in a constructivist atmosphere for learning and teaching that of science learning and experiences in the lives of students. There are many instructional advantages for placing students in situations where they must share information cooperatively, present their perspective of issues being studied and achieve group solutions regarding the issues (Eryaman & Genc, 2010). The implications of these processes affect both science teaching and learning by students. It is also interesting that most of students' confidence for solving personal, local and global problems were developed. In related literature, there are also studies which have similar conclusions. For instance, Chantaranima and Yuenyong (2014) concluded their study that students' analytical thinking skills were developed by STS approach. In another study done with 101 tenth grade students by Tsai (2000), he found that cognitive structure outcomes of STS oriented students outperformed than the students in traditional group.

This study does not provide comparative data for male and female students. Gender difference was investigated separately and it was concluded that when both male and female students learn science by using STS approach, they use much more process and creativity skills and more able to apply science concepts in new situations.

It was also observed that students even low achieving ones in STS group extended science beyond the classroom and school; they were more involved with their studies and continued to learn more. It was reached that STS approach is also beneficial for low achieving students in science classes as evidenced by this study.

Conclusion and Suggestions

STS is a reform effort that includes student interests, ideas, problem identification and problem resolutions. This study also supported that when students exposed to be more active and faced with daily life related issues more through learning process, they become more successful. The most impressive conclusion of current study is students can use the information and skills on their own in new situations. This suggests that student involvement with real world problems should be encouraged much more by different strategies as STS approach.

Based on the results of this study, there are mainly two groups for whom suggestions can be made, one of which is in-service science teachers. They should use STS strategies in their science classes, such as, associating a problem with daily life, promoting inquiry science teaching strategies for students, enabling students to study collaboratively, emphasizing the relations between science and technology and the effects of these on society. Such efforts will enable them to de-emphasize such methods which only require following directions and getting results that verify what the book and teacher reported that would happen. For these reasons, in-service teachers should be prompted to attend professional development programs like Iowa Chautauqua Program. The other group is teacher educators and curriculum developers who prepare individuals to be science teachers for future careers. They should teach students how they can take advantage of the STS approach in their classes. In teaching practice courses, they should enable their students to use STS based instruction and evaluate them to become better teachers. Teacher education programs should consist of courses which involve theoretical and practical foundations of the STS approach.

References

Aikenhead, G. S. (1986). The content of STS education. *STSRN Missive, 2*(4), 17-23.

Aikenhead, G. S. (1997). Integrating the scientific disciplines in science education. In H. Behrendt (Ed.), *Vortrage auf der Tagung für Didaktik der Physik/Chemie in Potsdam*, (pp. 21-30). Leuchtturm-Verlag.

Akcay, B. & Akcay, H. (2015). Effectiveness of Science-Technology-Society (STS) instruction on student understanding of the nature of science and attitudes toward science. *International Journal of Education in Mathematics, Science and Technology, 3*(1), 37-45.

Akcay, H. & Yager, R. E. (2010). The impact of a science/technology/society teaching approach on student learning in five domains. *Journal of Science Education and Technology, 19*(6), 602-611.

Akcay, H., Yager, R. E., Iskander, S. M., & Turgut, H. (2010). Change in student beliefs about attitudes toward science in grades 6-9. *Asia-Pacific Forum on Science Learning and Teaching, 11*(1), 1-18.

Aliaga, M. & Gunderson, B. (2000). *Interactive statistics.* Saddle River, NJ: Prentice Hall.

American Association for the Advancement of Science (AAAS). (1993). Benchmarks for Science Literacy: A Project 2061 *Report.* New York: Oxford University Press.

Amirshokoohi, A. (2016). Impact of STS issue oriented instruction on pre-service elementary teachers' views and perceptions of science, technology and society. *International Journal of Environmental and Science Education, 11*(4), 359-387.

Bingle, W. H. & Gasket, P. J. (1994). Scientific literacy for decision-making and the social construction of scientific knowledge. *Science Education, 78*(2), 185-200.

Brooks, J. G. & Brooks, M. G. (1999). *In search of understanding: The case for constructivist classrooms*. ASCD: Virginia, USA.

Bybee, R. & McCrae, B. (2011). Scientific literacy and student attitudes: perspectives from PISA 2006 science. *International Journal of Science Education, 33*(1), 7-26.

Chantaranima, T. & Yuenyong, C. (2014). The outcomes of teaching and learning about sound based on science technology and society (STS) approach. Procedia-*Social and Bheavioral Sciences, 116*, 2286-2292.

Cho, J. (2002). The development of an alternative in-service programme for Korean science teachers with an emphasis on science-technology-society. *International Journal of Science Education, 24*(10), 1021-1035.

Dass, P. & Yager, R. E. (1997). Iowa Chautauqua Program final performance report. Iowa City, IA: University of Iowa.

Enger, S. K. & Yager, R. E. (2001). *Assessing student understanding in science*. Thousand Oaks, CA: Corwin Press Inc.

Enger, S. K. & Yager, R. E. (2009). *Assessing student understanding in science*. (2 nd Ed.) Thousand Oaks, CA: Corwin Press Inc.

Eryaman, M. Y. & Genc, S. Z. (2010). Learning theories. In C. Kridel (Ed.). *Encyclopedia of Curriculum Studies.* Sage Publications.

Fourez, G. (1995). The science, technology and society (STS) movement and the teaching of science. *Prospects, 25*(1), 27-40.

Glynn, S. M. & Muth, K. D. (1994). Reading and writing to learn science: Achieving scientific literacy. *Journal of Research in Science Teaching, 31*(9), 1057-1073.

Jones, R. A. (2012). What were they thinking? *The Science Teacher, 79*(3), 66-70.

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education, 84*(1), 71-94.

Mbajiorgu, N. M. & Ali, A. (2003). Relationship between STS approach, science literacy and achievement in biology. *Science Education, 87*(1), 31-39.

McClure, J. R. & Bell, P. E. (1990). Effects of an environmental education-related STS approach instruction on cognitive structures of preservice science teachers. University Park, PA: Pennsylvania State University. (ERIC Document Reproduction Service No. ED 341 582).

Ministry of National Education. (2013). Science education curriculum for graders 3, 4, 5, 6, 7 and 8. Retrieved 3 July 2015, from http://ttkb.meb.gov.tr/www/guncellenen-ogretim-programlari/icerik/151.

National Research Council (NRC). (1996). National science education standards. Washington, DC: National Academic Press.

National Science Teacher Association (NSTA). (1991). Science/Technology/Society: A new effort for providing appropriate science for all (Position Statement). In NSTA Handbook (p. 47-48). Washington DC: National Science Teacher Association.

Sadler, T. D. & Zeidler, D. L. (2005). The significance of content knowledge for informal reasoning regarding socio-scientific issues: Applying genetic knowledge to genetic engineering issues. *Science Education, 89*, 71-93.

Tsai, C-C (1999). The progression toward constructivist epistemological views of science: A case study of the STS instruction of Taiwanese high school female students. *International Journal of Science Education, 21*(11), 1201-1222.

Tsai, C-C. (2000). The effects of STS-oriented instruction on female tenth graders' cognitive structure outcomes and the role of student scientific epistemological beliefs. *International Journal of Science Education, 22*(10), 1099-1115.

Vazquez-Alonso, A., Garcia-Carmona, A., Manassero-Mas, M. A. & Bennassar-Roig, A. (2013). Spanish secondary-school science teachers' beliefs about Science-Technology-Society (STS) issues. *Science & Education, 22*(5), 1191-1218.

Yager, R. E. (1991). The Constructivist Learning Model: Towards real reform in science education. *The Science Teacher, 58*(6), 52-57.

Yager, R. E. (Ed.). (1993). *What research says to the science teacher: The science, technology, society movement.* Washington, DC: National Science Teachers Association.

Yager, R. E. (Ed.). (1996). *Science/technology/society as reform in science education.* Albany, NY: State University of New York Press.

Yager, R. E. (2000). The history and future of science education reform. *The Clearing House, 74*(1), 51-54.

Yager, R. E. & Akcay, H. (2007). What results indicate concerning the successes with STS instruction. *The Science Educator, 16*(1), 13-21.

Yager, R. E. & Akcay, H. (2008). Comparison of student learning outcome in middle school science class with an STS approach and a typical textbook dominated approach. *Research in Middle Level Education, 31*(7), 1-16.

Yager, R. E., Choi, A., Yager, S. O. & Akcay, H. (2009). Comparing science learning among 4^{th}, 5^{th}, and 6^{th} grade students: STS versus textbook-based instruction. *Journal of Elementary Science Education, 21*(2), 15-24.

Yalvac, B., Tekkaya, C., Cakiroglu, J., & Kahyaoglu, E. (2007). Turkish pre-service science teachers' views on science-technology-society issues. *International Journal of Science Education, 29*(3), 331-348.