The Influence of Hands on Physics Experiments on Scientific Process Skills According to Prospective Teachers' Experiences[1]

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Abstract
In this study, relationship between prospective science and technology teachers' experiences in conducting Hands on physics experiments and their physics lab I achievement was investigated. Survey model was utilized and the study was carried out in the 2012 spring semester. Seven Hands on physics experiments were conducted with 28 prospective science and technology teachers (18 female and 10 male) enrolled in physics I laboratory course. The results showed that although there was no significant correlation among the observation, providing explanations, prediction, making an inquiry, forming logic skills and academic achievement, it was found a significant relationship between the *producing according to a plan* skill regarding their physics I lab achievement (Pearson r = .385 and p = .04 < .05). This study points out that physics instructors, whenever they need, may prepare syllabuses for physics laboratory courses that include low cost materials instead of laboratory equipment to enhance their students' scientific process skills.
Keywords: Hands on science, physics experiment, scientific process skills, low cost material.

Introduction

Students learn science by direct experience with the methods and process of inquiry (NSF, 1996). Moreover, they learn better when they measure, touch, feel, make charts, manipulate, draw, record data (Ateş and Eryılmaz, 2011) instead of passive recipients of textbook material (NSF, 1996; NRC, 1999). Furthermore, reforms in science education around the world had been continuing during the last decade and thus, Ministry of National Education of Turkey (MNET) decided to revise science and technology curriculum. The new curriculum focused on "less information is more" and emphasized importance of the nature of science, scientific process skills (SPS) and their interdependence with the society (MNET, 2005). The new science and technology curriculum underlined that ''scientific and technological literacy of all students, regardless of individual, should be developed" (MNET, 2005). Therefore, science and technology course efforts to make students capable of (a) using scientific process in solving problems, making decision, (b) understanding the nature of science and technology, (c) critically analyzing of recently provided scientific knowledge and its role in human society (Özkal et al., 2010).

Scientific knowledge is identified as two broad domains: content knowledge and process skills. Content knowledge (sometimes known as declarative knowledge) includes the facts, principles, conceptual models, theories and laws which students are expected to understand and remember. In the other hand, process skills (sometimes known as procedural knowledge) are the techniques used in science, for example, observation, measurement, and developing hypotheses, which students are to master. Both domains are considered necessary in order for students to fully understand science concepts and be able to apply them.

Gagne (1965) defined science process skills (SPS) as "*intellectual skills together with the associated learned capabilities which scientists use as a self-management procedure in carrying out their activities*". In fact, SPS is very important for every individual because, every individual uses SPS at some stages of their daily life. In science education literacy, SPS can be divided into two groups as "Basic" and "Integrated". Science process skills refer to the following six actions, in no particular order: observation, communication, classification, measurement, inference, and prediction. The integrated SPS are complex processes that combine two or more basic SPS such as controlling variables, interpreting data, formulating hypotheses and experimentation (Azizoğlu and Dönmez, 2010). The basic SPS in the new science and technology curriculum were determined as observing, comparing, 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 (Ergül et al., 2011). In the present study, the SPS have been dealt with six sub-headings as observing, providing explanations, predicting, forming logic, making an inquiry, producing according to a plan (Arslan and Tertemiz, 2004).

Improvement of SBS is integrated laboratory applications, because students learn considerably to use SBS with the laboratory experiments. Laboratories also contribute to improving students' scientific thinking, observation, creative thinking, interpretation of events, data collection and analysis, and problem solving (Ausubel, 1968; Karamustafaoğlu, 2011). But, some studies stated that qualified teachers couldn't have done experiments in science lessons because of inadequate laboratory equipments even if they are really sophisticated in their field (Ayas et al., 1994; Böyük et al., 2010), even though science teachers have to known how to reach their students and how to make physics concepts be understood by their students when they couldn't reach any laboratory equipment. According to Ateş and Eryılmaz (2011) many valuable data collection science experiments can be performed using simple set-ups or low cost materials that can be found readily and assembled very easily. Besides, these experiments do not necessarily need special equipment. Being not a new method entered into the science literature, the science curriculum improvements and science works had been enriched by learning through simple tools as known hands on learning at the early 1960's and 1970's (Uzal et al., 2010). Moreover, some SPS are best learned and developed through Hands-on experiment such as measurement and the others may be linked to Hands-on experiments. For example, inferring is based on results derived from Hands-on experiments (Ruby, 2001). Ruby (2001) also argues that students can develop by practicing their SPS using results drawn from other sources than in-class activities leading to debate over the need for Hands-on science when teaching them. Further, Klopfer (1990) claims that Hands-on experiments allow students to gain observation and measurement. Hands-on science also offers students additional opportunities except for learning and makes students busy with doing activities but not thinking about the topic (Ruby, 2001). Furthermore, Ateş and Eryılmaz (2011) stated that these activities are important especially for developing countries that can't use specific and high cost materials to engage students into physically active science learning environment.

Several studies exposed that Hands-on experiments help students to encourage their creativity in problem solving, promote student independence, and improve science attitudes and SPS (Haury and Rillero, 1994; Staver and Small, 1990; Turpin, 2000; Uzal et al., 2010; Ateş and Eryılmaz, 2011). For example Önen and Çömek (2011) and Uzal et al., (2010) formed studies that include to conduct science experiments with easily available materials to find out the teachers' point of view and their attainments. After the applications, researchers determined that the participants agree on all opinions on the science experiments conducted with easily available materials. When they compared the opinions of class teachers with science teachers', they found a significant difference in favour of science teachers. Lastly, they found no significant difference between the teachers' opinions of science experiments conducted with easily available materials. According to the conclusion of another study (Önen and Çömek, 2011), prospective teachers expressed positive

opinions about science teaching with easily available materials. Ateş and Eryılmaz (2011) studied with 130 ninth grade students' for investigating the effectiveness of Hands-on and minds-on activities on their achievement and attitudes towards simple electric circuits. Although they investigated a significant difference between students' physics achievement, they didn't find out any significant differences between the means of the students' attitudes towards simple electric circuits. Ergül et al. (2011) investigated 241 elementary school students' level of success on SPS and science attitudes. They found that the use of inquiry based teaching methods significantly enhance their SPS and attitudes. In a similar study, Holstermann et al. (2010) examined students who experienced in Hands-on activities were showed higher interest in these activities than non-experienced students. Eventually, they found that the performance of various Hands-on activities could influence students' interest differently. They also indicated that the quality of hands-on experiences showed positive correlations with interest in the respective hands-on activities. In contrast to Hands-on science based studies, Sinan and Uşak (2011) conducted a study in well-equipped biochemistry laboratory with twenty-seven prospective biology teachers. They found a positive relationship between students' scientific process skills and course achievement grades.

In line with these empirical findings and the theoretical assumptions, in spite of Hands on Physics Experiments (HoPE) encourage students' creativity in problem solving, promote their independence, improve science attitudes, one justification for this study was that researcher have not been accessed any published studies that had investigated the influence of HoPE on each scientific process skills (SPS). For this reason, the influence of HoPE on each SPS (observing, providing explanations, predicting, forming logic, making an inquiry, producing according to a plan) and physics I lab course achievement grades is of interest to researcher.

Methodology

Purpose of study

Everyone knows that physics experiments, which conducted in well-equipped laboratories, improve students' SPS. In addition to, in this study the researcher tried to demonstrate whether HoPE can improve SPS. It should be stated that the aim of this study is not to compare whether the HoPE learning method was more effective than any other approaches or not.

Sample

This study designed as survey model was conducted with 28 prospective science and technology teachers (18 female and 10 male) in the 2012 spring semester.

Data Source

In this study, the data was gathered via Science Process Skill Evaluation Test (SPSET), which was designed by researcher based on SPS objectives, which were identified, by Arslan and Tertemiz (2004). They defined SPS as *observing, providing explanations, predicting, forming logic, questioning, making an inquiry, producing according to a plan,* and *developing ways of communication* and they identified several objectives for each. Researcher converted these objectives into Likert type scale for prospective science and technology teachers to evaluate the influence of HoPE on SPS. The Likert scale is a five point scale ranging from "Strongly Disagree=1", "Disagree=2", "undecided=3", "Agree=4", "Strongly Agree=5". Some SPS samples, their objectives and their converted into item versions in SPSET are given in Table 1.

SPS	Objectives Samples	Test Items Samples	Level
Observing	S/he determines properties and relevant details of object	Hands on Physics Experiments can allow students to determine properties and relevant details of object	① ② ③ ④ ⑤
Predicting	S/he makes suitable predictions supported by evidences	Hands on Physics Experiments can allow students to makes suitable predictions supported by evidences	① ② ③ ④ ⑤
Making an inquiry	S/he decides which variable should be manipulated or changed (independent) and which variable is affected by the independent variable (dependent)	Hands on Physics Experiments can allow students to decide which variable should be manipulated or changed (independent) and which variable is affected by the independent variable (dependent)	① ② ③ ④ ⑤

Table 1. Some objectives of SPS and their item versions in SPSET

The final version of SPSET has 29 items that are under 6 dimensions as mentioned above. As a whole, there are 7 items related to *observation* dimension and for this dimension possible overall scores are range from 7 to 35, 5 items related to *provide explanations* dimension and for this dimension possible overall scores are range from 5 to 25, 5 items related to *predicting* dimension and for this dimension possible overall scores are range from 5 to 25, 4 items related to *forming logic* dimension and for this dimension possible overall scores are range from 4 to 20, 3 items related to *making an inquiry* dimension and for this dimension possible overall scores could range from 3 to 15and 5 items related to *producing according to a plan* dimension and for this dimension possible overall scores could range from 5 to 25. The results of the instrument's dimensions are presented below table.
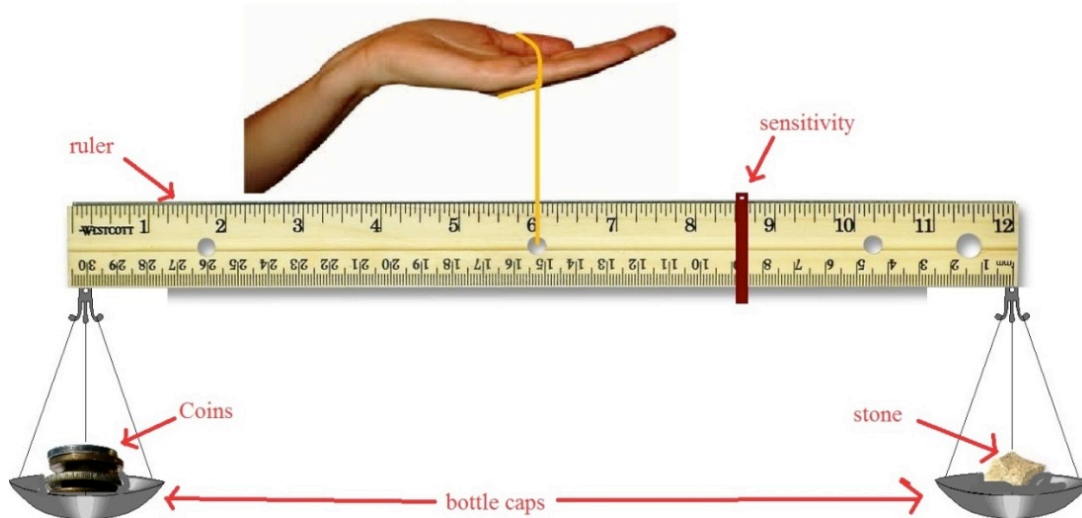
	Observation	Explanation	Prediction	Inquiry	Logic	Producing
N Valid	28	28	28	28	28	28
Mean	29.39	20.35	20.89	11.78	16.25	20.03
S.D	4.11	3.22	3.04	1.89	2.78	3.29
Variance	16.91	10.38	9.28	3.58	7.75	10.85
Minimum	19.00	14.00	14.00	9.00	8.00	15.00
Maximum	35.00	25.00	25.00	15.00	20.00	25.00

Table 2. Descriptive Statistics for SPSET

Student responses were input into SPSS 18 and means were calculated. Cronbach's alpha reliability coefficient of SPSET was found 0.84.

Content of Instruction

Prospective science and technology teachers attended the two-hour lecturers per-week in Physics Lab-I course. They were encouraged how to perform physics experiments using easily available low cost materials before lab course. On the other hand, researcher modified physics I lab syllabus by replacing specific laboratory equipments with low cost materials such as coins and paper clips instead of weight, thread reel instead of pulley, hole punched wooden ruler instead of equal-arm balance etc. in seven experiments which were; 1) Measurement of mass with equal-arm balance 2) Velocity and acceleration, 3) Newton Laws and Atwood Machine, 4) Simple harmonic motion, 5) Changing Potential Energy, 6) Centripetal Force, 7) Kinetic and Static Friction Coefficient. Students worked in groups of at least 4 and maximum 6 students. An example of HoPE was shown in below.

Measurement of mass with equal-arm balance

Overview: Mass measurement is a fundamental skill in most physical sciences, including biology, chemistry, and earth science. Students must be familiar with mass measurement and properties in order to understand practical and theoretical topics in science.

Objectives: In this experiment, students deepen their understanding of the uses of the simple design equal-arm balance as they place a variety of objects in the pails and observe and compare the results. Also, they find out how much they can trust their balance in answering questions.

Hypothesis: Predict about the individual weights of each object in the pair, as well as which object will be heavier and by how much.

Materials: Wooden or plastic ruler, coins, stones, bottle caps, tightrope, paper clips (Hint: paper clip to nearest 1 g, mass of 1 kuruş is 2.2 g (kuruş is Turkish coin), mass of 5 kuruş is equal to 2,9 g, 25 kuruş is equal to 4 g, 50 kuruş is equal to 6,8 g).

Procedures: Take a wood or plastic ruler and make a hole in the center of it. Make two weighing pans from bottle caps and tie them to ruler. First of all, move the rider (sensitivity) to the left and right when the cups are clean and empty for balance. Use coins for compensation weight and measure the stone's mass by using coins. Put the stone in right cap and for balancing, put the coins in left caps one by one and calculate the mass of stone five times to get a good average value. Record these calculations in your data sheet below:

Massing number	Balance reading	Massing number 2	Balance reading
1.		1.	
2.		2.	
3.		3.	
4.		4.	
5.		5.	

Compare and   discuss your data with your friends in your lab group.

Mathematical operation: An important aspect of doing experiment in physics is learning to take accurate measurements and to have an estimate of the error involved in making such measurements. You took five measurements of the same quantity for calculating the standard deviation. Now, calculate the average of your measurements and the difference between each of the measurements from the average. Sum the squares of the differences and divide by the number of measurements. Take the square root and this is your standard deviation. In equation form this method looks like:

$$\sigma = \sqrt{\frac{\sum_i (a_i - \bar{a})^2}{n}},$$

where, σ is the standard deviation, a is a measurement, $\bar{a}$ is the average of the measurements and n is the number of measurements made.

Conclusion: What is your standard deviation? Why did you calculate same object in several times? Do you believe in accurate measurement?

Data Analysis

A correlation analysis was conducted to examine the study the possible role of HoPE on SPS. The Pearson's correlation was used to analyze and find out if there was a relationship between influence of HoPE on SPS and course achievement grades in SPSS 18 or if not. The value for a Pearson's correlation number changes between -1.00 (negative correlation), and 1.00 (perfect correlation). Microsoft excel used for graphic presentations and calculations.

Results and Discussion

The data of the study was analyzed, tabulated and presented in different tables. The following table shows teacher candidates' achievement and total SPS means and standard deviations.

	N	Minimum	Maximum	$\overline{X}$ (Mean)	SD
Achievement	28	47,00	78,00	61,39	7,79
Total SPS	28	87,00	141,00	118,71	15,95

Table 3. Teacher candidates' physics lab achievement and total SPS means

Table 3 shows that on the basis of their university assessment, participants' grade point average in physics lab course mean is 61.39 (SD = 7,79) over 100 and their perception of SPS average score is 118,71 (SD = 15,95) over 145. This finding evinced that teacher candidates' believe in HoPE can improve students' scientific process skills even if they have low average achievement grade regarding SPS score. In that case, this finding should be explained with different factors such as lack of practical experience, measurement error, exam anxiety and difficulties of conducting HoPE, etc. This result shows similarities to the research findings of Stohr-Hunt (1996).

The main purpose of study was to investigate according to the perceptions of prospective teachers about whether HoPE based science lab course is able to improve students' SPS. The findings were computed in Table 4.

		SPS
	Pearson Correlation	0,293
Achievement	Sig. (2-tailed)	0,130
	N	28

Table 4. Relation between prospective teachers HoPE and their academic achievement

Table 4 shows that although there was positive correlation between prospective teachers' perceptions about influence of HoPE on SPS and their academic achievement, the data points it isn't statistically acceptable (p=.13>.05). These finding is similarity with previous relevant studies (Walters and Soyibo, 2001; Bilgin, 2006; Sinan and Uşak, 2011) revealed that the students had good scientific process skills and a positive relationship between scientific process skills regarding course achievement grades. This relationship is shown graphically in Table 5.
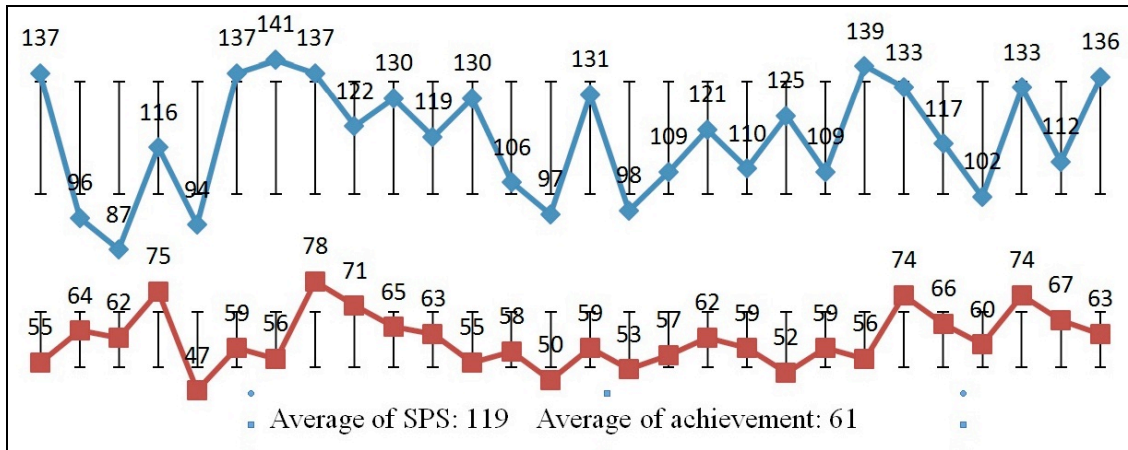
Table 5. *Students' average score of SPS and their average achievement with SD*

When comparing with students' average perception score about influence of HoPE on SPS and their average achievement grade in physics lab course as can be seen Table 3; %25 higher (S8,S9,S10,S18,S23,S26,S28) and %18 with a lower average achievement students (S2, S3,S4,S24,S27) stated that HoPE can improve SPS with a higher than average score. On the contrary, there are %25 higher (students S1, S6, S7, S12, S15, S20, S22) and %29 with a lower average students (student S5, S13, S14, S16, S17, S19, S21, S25) who indicated that HoPE can improve SPS with a lower than average score.

Table 6 shows the correlation between each SPS which are *observation*, *provide explanations*, *predicting*, *forming logic*, *making an inquiry*, *producing according to a plan* with students' achievement in physics I lab course.

Achievement	Observation	Producing	logic	Inquiry	Prediction	Explanation
Pearson Correlation	0,216	**0,385**[*]	0,243	0,290	0,200	0,214
Sig. (2-tailed)	0,270	0,043	0,213	0,135	0,308	0,274
N	28	28	28	28	28	28

*Correlation is significant at the 0.05 level (2-tailed).

Table 6. *Relation between each SPS and students' achievement scores*

In Table 6, although prospective teachers specified high score for HoPE whether able to improve SPS according to their experiences as seen table 2, it is found that there was no significant correlation between *observation skill score, providing explanations skill score, prediction skill score, making an inquiry skill score, forming logic skill score* and physics lab achievement. In contrast to this finding, there are significant relationships between the *producing according to a plan* skill, which improved by HoPE, and prospective teachers' physics lab achievement (Pearson r = .385 and p= .04 < .05). Educators should explain this finding and teachers may prepare science experiment syllabus for improving their students SPS when they haven't reach adequate laboratory equipment. Similarly, in this study, prospective teachers expressed positive opinions about science teaching with simple tools (Önen and Çömek, 2011).The findings of this study also support the findings of Ergül et al. (2011) who determined that use of inquiry based teaching methods significantly enhances students' SPS. These results are in a harmony with those of Önen and Çömek (2011) and Uzal et al. (2010).

Conclusion and Discussion

The laboratories have long been a distinctive feature of science education. Because, everyone knows that laboratory experiments provide students considerably learning science and developing their SPS. But, Modern experimental physics uses very sophisticated and expensive apparatus, for the most part, in large research institutes and several physics laboratories. Some schools don't have laboratory and their teachers can't do science experiment because of high-priced experiment apparatus. Thus most of experienced teachers have difficulties in doing experiment or they prefer not to do experiment due to lack of specific apparatus and adequate laboratory equipment (Ayas et al., 1994; Böyük et al., 2010). When analyzed new science and technology curriculum from this perspective it is understood that they recommended science teachers to do experiments with low cost material or child's toys instead of laboratory equipment. But teachers who are really sophisticated in their field can't use low cost material appropriately. So, science teachers must know how to do science experiments with low cost materials unlike they couldn't reach adequate laboratory equipment in their school.

In recent years, some courses were have been implemented to familiarize prospective teachers with linking Hands on science activities in some education faculties in Turkey (Ateş and Eryılmaz, 2011). It is expected that these course should be developed to prepare science experiment syllabus which able to improve SPS such as formulating models, constructing tables of data and graphs, identifying and controlling variables skills as new science and technology program recognized. In that time teacher candidates, when they need, can prepare science experiments syllabus that include low cost materials instead of laboratory equipment for improving their students' SPS.

Overall then, the author do not claim that there are relationship between hands-on science and achievement. Because, although science education curricula focused on research that has found a relationship with achievement, studies have not supported the relationship between hands-on science and student achievement (Ruby, 2001). To sum up, Jaus (1975) reiterates the vital message that teachers must be recognized the science process skills because they design activities for teaching these skills to their students.

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