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An Investigation of the Relationship between Science Process Skills with Efficient Laboratory Use and Science Achievement in Chemistry Education

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ABSTRACT

The present study aims to investigate whether science process skills and efficient laboratory use are significantly correlated with the university students' basic chemistry course achievement. The Questionnaire for Student Opinions on their Scientific Process Skills was used to determine the extent to which science process skills that were taught in laboratory applications from the students' perspective. The Efficient Laboratory Attitude Scale was employed to assess whether they used laboratories effectively. And the students' course achievement scores were measured by using the Science Achievement Test. The sample consisted of 180 university students who took the general chemistry course at a state university in the second semester of the academic year 2006–2007.

A positively significant and linear relationship was found between science process skills taught in laboratory applications and efficient laboratory use of the students; between their efficient laboratory use and their achievement in the course; and between their science process skills and achievement in the course.

Keywords: Basic and High-Level Science Process Skills; Efficient Laboratory Use; Academic Achievement.

INTRODUCTION

In today's age of science and technology when scientific knowledge has grown exponentially, technological innovations have progressed at a rapid pace, and the effects of science and technology are clearly witnessed in all aspects of our lives, it is obvious that science and technology education plays a key role for the futures of societies. Because of its importance, all societies and particularly developed countries have continuously sought to improve the quality of science and technology education (Aydoğdu, 2006).

In the present age, new information is constantly added to the existing information in chemistry education. Therefore, the main objective of chemistry education at secondary level should be to equip students with the skills of accessing information, rather than trying

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to transfer information to students. Instead of learning by rote, students should be equipped with problem solving skills for new situations and transferred accumulated knowledge properly. Furthermore, their skills of accessing and producing information should also be improved (Gedik, Ertepınar & Geban, 2002).

Laboratories play a significant role in effective chemistry education. Laboratory classes are supplementary to chemistry education and make up a crucial part of chemistry courses. Laboratories are very important to comprehend abstract chemistry concepts (Demirtaş, 2006).

Şahin-Pekmez (2001) inquired why science teachers felt they need to carry out experiments in their classes. Teachers' responses included:

- helping students understand and learn better,
- enhancing their interest in classes,
- improving their manual skills,
- helping them discover knowledge on their own,
- improving their observation skills,
- enhancing their problem-solving skills,
- ensuring students learn through experience.

Hofstein and Naaman (2007) reviewed and reported several studies conducted in various countries about laboratory applications. In their evaluation, they stated that laboratory applications aimed to enhance students' science process and problem-solving skills and their interest in and attitudes toward scientific approaches in accordance with the objectives of basic science education.

Garnett and Hackling (1995) argued that laboratories will contribute to improving students' conceptual understanding, application skills and techniques, and ability to analyze inter-variable relationships and chemical analyses-syntheses. The study aimed to demonstrate the importance of laboratory work in chemistry education for chemistry instructors. The authors highlighted the need to use student-active laboratory approaches so as to enhance students' research skills including problem analysis, research plans, research management, data recording, and interpretation of the findings.

Gott and Duggan (1995) and Şahin-Pekmez (2000) asked science teachers, "What kind of activities do you perform in science laboratories?" to which they received answers such as demonstration experiments, group work, and rotational experiments (weekly alternating performance of different experiments by each student). The results of the studies by Wilkinson and Ward (1997), Nott and Wellington (1997), and Hodson (1992) revealed that science teachers are not aware that various experiments they perform should have differing objectives. Laboratory applications make use of deduction (verification), induction, and research-based approaches. These approaches correspond to close-ended, open-ended, and hypothesis-testing experiments, respectively. Traditional laboratory applications in high-schools often employ the deductive approach. Laboratories should not only aim to reinforce theoretical knowledge, but also allow students to discover knowledge on their own. It should be noted that, these approaches should not be considered as completely independent processes (Ayas, Cepni, Johnson & Turgut, 1997).

Besides offering scientific knowledge, laboratory classes also contribute to improving student skills including, scientific thinking, observation, creative thinking, interpretation of events, data collection and analysis, and problem solving (Ausubel, 1968). Therefore, due importance should be attached to laboratory classes for chemistry education to achieve its goal.

In laboratory environment, these skills cannot be improved only through close-ended (deductive) experiments. Thus, the methods used in laboratories should be selected accordingly. As suggested by Hofstein and Lunetta (2003), students work like technicians in "cookbook" laboratory activities which focus on improving low-level skills and are still commonly used in laboratories. Students are provided with very few opportunities to have experimental discussions, to construct and test hypotheses or to design an experiment; that is, to conduct an authentic experiment (Lunetta & Tamir, 1979). Researchers reported that most laboratories at universities still employ the traditional "cookbook" approach (Tümay, 2001).

The Turkish case is not much different from those described in cited literature. Let alone discussing the sufficiency of our laboratories, it is well-known that demonstration experiments and verification laboratories are usually preferred. Thus, it is obvious that these laboratory activities fail to improve students' psychomotor skills sufficiently and to help them reconstruct knowledge on their own (Yeşilyurt, Bayraktar & Erdemir, 2004).

In order to construct knowledge on their own and to acquire problem-solving skills, students need to study in a laboratory environment that brings science process skills in prominence. Science process skills form the basis of the ability to conduct scientific research. These skills constitute a general definition of the logical and rational thought that an individual uses throughout his/her lifetime (Aydoğdu & Kesercioğlu, 2005). Studies aiming to equip students with science process skills have concluded that students acquire each science process skill through certain stages (Saat, 2004). These stages have been identified as recognition of scientific process, making habits, and automation. At the stage of recognition, a student recognizes the skill and related terms either in lower-grade chemistry classes or in the learning environment developed by the researcher. At the second stage, the student is familiarized with the process skills and can provide different examples related to these skills, but cannot use them in different areas as s/he is experiencing a mental confusion. At the third stage, s/he can easily define the terms related to the skills and can apply them to other situations. Laboratories should be used efficiently and classes should employ student-active learning processes for students to go through these stages easily (Aydoğdu & Kesercioğlu, 2005).

An effective laboratory environment requires the following conditions: teachers should be prepared and planned for classes and have previous experience for the experiment to be carried out in the class; students should have conceptual pre-knowledge about the experiment; students should be provided an environment to use and reinforce such knowledge; basic and higher-level science process skills should be used; links should be established between the subjects taught in classroom and laboratory and their daily lives; and the laboratory environment should introduce innovations. Furthermore, laboratory safety should be effectively maintained and safety awareness should be raised among students.

To equip students with science process skills in classroom environment, laboratories should be efficiently used by teachers and students and teachers themselves should possess these skills. Nevertheless, in numerous studies conducted with university students and prospective teachers demonstrated that they have insufficient science process skills. A teacher who is not properly equipped with these skills may experience difficulties to deliver these skills to his/her students (Lavrenz, 1975).

It is observed that the teachers not possessing science process skills and cannot use laboratories efficiently and avoid performing experimental activities, thus chemistry courses are mainly presented theoretically (Şahin-Pekmez, 2001).

Lack of chemistry labs in some schools; sharing physics, chemistry, and biology labs; unsafe labs due to the use of hazardous substances in experiments (Yılmaz, 2005); overcrowded classrooms (Johnstone, 1989); lack of time and materials; equipment costs (Millar, 2004); and insufficient laboratory applications in chemistry classes at schools due to the inability of teachers to use labs effectively and their negative attitudes toward laboratory applications (Ekici, Ekici & Taskin, 2002) all demonstrate the inefficient use of laboratories (Çepni, Şan, Gökdere & Küçük, 2001).

In their study, "Evaluating the Applications of Science Laboratory", Uluçınar, Cansaran and Karaca (2004) aimed to determine the extent to which the laboratory method is used in the teaching of science courses (physics-chemistry-biology and science) and teachers' opinions about the aim of such applications and their effects on learning. The participating teachers stated that they could not efficiently use laboratories in course instruction because of several reasons including, *insufficient laboratory conditions at schools and overcrowded classrooms* etc. The researchers suggested that for efficient laboratory applications; class sizes should be reduced; weekly hours of science courses should be increased; safety of laboratories should be enhanced; and teachers should be occasionally provided with in-service training about curricula innovations.

Accepting that the main objective of efficient chemistry education is to improve student skills of critical thinking, scientific operation, and comprehension of scientific meaning principles (Aydoğdu & Kesercioğlu, 2005), the present study aimed to determine how efficiently the laboratory applications are used and accordingly, the extent to which science process skills are taught in the studied school from the students' perspective. The study also sought answers to the following questions:

1. Is there a significant relationship between the basic science process skills used in chemistry education and students' course achievement from the students' perspective?
2. Is there a significant relationship between the higher-level science process skills used in an introductory chemistry course and students' course achievement from the students' perspective?
3. Is there a significant relationship between the reports prepared by the students at the end of laboratory classes and the basic and high-level science process skills used in laboratory classes?
4. Is there a significant relationship between efficiency of laboratory use, and the basic- and high-level science process skills and students' achievement in the courses?
5. Is there a significant relationship between efficiency of laboratory use and the reports prepared by the students at the end of the experiments?
6. Is there a significant difference between the achievement levels of the students who think that only basic science process skills are taught in their classes and those who think that high-level science process skills are taught along with basic skills in their classes?

METHODOLOGY

(a) Sample

The sample group of this study consisted of a total of 180 freshman students who took the Basic Chemistry course in a public university in the academic year of 2006-2007. The participants were selected from different departments at the school of engineering including industrial, mechanical, naval architecture, computer, and electric/electronic engineering. The study was conducted with a total of six classes, each containing 30 students.

(b) Data Collection Instruments

To collect data, to evaluate the study, to determine how efficiently the students used the laboratories and the extent to which basic and high-level science process skills are taught in laboratories, and to assess and evaluate the relationship between these skills and students' course achievements, the questionnaire for students' opinions on their Science Process Skills (SPS), Efficient Laboratory Attitude Scale (ELA), and Science Achievement Test (SAT) were developed and used as measurement instruments in the study.

i- The Questionnaire for Students' Opinions on their Science Process Skills (SPS): This scale was developed by the researcher to determine to what extent students believe that teachers use basic (BSPS) and high-level science process skills (HSPS) in laboratory classes. A literature review on science process skills revealed different classifications of the process skills **(**Ergin, Şahin-Pekmez & Öngel-Erdal, 2005; Gabel, 1992; Lancour, 2005; Rezba, Fiel & Funk, 1995; Smith, 1995; Valentino, 2006). In order to develop the scale, literature review was followed by the formulation of statements that represent basic and high-level science process skills (Ergin, Şahin-Pekmez & Öngel-Erdal, 2005). The following order was applied while writing down the statements:

- **Identification of the Problem**
  1. Identifying the problem, defining the problem
  2. Hypothesis construction – estimation
- **Identification of the Variables and Experiment Design**
  1. Designing experiments according to the hypotheses
  2. Identification of the dependent and independent variables
  3. Organizing the variables and constant values according the hypothesis
  4. Selecting the right research method
- **Observation, Assessment, and Data Collection**
  1. Selecting an appropriate measuring instrument
  2. Correctly selecting the variable to be observed
  3. Selection of appropriate tools and materials for observation
  4. Estimating the result of the observation
- **Classification**
  1. Classification of the observed events
  2. Identifying the similarities and differences between events
  3. Identifying qualitative and quantitative aspects
- **Processing and Visual Representation of Obtained Data**
  1. Preparing tables for the observed variable
  2. Checking the relationship between variables
  3. Graphing the obtained data
  4. Tabulating the obtained data
- **Interpretation and Evaluation**
  1. Checking the reliability of the obtained results
  2. Determining whether the aim was achieved using the obtained data
  3. Interpreting the conclusion of the experiment using data
  4. Comparison of the results and the hypothesis
  5. Determining the conditions under which the obtained data will be valid
  6. Accepting or modifying the hypothesis
  7. Inquiring and speculating about the reasons for committing errors

Formulated by the researcher and representing the abovementioned scientific processes skills, a total of 54 (Basic Level = 22; High Level= 32) items were examined and the scale was subjected to content validity analysis by experts (an expert of assessment and evaluation, an expert in chemistry education, and an expert in program development). As a result of content validity analysis, some of the items were modified and four items were removed from the scale (1 Basic Level, 3 High Level) before the pilot application. As a pilot study, the questionnaire was administered to 356 students enrolled in various departments of the school of engineering at a state university. The participants of the pilot study previously took the general chemistry course and laboratory classes in the fall semester of the academic year of 2006-2007. Using the pilot study, the comprehensibility of the scale was measured to sort out the complex terms and to remove the items that were inappropriate for the students' levels. The structural validity of the scale was examined through factor analysis and item-total correlations.

Before conducting the factor analysis, suitability of the data to factor analysis was assessed by Kaiser-Meyer-Olkin (KMO) and Barlett's sphericity tests. In the study, the KMO value of the scale was found to be 0.93. The value of 0.93 in this case was quite high and demonstrated that the data were suitable for factor analysis (Leech, Barrett & Morgan, 2005). Barlett's sphericity test is used to test whether the data belong to a multivariable normal distribution (Tavşancıl, 2002). The test result shows that the data has a normal distribution[34889.3 ($p< 0.000$)]. Thus, the results of the KMO and Barlett's tests revealed that a factor analysis can be performed on the data, or the data were suitable for a factor analysis.

The factor analysis was started with 50 items – 21 basic-level and 29 high-level. Examination of the initial results of the analysis revealed that the eigenvalue of the scale was three factors greater than 1 and the total variance explained by these factors was 45.53%. The data were examined using the varimax orthogonal rotation technique. As a result, items with item-total correlations were smaller than 0.30 (6 (1 from the 1st factor, 3 from the 2nd factor, 2 from the 3rd factor) items); items with factor loading values were below 0.45 (8 (3 from the 1st factor, 2 from the 2nd factor, 3 from the 3rd factor) items); and overlapping items with a difference between the two factor loadings were smaller than 0.10 (6 (1 from the 1st factor, 4 from the 2nd factor, 1 from the 3rd factor) items) were removed from the scale. Then, the rotation procedure was repeated twice. After the second rotation operation, it was observed that there were no items that exhibited overlapping and the scale's eigenvalue was two factors greater than 1. The final version of the scale consisted of 2 factors and 30 (14 basic-level, 16 high-level) items, as shown by the factor analysis. The variance explained by the two factors was 41.51%. This study calculated the Cronbach's alpha, the internal consistency coefficient commonly used to determine whether the items of a scale are consistent with each other. The Cronbach's ά- internal consistency coefficient was calculated to be 0.90 for all items of the five-point Likert-type rating scale.

ii- Efficient Laboratory Attitude Scale (ELA) : This scale was originally developed by Tüysüz, Kartal and Feyzioğlu (2008) to assess student attitudes and opinions about the efficient use of laboratories in chemistry education. As a five-point Likert-type rating scale, the scale was designed in two stages: preparation stage before the experiment and activities in the application stage. The preparation stage before the experiment contains the following components:

- Whether the teacher personally performs the experiment before the application
- Preparation of experiment materials and setup
- Addition of laboratory applications into the curricula

- Planning.

The application stage contains the following components:

- Method employed by the teacher
- Efficient use of time (planning)
- Sufficient use of technology
- Laboratory safety
- Adequate materials and physical environment
- Association with daily life
- Evaluation.

The Cronbach's ά- internal consistency coefficient of the scale containing 20 attitude statements was calculated to be 0.86.

iii- Science Achievement Test (SAT): The SAT was designed by the researcher and the chemistry instructors in the studied school to assess students' science achievements about the subjects of radioactivity and electrochemistry. The test consisted of 20 multiple choice and 6 open-ended questions. The multiple-choice section of the test had a Cronbach's ά- internal consistency coefficient of 0.78. The open-ended questions were prepared and revised upon the advice of the chemistry instructors.

iv- Experiment Reports (ER): ERs were prepared by the students at the end of each laboratory class to assess to what extent they can apply and report on the science process skills during laboratory experiments.

Table 1. *Evaluation Criteria for Experiment Reports*

TYPE OF EXPERIMENT	**Semi-Open-Ended Experiment**	**Open-Ended Experiment**	**Hypothesis-Based Experiment**
Criterion	Score	Score	Score
Does the student know about the experimental purpose, procedure, and the materials to be used?	-	1	1
Did s/he define the problem correctly?	1	1	1
Did s/he construct a hypothesis?	-	-	1
Did s/he manage to design the experiment?	-	1.5	1
Did s/he manage to set up the experiment?	-	1.5	1
Did s/he manage to identify the dependent and independent variables and the constant value?	-	-	1
Did s/he manage to perform the measurement using the right measuring instruments?	-	-	1
Did s/he manage to interpret the causes of the events on the basis of observation?	2	1	0.5
Did s/he use tables or graphs to define the problem or when evaluating the data?	2	1	0.5
Did s/he manage to compare (his/her) hypothesis and results to arrive at a generalization?	2	1	1
Did s/he manage to identify and interpret the sources of errors?	1	1	0.5
Did s/he manage to link the result of the experiment with theoretical knowledge correctly?	2	1	0.5
Total	**10**	**10**	**10**

The student reports were examined and evaluated separately for each experiment type according to the criteria in Table 1 by three chemistry instructors employed at a university. The mean of the three evaluators' scores for each student was calculated and reported.

(c) Procedures

The study was conducted using the relational survey model, which aims to determine the presence and the level of change between two or more variables, and the single-group posttest-only design, in which the independent variable is applied on a single group to examine its effect on the dependent variable (Karasar, 2003). The application data were collected during and at the end of the process in which the students took the General Chemistry II and General Chemistry Laboratory II courses. Six classes (30 students in each class) participated in the study. The students received weekly two hours of general chemistry and another two hours of general chemistry laboratory courses. Laboratory applications were performed with groups of three or four. The laboratories had sufficient chemicals and equipments and experimental setup was sufficient for all groups. General chemistry course and the laboratory applications were conducted in a parallel fashion.

Laboratory applications were carried out in the study by using three different methods:

Semi-Open-Ended Experiments: In this method, the students were informed about the purpose of the experiment, what materials they would use, and how they will conduct the experiment and were asked to find solutions by themselves (Aydoğdu & Kesercioğlu, 2005). Experiments about determination of radioactive rays and Cu-Zn Galvanic Battery and measurement of its electromotive force (emf) were performed by this method.

The concepts of electrochemical battery, galvanic battery, emf, factors that affect emf and the Nernst equation were taught in general chemistry course. Subsequently, in the laboratory application, the students were asked to form a galvanic battery and calculate the electrochemical battery potential using the given materials. Students were guided in experimental setup and performance and were asked to estimate the results. They compared their estimates and the results they obtained at the end of the experiment and presented their work in a report.

Open-Ended Experiments: In this method, the students were informed about the purpose of the experiment and provided with the required materials. Then, students are required to conduct the experiment and report the results (Aydoğdu & Kesercioğlu, 2005). Electronic and ionic conductivity, electrolysis of water and Faraday's law, fuel cell, and corrosion experiments were carried out by using this method.

The students were taught the related concepts in the general chemistry course and they were asked to establish links between the concepts in laboratory environment. For instance, the students were introduced with fuel cells, a PEM fuel cell, and a solar cell in the general chemistry course and were asked to demonstrate their energy conversions using these cells in laboratory class. To demonstrate the energy conversions, students need to construct the correct experimental set-up using the cells and to correctly explain the reaction mechanisms occurring in the cells. Open-ended experiments took longer than semi-open-ended experiments to carry out since students spent a long time on constructing the correct experimental set-up. The students received support from the supplementary textbooks, internet and course instructor to construct the experimental setup and understand the reaction mechanisms occurring in the cells. Students' reports were examined in accordance with the experimental setup they constructed; how they carried out the experiment; the links they established between theoretical knowledge and the experiment; and their interpretations of the obtained results.

Hypothesis-Based Experiments: In this method, a problem was formulated in accordance with course requirements and the students were asked to construct a hypothesis and perform an experiment to prove their hypothesis in order to solve this problem. The problem case was given in a scenario in the general chemistry course and the students were asked to construct hypotheses to solve the problem in class. The scenario was provided in two steps for students to limit their hypotheses and be guided toward the correct problem. In the second step, the next part of the scenario, the hypotheses constructed in the first step, were sorted out. This method was used for the concentration cell formation and the wet corrosion experiment. For instance, the students were given the following problem about corrosion and asked to solve it:

"Although it had been subjected to yearly maintenance in the dockyard only two months ago, corrosion was observed in the lower parts of a ship. Though recently undergone maintenance, what might the cause of corrosion in the ship?"

The students constructed the following hypotheses:

- The maintenance might have been inadequate
- After maintenance, the ship might have been damaged particularly in the corroded part
- The corroded part of the ship was not properly painted.
- Corrosion in two months is normal.

The scenario continued in general chemistry course: "Seriously corroded, the ship was taken to the dockyard and the corroded part was examined. The technicians in the dockyard said that they were surprised at seeing a recently-maintained ship underwent such serious damage. In fact, during a storm that broke out last year, the ship hit the quay on the corroded area and the paint on this part was observed to be removed. A second point of interest for the technicians was that the damaged part was not completely damaged; instead, the bottom part of the ship was corroded in particular." In order to solve the given problem, the students were required to hypothesize after researching. The experiments designed by the groups in accordance with their hypotheses were examined and they were asked to carry out experiments by providing the required materials and taking into account the laboratory conditions. As different from the other methods, another four hours were spent on the laboratory application in this method. The students' reports were evaluated based on a set of criteria including their hypotheses; the variables they identified and the experiment setups they constructed in accordance with their hypotheses; their experimental procedures; and linking their experiment with correct theoretical knowledge. The laboratory work performed during the application period is shown in the table below.

Table 2. The Experiments Performed and the Methods Used During the Application Period

Subject	Name of Experiment	Type of Experiment
Radioactivity	Determination of radioactive rays	Semi-open-ended experiment
Electrochemistry	Electronic and ionic conductivity	open-ended experiment
	Electrolysis of water and Faraday's Law	open-ended experiment
	Cu-Zn Galvanic Battery and Measurement of its emf	Semi-open-ended experiment
	Fuel cell	open-ended experiment
	Corrosion	open-ended experiment
	Concentration cell formation and wet corrosion	Hypothesis-based experiment

The students were allowed time to write their reports after they finished the experiments. Although the experiments were conducted in a group environment, students were asked to write their reports individually. The reports received at the end of each experiment were evaluated according to the criteria for evaluating experiment reports.

At the end of the application, the students' effective laboratory use, high and basic level science process skills, and course achievement were determined by administering the

SPS, the ELA, and the SAT.

The data obtained in the study were analyzed by using the SPSS statistical program. The following methods were used in the analyses:

- Correlation analysis to determine whether there was a significant relationship between the variables,
- Regression analysis to express the relationship between the variables, and
- T-test to compare the achievement levels of the students who stated that basic-level and high-level science process skills were taught in laboratory applications.

In the analysis of the application data, the number of students was represented by (N), mean values by (X), standard deviations by (S.S.), mean standard deviations by (δ), t values between a group's pre- and posttests or between groups by (t), degree of regression by (r), p values by (p).

The p values were examined to determine whether there was a significant relationship between the variables and whether there was a significant difference when comparing the groups. It was assumed that there was no significant difference when $p>.05$ and there was a significant difference when $p<.05$.

RESULTS

In order to determine how efficiently the laboratory applications are used and the extent to which science process skills are taught, the following relationships were examined by applying ***Pearson's correlation analysis***:

- The relationship between the students' course achievement (SAT) and their responses concerning the extent to which basic science process skills (BSPS) are taught in course,
- The relationship between students' course achievement (SAT) and their responses concerning the extent to which high-level science process skills (HSPS) are taught in course,
- The relationship between the reports that students prepared at the end of each experiment (ER) and HSPS and BSPS in laboratory classes,
- Whether there was a significant relationship between the reports that students prepared at the end of each experiment (ER) and the efficiency of laboratory use (ELA),
- The relationship between the efficiency of laboratory use (ELA) and high-level science process skills (HSPS) used in laboratory applications, basic-level science process skills (BSPS), and the students' course achievement (SAT).

An examination of the results of the Pearson's correlation analysis (see Table 3) revealed that there is a significant and a positively linear relationship between the students' course achievement (SAT), and basic-level science process skills (BSPS) used in laboratory applications as well as high-level science process skills (HSPS) ($r=0.608$, $p=0.000$ SAT-BSPS; $r=0.746$, $p=0.000$ SAT-HSPS).

As can be seen in Table 4, the results of the analysis regarding the relationship between experiment reports (ER), and high-level science process skills (HSPS) used in classes and basic-level science process skills (BSPS) were examined. According to r values and p ($p<.005$) significance levels, a significant and a positively linear relationship was found between them ($r=0.487$, $p=0.000$ ER-BSPS; $r=0.524$, $p=0.000$ ER-HSPS).

Table 3. *Results of the Pearson's Correlation Analysis*

N=180	**Correlation**	
	r (correlation coefficient)	**P significance level**
SAT-BSPS	0.608	0.000
SAT-HSPS	0.746	0.000
BSPS-ER	0.487	0.000
HSPS-ER	0.524	0.000
ELA-ER	0.673	0.000
BSPS-ELA	0.410	0.000
HSPS-ELA	0.661	0.000
SAT-ELA	0.858	0.000

The p values in Table 3 demonstrate that there is a significant relationship between the efficiency of laboratory use (ELA), basic-level science process skills used in classes (BSPS), high-level science process skills (HSPS), and course achievement (SAT). A comparison of the r values showed that the students believed that high-level science process skills were predominantly taught along with basic-level science process skills in courses where the laboratory was used more efficiently. (r=0.661 HSPS-ELA, r=0.44 BSPS-ELA).

Moreover, a positively linear relationship was found between efficient laboratory use (ELA) and course achievement (r=0.858). This value demonstrates that efficient laboratory use was correlated with high-level science process skills and the students' course achievement.

As can be seen in Table 3, an examination of the relationship between efficient laboratory use (ELA) and experiment reports (ER) revealed that there is a significant relationship between them according to p values (p=0.000).

The relationship between some examples selected from the open-ended questions of the science achievement test and experiment reports and science process skills was also examined. Below is an example of the open-ended questions of the science achievement test concerning concentration cell formation and wet corrosion.

> *"A metal immersed in seawater will have corrosion after a while. Discuss the cause of corrosion formation on the metal figure and write down the reaction equations for the resulting cell. Given that solubility of oxygen in water is 9 ppm at 1 atm pressure at 20^0C and 3 ppm at 85 ^0C, find the emf of the concentration cell above."*

This question probed the students' understanding of the formation of wet corrosion and the concentration cell. At this stage, the students were asked to show the cathode and anode on the metal, to write down the anode and cathode reactions, and to find the emf of the concentration cell. During the laboratory applications before the test, they were asked to solve a given problem situation about wet corrosion. In the experiment reports prepared following the laboratory applications, the students were expected to correctly define the problem, to construct hypotheses that solve the problem and explain the situation, to design an experiment suitable for the problem, and to construct the experiment setup. They were also supposed to make accurate measurements after correctly identifying the variables, to plot their measurements on graphs and tables to interpret them, and to compare their results with their hypotheses. Another evaluation criterion for the experiment reports was the extent to which they used theoretical information when comparing their results with their hypotheses. An examination of the reported results obtained from the experiment about concentration cell formation and wet corrosion based on the abovementioned hypothesis and students' performance on the related question in the science achievement test revealed that 125 of 180 students successfully answered the question (a student receiving 5 pts or more on a question out of 10 pts was deemed as successful), while 55 of them were considered as unsuccessful. Similarly, in the experiment reports, 132 of 180 students were determined to be successful in this experiment and 48 were unsuccessful. The students who correctly answered this question in the science achievement test were also observed scoring high in their student reports. Furthermore, detailed analyses of the reports revealed that existence of the criterion -required during preparation of the reports - comprising high-level science process skills increases students' academic achievement rates in laboratory applications.

Another open-ended question in the science achievement test concerned Cu-Zn galvanic battery and measurement of its emf. The students were asked to identify the anode and cathode poles; to write down the reactions occurring in these poles; and to calculate the battery's emf. Semi-open-ended experiments were used for Cu-Zn galvanic battery and the measurement of its emf in the laboratory application prior to the test. In their experiment reports, students were specifically evaluated according to their skills of using tables and graphs when defining the problem and recording the data, comparing the hypotheses with the results of the experiment, linking the experiment results with theoretical knowledge, and interpreting on the basis of observation about the causes of events.

An examination of the reported results obtained from the experiment on Cu-Zn galvanic battery and measurement of its emf and the students' performance in the related question in the science achievement test revealed that 148 of 180 students successfully answered the question (a student receiving 5 pts or more on a question out of 10 pts was deemed as successful), while 32 were regarded as unsuccessful. In the experiment reports, 157 of 180 students were determined to be successful in this experiment and 23 were unsuccessful. The students who correctly answered this question in the science achievement test were also observed scoring high in their student reports. Furthermore, an examination of the reports revealed that the success rate was higher in the laboratory applications including high-level science process skills as the mentioned criteria contained both basic- and high-level science process skills.

Another open-ended question in the science achievement test concerned the PEM fuel cell. In this question, the students were asked to write down the reactions occurring in the anode and cathode of the cell, to show the movement of electrons and ions and gas egress on the experiment setup, and to calculate the cell's emf. Open-ended experiments were carried out on the PEM fuel cell in the laboratory applications prior to the test. In their experiment reports, students were evaluated according to their skills of constructing experimental setup, linking the experiment results with theoretical knowledge, and interpreting their results.

An examination of the reported results obtained from the experiment on PEM fuel cell and measurement of its emf and students' performance on the related question in the science achievement test revealed that 156 of 180 students successfully answered the question (a student receiving 5 pts or more on a question out of 10 pts was deemed as successful), while 24 of them were considered as unsuccessful. In the experiment reports, 165 of 180 students were determined to be successful in this experiment and 15 were unsuccessful. The students who correctly answered this question in the science achievement test were also observed scoring high in their student reports. Furthermore, an examination of the reports revealed that the success rate was higher in the laboratory applications including basic-level science process skills as the mentioned criteria contained basic-level science process skills.

The t-test was performed to compare the course achievement of the students who stated that basic-level science process skills were more commonly taught in laboratory applications and those who stated that high-level science process skills were more commonly taught. To make these comparisons, the students were grouped according to the scores they had in the science achievement test (SAT). As a score of 50 or above was considered as passing grade at the university, students who scored 50 or above were deemed as successful and those scoring below 50 were deemed as unsuccessful.

The responses of successful and unsuccessful students on the basic- and high-level scientific skills scale were compared. Before the comparison, data distribution graphs were examined and the distribution was observed being normal according to the analysis of homogeneous variance p>0.05 (p=1.09). With a normal distribution, the t-test, a parametric analysis method, was used in data comparison.

Table 4. *Results of Between-Groups t-test (p<0.05)*

GROUPS	N	X	SS	P
HSPS-UNSUCCESSFUL	38	42.0000	5.85870	0.000
HSPS-SUCCESSFUL	142	57.8947	6.62832	
BSPS-UNSUCCESSFUL	38	40.4474	6.67669	0.001
BSPS-SUCCESSFUL	142	57.6053	9.18147	

An examination of Table 4 demonstrates that there is significant difference in favour of successful students between the successful and unsuccessful students in the chemistry course who stated that high-level science process skills are mostly used in their classes (p=0.000).

Similarly, there is significant difference in favor of successful students between the successful and unsuccessful students in the chemistry course who stated that basic-level science process skills are mostly used in their classes (p=0.001).

DISCUSSION

For efficient use of laboratories, teachers should have a positive attitude toward laboratory use and the laboratory environment in which they work should have suitable conditions. A study by EARGED (1995) revealed that due to inadequate space and equipment, overcrowded classrooms, lack of laboratory technicians, and intensive curricula, teachers developed negative attitudes toward laboratory environment and as a result, laboratories are not used efficiently (Ekici, Ekici & Taşkın, 2002; Çepni et al., 2001).

In a study titled “Rediscovering the Lab”, Renner et al. (1986) argued that no one doubts that laboratory applications are important for science education. However, in the following parts of his study, Renner et al. (1986) underlined the fact that most laboratory guides create the impression in students’ minds that the aim of laboratories is to confirm what is told by a teacher, a coursework, or another authority, which is not the actual role of laboratories. In the laboratories of universities and colleges where the traditional verification method is employed, students work like technicians and only improve their low-level skills. On the other hand, laboratory applications including practices such as hypothesis construction, testing, and designing experiments that require high-level skills are not taught due to inefficient use of labs. Studies have demonstrated that science process skills are not improved in cases where laboratories are not used efficiently (Hofstein & Naaman, 2007; Lunetta & Tamir, 1979; Tümay, 2001). The significant and high correlations between efficient laboratory use, the experiment types used, and basic- and high-level science process skills are consistent with the results of the previous studies.

Factors affecting efficient use of laboratories include the use of laboratory methods that can reveal science process skills, preparedness of teachers for laboratory applications, employing technological innovations in laboratory environment, and establishing links between laboratory work, daily life, and conceptual knowledge. Students are expected to employ their science process skills in the process if labs are effectively used in accordance with these criteria. Reports prepared at the end of the experiments would provide clues to what extent laboratories are used efficiently in this process.

According to the study criteria, students with a high performance in their experiment reports were also observed having high academic achievement levels. Students stated that high-level science process skills were more commonly taught in laboratory applications that employ the open-ended and hypothesis-based experiment types. An examination of the student reports also showed that the predominant use of high-level science process skills in laboratory applications is confirmed by the fact that each group constructed different experimental setups that served the same purpose; that the constructed hypotheses and determined variables were specific to each group; the tables and graphs drawn were shaped by the variables; and that each student presented different interpretations when linking theoretical information with their experiment. The reports about the corrosion experiment revealed that the students constructed different experimental setups to explain corrosion. Some students tried to explain corrosion by observing the color changes that occurred on metal bars in a corrosive solution, while others attempted to explain it by connecting the metals immersed in seawater to an electrical circuit and observing the resultant voltage changes in the circuit.

Myers (2004) examined the effects of research laboratories on students' science process skills and found that students instructed by using the research lab approach had higher levels of science process skills and content knowledge when compared to students taught by traditional methods. As observed in students' reports, although open-ended experiments were carried out in laboratory applications, the initial experiment reports revealed that applications that employed high-level science process skills were not properly reflected in the experiment reports. German, Aram and Burke (1996) investigated the effect of higher-order thinking skills of question posing, inquiry, and modeling on students doing experiments. It was observed that high-level science process skills employed in laboratory applications were reflected in the last experiment reports, more than they were reflected in the initial student reports.

In the study, students were first introduced to the concepts in the general chemistry course related to experiments (semi-open-ended or open-ended) to be carried out. Then, students were asked to examine the relations among these concepts. Presentation of the concepts concerning the lab experiment during general chemistry classes before the laboratory classes and reinforcing these concepts in a laboratory environment might help increase success (Doğan et al., 2002). Prior to the hypothesis-based experiments, a problem containing the experimental concept was given, instead of the concept itself. Students' skills of correctly solving the problem and linking the result with correct concepts were observed. Ergin, Şahin-Pekmez & Öngel-Erdal (2005) argue that conceptual knowledge is not always required to solve a problem, which can also be solved by using science process skills.

A high correlation was also detected in the study between science process skills and students' academic achievement. A review of the related literature revealed that there is a positive relationship between science process skills and students' academic achievement (Doğan et al., 2002; Harlen, 1999; Jackson, 2000; Koray et al., 2007; Özdemir, 2004; Saat, 2004; Sittirug, 1997; Tamir, 1997; Unutkan, 2006). German (1994) examined various variables that might have direct or indirect influence in acquiring science process skills. In this study, the author found that students' cognitive development and academic competency have the strongest influence on their science process skills. Ferreira (2004) examined the relationship between academic achievement and science process skills and underlined those affective activities, cooperative learning, and basic and high-level science process skills should be promoted. The results of the present study also revealed a significant difference between the successful and unsuccessful students in favor of successful students in the chemistry course who stated that high-level science process skills are mostly used in their classes. An active participation of students in classes was achieved in a laboratory environment by employing science process skills. As reported by Turpin (2000) and Mabie and Baker (1996), students with the ability to define a problem, construct hypotheses, design experiments, and interpret data have higher academic achievement levels than they have in teacher-centered learning environments.

CONCLUSIONS

The present study aimed to determine how efficiently the laboratory applications are used and furthermore, the extents to which science process skills are taught in the studied school from the students' perspective. Moreover, the relationship between the efficiency of laboratory use and science process skills and academic achievement was also examined by taking into consideration students' experiment reports. The statistical analyses revealed the following results:

- A significant and positively linear relationship was found between the extent to which basic-level science process skills and high-level science process skills are taught in laboratory applications and students' course achievements (for SAT-BSPS, $r=0.608$; $p=0.000$; for SAT-HSPS, $r=0.746$; $p=0.000$).
- A significant difference was found in terms of academic achievement between the successful and unsuccessful students in a general chemistry course in favor of successful students who thought that high-level science process skills are mostly used in laboratory applications. Similarly, there was a significant difference was found in terms of academic achievement between the successful and unsuccessful students in basic chemistry course in favor of successful students who thought that basic-level science process skills are used in laboratory applications.
- A significant and positively linear relationship was found between the reports prepared by students at the end of the laboratory classes and basic- and high-level science process skills dealt with during the laboratory applications (for BSPS, $r = 0.487$; for HSPS, $r = 0.524$, $p= 0,000$ for both).
- A significant and positive relationship was found between efficient laboratory use and the reports prepared by students at the end of the experiments ($r = 0.653$, $p= 0.000$).
- A significant relationship was found between efficient laboratory use, and basic- and high-level science process skills and students' course achievement.

In the light of all these findings, the following recommendations can be noted to guide future studies:

Considering that laboratory applications improve students' science process and problem-solving skills and enhance their interests and attitudes towards scientific approaches in accordance with the objective of basic science education, as stated by

Hofstein and Naaman (2007), laboratory applications should be employed for more effective chemistry education.

Laboratories should not only serve the aim of reinforcing theoretical knowledge, but they should also allow students to discover knowledge on their own. Therefore, there is a need to use student-active laboratory approaches that aim to enhance students' research skills including problem analysis, research plans, research management, data recording, and interpretation of findings (Garnett et al., 1995; Lunetta & Tamir, 1979; Tümay, 2001).

Students acquire each scientific process skill through certain stages (Saat, 2004). Thus, laboratory applications containing science process skills should be continuously employed in chemistry courses.

Given that the main purpose of science courses is to equip students with the skills of scientific process, problem-solving, and accessing and producing knowledge (Gedik, Ertepınar & Geban, 2002; TTKB, 2007), the following recommendations are noted for efficient use of laboratories by students:

- Existing physical conditions should be improved in the best way possible,
- Safety measures should be taken in labs and teachers and awareness should be raised among students about safety issues,
- Provision of laboratory materials, equipment, and devices should become a priority at schools,
- Teachers should be informed about laboratory methods and science process skills,
- Planning the curricula for chemistry courses in a flexible manner so that they can include open-ended and hypothesis-based experiments, which require much longer time allotment than close-ended and demonstration experiments.

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