THE EFFECTS OF INQUIRY-BASED SCIENCE TEACHING ON ELEMENTARY SCHOOL STUDENTS' SCIENCE PROCESS SKILLS AND SCIENCE ATTITUDES

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Abstract. The purpose of this study was to determine Turkish elementary school students' level of success on science process skills and science attitudes and if there were statistically significant differences in their success degree and science attitudes depending to their grade level and teaching method. The total 241 students comprised of 122 males, 119 females. For this purpose, a pretest-post test control group and experimental group design was used. The data were collected through using Basic Science Process Skill Test and Integrated Science Process Skill Test and Science Attitude Scale. Study was conducted during the two semesters. Results of the study showed that use of inquiry based teaching methods significantly enhances students' science process skills and attitudes.

Keywords: science education, inquiry teaching, science process skills, attitudes

Introduction

Science process skills (SPS) are defined as transferable skills that are applicable to many sciences and that reflect the behaviors of scientists.[1)] They are the skills that facilitate learning in physical sciences, ensure active student participation, have students develop the sense of undertaking responsibility in their own learning, increase the permanence of learning, and also have students acquire research ways and methods, that is, they ensure thinking and behaving like a scientist. For this reason, it is an important method in teaching science lessons. SPS are the building-blocks of critical thinking and inquiry in science (Ostlund, 1992).

Learning science lessons by apprehending requires using science process skills (SPS). Having science process skills acquired, at the same time, means preparing future scientists, having scientific literacy acquired, that is enabling students to use science information in daily life (personal, social and global) (Harlen, 1999). Science process skills are based on scientific inquiry and teaching science by inquiry involves teaching students science process skills, critical thinking, scientific reasoning skills used by scientists (Pratt & Hackett, 1998) and inquiry is defined as an approach to teaching, the acts scientists use in doing science and it can be a highly effective teaching method that helps students for to understanding of concepts and use of process skills (Yager & Akçay, 2010).

Due to the above-mentioned importance of science process skills, many researchers have focused on this subject matter. In recent years, many studies have been conducted on students' acquisition of basic science process skills (BSPS) and integrated science process skills (ISPS).

Science- A Process Approach (SAPA) grouped science process skills under two main headings.[1)] The first is called as basic science process skills (BSPS), such as observing, measuring and using number, and classifying. BSPS provide the intellectual groundwork in scientific inquiry (Walters &

Soyibo, 2001). These skills are those which must be acquired in the first level of primary education. And the latter is called integrated science process skills (ISPS), such as controlling variables, formulating hypotheses, and experimenting. These skills are structured on basic skills. Some studies have indicated that there is a positive relationship between SPS and Piagetian development level and finding supports the separation of process skills into a two-level-hierarchy, namely basic and integrated (Brotherton & Preece, 1995).

The role of science process skills in science learning

The studies aiming at developing school programs to improve science process skills began in 1960s. A perennial issue in science education concerns the emphasis to be given to methods of science the science process skills- in the school curriculum. AAAS started the studies on the issue in the USA in 1967 while DES did it in England in 1960s (Brotherton & Preece, 1995). Many studies have noted that science process skills are effective on teaching and learning about science (Brotherton & Preece, 1995; Harlen, 1999; Chang & Mao, 1999; Keys & Bryan, 2001; Walters & Soyibo, 2001; Turpin & Cage, 2004; Wilke & Straits, 2005).

Children are like scientists. For in the nature of many children is already the curiosity for searching and this curiosity leads them to search. In this way, children begin to search at early ages. That is to say, the skills and processes students use and develop are the same as those that scientists use while studying. These studies are necessary for understanding the functioning of nature and preparing livable environments. Scientists make observations, classifications, measurements, and inferences, propose hypotheses, and make experiments as well. Ways of thinking in science are called the process skills (Rezba et al, 1995). When we doing science we ask questions and find answers to questions, these are actually the same skills that we all use in our daily lives as we try to solve everyday questions. When we teach students to use these skills in science, we are also teaching them skills that they will use in the future in every area of their lives. The use of science process skills by students increases the permanence of learning. For learning by doing, student uses almost all of his or her senses and learning becomes more permanent and hands-on activities get them to acquire experience. The development of science process skills enables students to solve problems, think critically, make decisions, find answers, and satisfy their concerns. Not only do research skills get students to learn some information about science, but also learning these skills helps them think logically, ask reasonable questions and seek answers, and solve the problems they encounter in their daily life. Problem solving is the essence of scientific investigations. Students are given a problem or they identify a problem, then they follow the guidelines of problem based learning to solve in the problem. As they follow the investigative process, they use the science process skills which are the methods and procedures of scientific investigation.[2)]

Teaching methods such as inquiry teaching, problem solving, problem based learning and project based learning relies heavily on the effective use of the science process skills by students to complete an investigation (Colley, 2006). Inquiry science teaching is teaching science by having students engage in more science activities and exercises and encourages children to learn science and learn about science (Olson & Louks-Horsley, 2000). Also, students engaged in simple inquiry engage in processes such as observing, comparing, contrasting and hypothesizing (Cuevas et al., 2005). One area of contemporary research on inquiry is related to children's understanding and use of science process skills in designing investigations (Keys & Bryan, 2001). Scientific inquiry exercises typically serve as the primary source of science process skill development and inquiry is used to teach science process skills (Wilke & Straits, 2005). According to Minner et al. (2010), the term inquiry has figured prominently in science education, three distinct categories of activities: what scientists do, how students learn, and a pedagogical approach that teachers employ.

In a study done in Texas to compare the traditional program and inquiry oriented science program Mabie & Baker (1996) report that in favor of those following inquiry oriented science programs there was found a 75% difference in terms of the students' attitudes towards science. Furthermore inquiry-based instruction produced positive outcomes on student concept learning, (Chiappetta & Russell, 1982; Ertepinar & Geban, 1996; Gabel et al., 1977; Geban et al., 1992); and problem-solving, laboratory instruction, cooperative learning, and discovery instruction methods are commonly referred to as the inquiry science teaching, which often emphasizes extensive use of science-process skills and independent though (Basaga et al., 1994; Mao et al., 1998; Chang & Taipei, 2002; Brickman et al., 2009). It could be concluded here that having science process skills is a prerequisite to learn about science.

From a science perspective, inquiry-based science teaching engages students in the investigative nature of science. Inquiry involves activity and skills, but the focus is on the active search for knowledge or understanding to satisfy a curiosity. According to Ketpichainarong et al. (2009) inquiry teaching and learning methods affect student performances, for example in solving problems, reflecting on their work, drawing conclusions, and generating prediction. These qualities are necessary for a high-achieving graduate.

Science process skills in Turkish education system

Starting from 2000s, the significance of the acquisition of science process skills has been appreciated in Turkey when developing science syllabuses. Up until now, two major changes have been made in elementary education science programs concerning the 6-14 age groups. The first one of them was made in 2000 and has been applied since 2001-2002 academic year. Different from the preceding program, the scope of the units were narrowed and updated, and it was prepared considering the principle of reaching the content via science processes[3)] (Kaptan & Korkmaz, 2001). The program attached importance to also the improvement of scientific attitudes and it was student-centered. However, the science syllabuses were revised in 2004 and underwent a second change. The name of the course was made Science and Technology. The vision of the program was summarized in educating students as science and technology literates whatever their individual differences are. The main approaches while developing the program were, giving the gist in small amounts of information, dealing with all the dimensions of science and technology literacy, basing the learning and assessing activities on constructivist learning theory, revising and reviewing, parallelism to the syllabuses of other courses and conformity with students' physical and mental stages of development. The above mentioned last program has been followed in whole Turkey since the academic year of 2005-2006.[4)] There, science process skills were particularly emphasized to be the primary learning area.

Science process skills in the syllabus of science and technology course

The basic process skills in the program were determined as Observing, Comparing and Classifying, Inferring, Predicting, Defining Operationally, Measuring, Recording and Interpreting, Formulating Models, Constructing Tables of Data and Graphs, while the integrated process skills were to be Formulating Hypotheses, Identifying and Controlling Variables and Experimenting.

The program specified[3)] also some acquisitions needed by students to improve their skills of researching and questioning with a scientific and technological point of view, solving problems, conveying scientific views and results, working in cooperation and deciding sensibly.

The purpose of this study was to investigate the effects of hands-on activities incorporating inquiry based science teaching on fourth, fifth, sixth, seventh and eighth grades students' science process skills and attitudes toward science lessons. It compared the performance of the students using hands-on activities incorporating inquiry based science teaching to students using a traditional science curriculum.

Research questions

The study focused on two main problems and some related sub-questions has been provided to develop solutions to following research questions: (1) are there any effects of inquiry based science teaching on elementary school students' level of scientific process skills: i) are there any significant differences after the study on the elementary school 4th, 5th and 6th grade (10-12 age group) students' level of scientific process skills between the experimental and control groups; ii) are there any significant differences after the study on the elementary school 7th and 8th grade (13-14 age group) students' level of scientific process skills between the experimental and control groups; (2) are there any significant differences between the attitudes of experimental and control groups elementary school students towards Science Courses: iii) are there any differences after the study in the experimental and control groups 4th, 5th and 6th grade (10-12 age group) students attitudes towards science courses; iv) are there any differences after the study in the experimental and control groups 7th and 8th grade (13-14 age group) students attitudes towards science courses.

Methodology of research

In the study, pre-test and post-test experimental design (control-experimental group) was used. The main study sample comprised 241 students in total. 71 of them constituted the experimental group for the 4th, 5th and 6th grades and 68 students constituted the control group. The experimental group for the 7th and 8th grades was composed by 50 students while 52 students comprised the control group. When creating the experimental and control groups, it was aimed not to cause any distinct differences between the groups. To ensure this, SPST had been done before the study and then choices were made randomly in the classes that had similar performances to one another. Nearly all of the students had mid-level socioeconomic statuses. The study was conducted the one of the large elementary school in the city of Bursa. The school has 5 classrooms for each one of the 4th and 5th grades and 3 classrooms for each one of the 6th, 7th and 8th grades. Besides, there are science and mathematics laboratories in it. Study was conducted during the two semesters.

Science Process Skill Test (SPST): to measure the integrated science process skills, the test developed by Burns et al. (1985) with its 36 items was modified by the researchers with some particular changes and additions. So Integrated science process skills test (ISPST) redeveloped had 38 items. Besides that, another test basic science process skills test (BSPST) was developed in order to measure the basic science process skills of the 4th, 5th and 6th grade students (10-12 age group) and it consisted of 24 items. Thus, BSPST was administered to measure the basic science process skills and the ISPST was given to measure the integrated process skills of the 7th and 8th graders (13-14 age groups). For the pilot study, BSPST was applied to the 4th, 5th, and 6th grades students (ages 10-12) and the Cronbach's alpha reliability coefficient of the test was found to be 0.74, and ISPST was applied to the 7th and 8th grades students (ages 13-14) and the Cronbach's alpha reliability coefficient of the test was found to be 0.78.

BSPST, which has 6 dimensions, 6 items related to observation, 6 items related to classification, 6 items related to measuring, 8 items related to predicting, 4 items related to inferring and 4 items related to communicating. ISPST, which has 11 dimensions 6 items related to formulating hypothesis, 7 items related to identifying of variables, 7 items related to defining operationally, 6 items related to interpreting data, 4 items related to formulating models and 6 items related to experimenting.

Attitudes Scale towards Science (ASTS): this scale, developed by Oruç[5)] measures students' attitudes towards science and contains 40 items. The reliability of this scale was found to be 0.87.

Pre-test post-test control group design, which is one of the methods of the experimental design, is applied. All participants attended the three-hour lectures per-week in a science course. While the students in the control group were being taught by their teachers with traditional methods, the ones in the experimental group were supplied some hands-on activities prepared by the researchers to improve their science process skills. Throughout the studies, the topics to be studied were selected in conformity with the syllabus and what the control group students were studying. Throughout the year, the students did 108 hands-on activities to improve their science process skills. They worked in groups of at least 2 and maximum 4 students. The groups were heterogeneous with respect to their science achievement. Students in the experimental group were trained about inquiry teaching method and hands-on activities.

50 experiments set up were on physics subjects while 25 were about chemistry and 33 of them were on biology subjects. The numbers of the experiments are in proportion to the scopes of the units determined by the syllabus. The experiments were designed considering the levels of the students and the science process skills aimed to be given and improved. The numbers of the activities in all the grades are given in the Table 1.

Table 1. Numbers of the activities aiming to improve the skills in all the grades

SPS	Grades Level				
	4	5	6	7	8
Observing	16	22	18	10	8
Comparing and classifying	7	8	6	3	2
Inferring	11	20	14	7	4
Predicting	11	4	4	4	6
Measuring	10	10	12	18	10
Recording and interpreting	18	18	18	22	22
Formulating models	4	4	5	4	3
Constructing tables of data and graphs	11	4	4	7	9
Experimenting	-	-	-	6	6
Defining operationally	-	-	-	4	3
Formulating hypotheses	-	-	-	7	7
Identifying and controlling variables	-	-	-	6	6

During the studies, the students were asked some open-ended questions to attract their attention to the topics and activities and they were asked to answer them working cooperatively. At that stage, the students were often supported by the researchers. The groups were demanded their findings and results attained in writing or verbally whenever they finished working together. They write some group reports and different students in the work groups provided oral explanations to the rest of the students about each one of those reports. The findings were discussed all together to have some specific results. To consolidate things, the classification skill for example, the class was asked a common question on classification before ending the lesson.

Students all grade levels, the number of the hands-on activities, the content knowledge related to the science process skills, and the instructional time were held constant. Dependent variables of the study were the students' achievement scores of BSPST or ISPST and ASTS. Independent variables of the study were the different types of instructions employed.

When students' pre- BSPST and pre-ISPST scores and pre- ASTS scores were used as a covariate, ANCOVA was used to test the research questions and to determine the treatment effects on students' post- BSPST and post-ISPST scores and post- ASTS scores.

Results

To determine the science process skills and attitudes of the groups before the experimental studies, a t-test analysis was made using their pre-test scores. Descriptive statistics for pre and posttest scores for the control and experimental groups on BSPST, ISPST and ASTS are given in Tables 2-5.

Table 2. Descriptive statistics for pre- and post BSPST scores for grades 4-6

		Pre- BSPST		Post- BSPST	
Group	n	Mean	SD	Mean	SD
Experimental group	71	10,9155	3,99552	14,0423	2,58256
Control group	68	10,8382	3,46673	12,2206	3,36286

Table 3. Descriptive statistics for pre- and post ISPST scores for grades 7 and 8

		Pre- ISPST		Post- ISPST	
Group	n	Mean	SD	Mean	SD
Experimental group	50	11,3800	3,34963	12,1200	4,31722
Control group	52	8,2500	3,76712	8,1923	4,59342

Table 4. Descriptive statistics for pre- and post ASTS scores for grades 4-6

		Pre-ASTS		Post- ASTS	
Group	n	Mean	SD	Mean	SD
Experimental group	67	163,0000	16,58312	165,5821	20,61564
Control group	69	159,3478	20,25922	156,1159	22,43457

Table 5. Descriptive statistics for pre- and post ASTS scores for grades 7 and 8

Group	n	Pre-ASTS Mean	Pre-ASTS SD	Post- ASTS Mean	Post- ASTS SD
Experimental group	50	144,3600	23,07287	158,9400	20,75652
Control group	48	145,5417	21,39493	148,4375	19,92422

It is seen from the tables that the students' pre-BSPST scores (4th, 5th and 6th grades), pre- ASTS scores (4th-8th grades) were not significantly different between the control and experimental groups. ASTS scores were ($t= 2.554$, $df= 96$, $p> 0.05$) for 7th and 8th grades, and $t=1.149$, $df= 134$, $p>0.05$ for 4th, 5th, and 6th grades. BSPST scores were ($t= 0.122$, $df= 137$, $p> 0.05$) for 4th, 5th, and 6th grades. The only difference was found between the 7th and 8th grades' ISPST scores ($t= 4.428$, $df= 100$, $p<0.05$).

Analysis of Covariance (ANCOVA) was used to test the effects of the instruction done with inquiry teaching on students' science process skills and attitudes towards science considering the pre-test scores as a covariate. Before making comparisons between the groups, the relationship between the dependent and independent variables was analyzed and it was tested whether the assumption that the tendency of the regression lines that are to be used to predict the post-test scores compared to pre-test ones are equal to one another is achieved through the data obtained from the study. According to the results of the analyses, the relationships between pre-test and post-test scores were found to be $r=0.742$, for the experimental group and $r= 0.740$ for the control group ($p<0.01$) for the ISPST result scores belonging to the 7th, and 8th grades, and for the 4th, 5th, and 6th grades the BSPST result scores were $r=0.419$ for the experimental group ($p<0.05$) and $r= 0.636$ for the control group ($p<0.01$).

Tables 6 and 7 show the summary of ANCOVA comparing the mean scores of students' performances in both the experimental and control groups with respect to the post- BSPST, post- ISPST and post- ASTS.

Table 6. Results of ANCOVA of post- BSPST scores of the students in control and experimental groups with respect to treatment

Source	Type III Sum of Squares	df	Mean Square	F	p
Pre-BSPST	302,531	1	302,531	44,623	,000
Treatment	111,405	1	111,405	16,432	,000
Error	922,033	136	6,780		

Table 7. Results of ANCOVA of post- ISPST scores of the students in the control and experimental groups with respect to treatment

Source	Type III Sum of Squares	df	Mean Square	F	p
Pre-ISPST	623,678	1	623,678	45,211	,000
Treatment	64,323	1	64,323	4,663	,033
Error	1365,679	99	13,795		

As seen in Table 6 and Table 7 pre-BSPST and pre-ISPST scores have significant effects on students' post-BSPST and post ISPST scores. Also Table 5 and Table 6 show significant treatment effects on students science process skills ($F(1,136) = 16.432$, $p < 0.05$, and $F(1,99) = 4.663$, $p < 0.05$). As can be seen in these results, the students in the experimental group had a better performance in terms of BSPST and ISPST scores than the control group did.

In addition, it was found that there was no statistically significant interaction between treatment and gender on all test scores.

Table 8. Results of ANCOVA of post- ASTS Scores of the students (10-12-age group) in the control and experimental groups with respect to treatment

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Pre- test	18913,475	1	18913,475	58,012	,000
Group	1709,229	1	1709,229	5,243	,024
Error	43361,896	133	326,029		

Table 9. Results of ANCOVA of post- ASTS Scores of the students (13-14-age group) in the control and experimental groups with respect to treatment

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Pre- test	12024,169	1	12024,169	41,172	,000
Group	3013,272	1	3013,272	10,318	,002
Error	27744,464	95	292,047		

As seen in Table 8 and Table 9, pre-ASTS scores have significant effects on students post-ASTS. Also these Tables show significant treatment effects on students attitudes towards to science between the groups ($F(1,133) = 5.243$, $p < 0.05$, and $F(1,95) = 10.318$, $p < 0.05$). As can be seen in these results, the students in the experimental group had a better performance in terms of ASTS scores than the ones in the control group did.

Discussion

The first objective of this study was to compare the effects of hands-on activities incorporating inquiry-learning approach on the development of 4-6th grade students BSPST and attitudes toward science, 7-8th grade students ISPST and attitudes toward science.

The results given in Tables 2-5 suggest that the values about the experimental groups are higher than those about the control groups when comparing the average scores both 4-6th graders and 7-8th graders got about their process skills and attitudes towards science. Results of the study are consistent with results of similar studies previously conducted.

Many researchers have shown that hands-on activities incorporating inquiry based science teaching to science instruction will improve science attitudes and science process skills (Staver & Small,1990; Turpin & Cage,2004) and laboratories have long been recognized for their potential to facilitate the learning of science concepts and skills (Hofstein & Lunetta, 2004). Anderson (2002) states that the previous studies indicate employing inquiry based science teaching in science education has some positive effects on cognitive achievement, process skills and attitude towards science but it is relative. Aktamış & Ergin (2008) found in their study to teach scientific process skills to students to promote their scientific creativity, attitudes towards science, and achievements in science. German & Odom (1996) conclude after a study with 7th grade students that students need to be taught with inquiry teaching techniques to be able to practice and develop the process skills and understand the goal of the experimental context in science. Turpin & Cage (2004) found in their study that activity-based methods had some effects on achievement in SPS but they did not found any changes in attitudes towards science courses, and they concluded that teacher behaviors are more influential on attitudes. Walter & Soyibo (2001) discuss the change in the science programs that are mainly based on hands-on and minds-on activities done in laboratories, and such programs are based on BSPS and ISPS. Their study suggests that the 7th, 8th and 9th grade students in the schools following the new program were more successful than those who were in the schools adopting traditional methods. Bilgin (2006) found that when hands-on learning activities are used together with cooperative learning approach, 8th grade students were more successful in SPS and had more positive attitudes towards science than the control group students following the traditional methods. Butts et al. (1997) reported that students needed more practices to be done in laboratories to improve their problem solving skills and SPS. Hartikainen & Sormunen[6)] sought an answer to the question “Why the scientific skills are not familiar to pupils?” What they suggested as answer was that teachers do not teach about science process skills first and encourage students to search. They offered some solutions for it, and some of them are that teachers might give well-defined research problems, completed questions, obvious hypotheses, receipt-like methods, and teachers should offer students the possibility to plan their own investigations, where they make their own questions and hypotheses, choose methods and necessary equipment, discuss about the means for ensuring reliability and the ways of scientific reporting. In that way, the students can adopt a scientific skill, which means learning some fundamental features of the nature of science, and, consequently, even deepen their conceptual understanding of natural phenomena. Yager & Akçay (2010) indicated that student use and understanding of science skills and concepts in the inquiry sections increased significantly more than they did for students enrolled in typical sections in terms of process skills, creativity skills, ability to apply science concepts, and the development of more positive attitudes.

Teachers should first follow a program that would make students acquire the science process skills. Then they should integrate that program with the science curriculum since science process skills have a hierarchic structure. A student who does not have the basic skills could not improve the skills about performing experiments easily. Whereas, what we firstly do at schools is making students do experiments. That is starting from the end and a big mistake. For this reason, teaching science process skills should never be neglected giving such excuses as shortage of time and overloaded syllabuses.

Results of the present study show that hands-on activities incorporating inquiry based science teaching to science instruction will improve science attitudes and science process skills and support the fact that the new science and technology program followed in Turkey since 2004/2005 academic year is one that could make positive contributions to students achievement in science, scientific literacy and attitudes towards science.

The study was carried out in relatively crowded classrooms. The average population of the students per classroom was about 40 people. The lessons were given as based on hands-on activities under those conditions and the results achieved are particularly significant in that respect.

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NOTES

1. http://www.narst.org/publications/research/skill.cfm

2. http://www.suite101.com/content/problem-solving-and-science-process-skills-a65807

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