The Effects of a Laboratory Approaches on the Development of University Students' Science Process Skills and Conceptual Achievement

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Abstract

The purpose of this study was to compare the effects a laboratory based on the 7E learning cycle model with verification laboratory approach on university students' development of science process skills and conceptual achievement.

In this study the sample consisted of 81 freshman university students who were taking the General Physics Laboratory-I- course at the university in Türkiye. In this study pretest-posttest design with control group was used. The night class students (43) who took lower weighted standard points from university entrance exam (UEE) than day class students were selected as experimental group. Day class students (38) were selected as control group. Thus, this study was quasi-experimental in design.

In order to assess hypotheses of study was used "Science Process Skills Test-SPST" and "Force Concept Inventory -FCI" to compare skills and conceptual achievement of control and experimental groups students. Both tools were given to both groups as pretest and posttest.

Results of the analyses showed that there was a significant difference between the effect of verification laboratory approach and the laboratory approach based on 7E learning cycle model on development of students' science process skills and conceptual achievement. The findings of study suggest that the the laboratory approach based on 7E learning cycle model applications are more effective than the traditional verification laboratory approach applications to development of students' science process skills and remedy students' misconceptions about force and motion.

Introduction

The great knowledge explosion enlarges the knowledge repertoire of all the science branches in every passing minute. It is getting harder to follow the new realities which are commonly discovered by the addition of permanent changes and different dimensions. Even though the understanding that "the scientific knowledge must be given to the students by transferring it" is still regarded as one of the pillars of science education in our country, it has proven completely outdated in the vast majority of countries in the world. Considering this reality, that is why these questions must be addressed: "*How will the students reach the knowledge? How will they comprehend the nature of the scientific studies? Why should science be taught? Is science necessary for every student? What is the best method to teach science?*" These questions are the ones that are occupying the minds of science education researchers.

To answer these questions, while “Individualized Instruction” was in vogue at one period, “C*ooperative Learning”* was adopted by teachers afterwards. *Discovery Learning* was in vogue in 1960s. Then it came to agenda on inquiry science education studies; and then on “*Science-Technology-Society*”. Today, researchers turned back to inquiry and discovery (Alan, 2000). Is the reason of all these changes a search for a collective notion that is trying to integrate or unite learning strategies? Is there a single theory or at least approach that can unite all these learning theories of science teachers?

The aforementioned theories most of which were named as only a passing whim in science education are to sit on a strong basis. The studies made in the last years showed that “Constructivist Theory” has the potential to provide this unification. Besides this potential of the theory which has philosophical roots, many science teachers evaluate application of this theory as difficult and far from practically (Boddy, Watson and Aubusson, 2003). This is the reason why more accurate, easier and actively usable strategies and models have been developed to strengthen education based on this theory. 3E, 5E and lastly 7E Learning Cycles are the learning methods that take this theory as basis (Lawson 1995, 2001; Eisenkraft, 2003). One of the most basic truths that these models are for is: “T*he students must have some skills to reach the knowledge or to make scientific studies*”. These skills known as “Science Process Skills” or “Inquiry Skills” in the literature are actually present in the very natures of the students (Ostlund, 1992; Rezba et. al., 1995; Harlen, 1999). These skills are the basic skills which facilitate the learning of science, ensure the activeness of the students, improve the responsibility in their own learning, increase the continuity of learning and make students acquire research methods. A.A.A.S. defined the scientific process skills in two groups as basic and integrated. The basic scientific process consists of observation, classification, recording the data, measuring, using the space/time relations, using the numbers, reaching the conclusion and estimating. These skills form the basis of the complementary process skills which are much more complex (to change the variables and to control them, interpreting data, formulating hypotheses, defining operationally, to use data, to create models, to make experiments) (Esler 1977, Padilla and Okey, 1984). According to many researches, these skills are more important and effective in learning and teaching science(Ailello-Nicosia ve Sperandeo-MineoValenza, 1984, Padilla et al. 1983; Germann, 1994, 1996; Lavoie, 1999; Harlen, 1999).

No science/physics educator feels doubt that laboratory applications are importantly and significantly effective in giving these skills to students, developing positive attitudes towards science and understanding science (Hofstein, 1982; Renner, Abraham ve Birnie, 1985; Okebukola, 1986; Shymansky ve Kyle, 1988; Bryant ve Marek, 1987; Roth, 1994; Freedman, 1997, Hofstein ve ark. 2005). But the researches that have been made agree that the laboratory activities did not reach to its aim, did not enabled meaningful learning and did not develop positive attitudes towards science. Roth (1994) emphasized that the laboratory activities have been effective since 1960s, and that the students have not reached to the desired level yet as a result of these activities. In another research, it has been concluded that the laboratory study was not meaningful enough for students and thus it did not make a significant contribution to their conceptual learning (Novak, 1984).

According to Hofstein (1988), students work like technicians in “Cookbook” laboratory activities which still focus on developing their low level skills. Renner (1986) emphasized that nobody doubts whether laboratory applications are important to learn science or not today; but most laboratory guide made an impression on students that the aim of the laboratory is to confirm what is taught or told by a teacher, a course book or another authority, and the genuine role of laboratory is not this. In addition, little chance is given to students to make their experimental arguments, to state hypothesis and test it or to design an experiment, as a result to realize an experiment in a genuine meaning (Lunetta and Tamir, 1979). In Turkey, on the other hand, cookbook approach is adopted in the laboratories of universities and colleges.

Actually, laboratory experiences should enable students to develop problem solving, science process skills and technical skills; to provide conceptual development and to promote scientific attitudes and scientific inquiry. It can help students construct an important body of scientific knowledge, but many laboratory guides may make students think that the laboratory purpose is to verify something that the teacher, textbook, or some other authority has told them (Hofstein and Lunetta, 2004). *Is that the proper role of the laboratory? What is the real purpose of the laboratory? Is it true that the laboratory is used as cookbook laboratory by teachers?*

This research wants to find answers to three problems that exist in the literature and that especially appear in our country: *I. Problem*: The insufficiency of concrete studies directed to exercise about constructivist theory in science/physics education in our country, *II. Problem*: Existence of problems about the efficacy of laboratory activities in skills, attitudes and success, *III. Problem*: The deficiency in giving proper importance to student's development of science process skills and the existence of the problems about how to realize this development.

Parallel to these problems, the purpose of this study was to compare the effects of the verification laboratory (VL) with a laboratory based on the 7E Learning Cycle Model (LCM) on the development of science process skills and conceptual achievements of students.

Methods and Samples

Samples and Investigation Process

In this study the sample consisted of 81 freshman university students who were taking the General Physics Laboratory-I- course at the university in Turkey. In this study pretest-posttest design with control group was used. The night class students (43) who took lower weighted standard points from university entrance exam (UEE) than day class students were selected as experimental group. Day class students (38) were selected as control group. Thus, this study was quasi-experimental in design.

In this research, LCM laboratory was applied in experimental group and VL was used in control group. The differences between these approaches: a) In the control group, lab guide or teacher identifies the problem, the experimental design, the method of data analysis, and (through the introductory theoretical discussion) suggests an explanation for the data. Students follow the step by step instructions in this guide. The main purpose of this approach is to allow the students to verify that the experiment as presented does work. b) In contrast, in the experimental group, students were not given a theoretical introduction or methods of data analysis. Students were allowed to design their own experiments and to formulate an analysis of and an explanation for their data. Students identify dependent-independent variables, state hypothesis, construct table of data and analyze their data and draw conclusion from the experiment. Besides, laboratory guides of experimental groups which are based on 7E LCM: Excite, Explore, Explain, Eloborate, Extend, Exchange and Evaluate-were developed(Bybee, 2003).

While preparing "8" mechanical laboratory guides according to the phases of 7E Learning Cycle, students and laboratory instructor were asked to take below written principles into consideration for every phase in Table-1 and Table-2.

Measurement Method

In order to assess hypotheses of study two assesment tools were used: First tool is Science Process Skills Test (SPST), a multiple choice achievement test consisting of 36 questions improved by Burns, et. al. (1985), was used whether the development of science process skills of students is related to two types of laboratory approach. In this test, the ability to identify and control variables, the ability to operationally define, state hypothesis, data and graph interpretation and to design investigations skills are measured. The second tool, Force Concept Inventory (FCI) improved by Hesteness, was used to compare conceptual achievement of control and experimental groups' students. ANCOVA (Analysis of Covariance) and dependent t-test were used for testing the hypotheses of study. The meaningful level of the results was accepted .05

7 E	**Table 1.** Laboratory Principles for Students
Excite	**Know what you know:** ➢ Put your former knowledge in action by saying “What do I know about this subject?”. **Focus on Thinking:** ➢ Ask the questions of*“What can I learn about this experiment/subject? Why/how did this happen? How can I solve the given Research problem?* **Look and Try to See:** ➢ Observe the event carefully. Share your ideas about the event with your teacher and others via cyberspace
Explore	**Time of Discovery (Euroka):** ➢ Determine variables, state hypothesis and design an experiment to test. ➢ Question experiments/events, make predicitions. ➢ Think freely within the limits of activity. ➢ Forms new predicitions and state new hypothesis. ➢ Do alternative experiments when necessary and discuss with your friends. ➢ Records your observations and the ideas you brought forward. ➢ Save data and create tables.
Explain	**Time to Conclude:** ➢ Explain the experiment/event starting from your previous experiences. ➢ Propose possible solutions. ➢ Discuss with your friends and listen their explanations carefully. ➢ Ask questions about explanations of your friends. ➢ Listen the explanations that your teacher presented and try to understand them. ➢ Refer to previous activities. ➢ Use the data and observations that you saved in your explanations by drawing graphics when necessary. ➢ Accept or refuse the hypothesis you established. ➢ If you refused your hypothesis, recommend new hypothesis and repeat the process.
Elaborate	**Time to Apply to Different Situations** ➢ Apply new definitions, explanations and skills to different situations. ➢ Ask questions using your previous knowledge, recommend new solutions, make new inferences and establish new hypothesis if necessary, design new experiments. ➢ Conclude reasonable results from the findings you obtained. ➢ Save your explanations and observations again. ➢ Listen the explanations of your friends in a judgemental way.
Extend	**Time to Associate** ➢ Try to see and establish the relation of the concepts you obtained with the concepts/subjects in other fields. ➢ Shape by expanding the meanings of present concepts. ➢ Try to associate present concepts/subjects with real life. ➢ Report the experiences you acquired.
Exchange	**Time to Share** ➢ Discuss what you know about new concepts/subjects first with your group friend, and then with your friends within other group. ➢ Report the data that you acquired at the end of the discussion.

Evaluate	**Time to Evaluate What We Learned** ➢ Answer to open-end questions using the explanations, observations and findings that you accepted before. ➢ Prove/show that you obtained concepts or skills. ➢ Evaluate your own information and development. ➢ Ask related questions for further researches. ➢ Answer evaluation questions by showing proofs. ➢ Find the errors of the experiment.

7 E	**Table 2.** Laboratory Principles for Teachers
Excite	➢ Provide the students with the thoughts of the first scientist and make them feel them. ➢ Intrigue to ensure students' participation (a simulation may be watched about experiment/subject, a story may be read, etc.) ➢ Make a spark about the subject. ➢ Try to discover what students know about new concept or subject ➢ Ask questions that may confuse minds (create unbalance). ➢ Ask questions about misconception.
Explore	➢ Provide enviroment for concrete, tangible activities that include skills and concepts. ➢ Ask probing questions. ➢ Listen and observe students. ➢ Just play the role of a good adviser or coach in students' journey to cognitive balance. ➢ Create a rubric that will evaluate the skills of students about determining variables, establishing hypothesis in this phase. ➢ Ensure students to save the data they acquired correctly.
Explain	➢ Encourage students to explain and determine concepts. ➢ Demand explanations and proofs from students. ➢ Emphasize that students should use the data they acquired to make reasonable explanations. ➢ Bring forward new concepts by taking students prior experiences and making explanations and definitions.
Elaborate	➢ Encourage students to apply concepts and skills into new situations. ➢ Demand from students to use concepts, explanations and definitions with the previously acquired ones. ➢ Remind students that they have required proofs and data and ask them. "What did you learn/know before?", "What do you think about ......?", and "What can you do with your present knowledge?"
Extend	➢ Guide students in associating present concepts with other fields and/or other concepts/subjects. ➢ Ask research questions to help students associate other concepts/subjects and fields.
Exchange	➢ Prepare proper enviroment for students to discuss their ideas with their friends. ➢ Observe and listen the students who are sharing their knowledge. ➢ Ensure the interaction within student groups, compete student ideas.
Evaluate	➢ Observe students that apply new concepts and skills. ➢ Evaluate knowledge and skills of students. ➢ Search the reasons of students' changes of attitudes and ideas. ➢ Let the students evaluate their knowledge and group process skills. ➢ Ask the open-end questions such as "Why did you think like that?", "What is your proof for this?", "What do you know about ....?", "How do you explain ....?".

Results

It is analyzed whether there is a significant difference between the SPST and FCI pre and post test scores of the experiment and control groups. According to the Table-3, there were significant differences between the scores of SPST test in the control and experimental groups. On the other hand, although there was a significant difference between in experimental group, there is not a significant difference betweeen the scores of FCI test in the control groups.

Table-3: SPST and FCI Test Scores (in %), Means, Standard Deviation and Gain Scores for Groups

Group	SPST								FCI							
	Pretest		Posttest		Gain Scores		t	p	Pretest		Posttest		Gain Scores		t	p
	Mean	S.D	Mean	S.D	g	SD			Mean	S.D	Mean	S.D	g	SD		
Control	22.15	3.07	27.26	3.05	0.31	.21	10.012	.000*	9.02	3.09	9.76	3.00	.03	.16	1.722	.093
Experimental	21.68	3.48	31.47	2.81	0.68	.21	15.700	.000*	8.27	3.39	12.25	3.54	.24	.19	7.161	.000*

(SD = Standard Deviation; Gain score= ((%posttest -%pretest)/(100 -%pretest)), max. SPST point: 36; max. FCI Point: 25)

The null hypothesis of this research was given as: “A Laboratory Based on the LCM and VL approach will have no effect on students’ SPST and FCI pre and posttest mean difference scores”. The comparison of the groups of test scores is shown in Table 4.

Table-4-Summary Table of Group Memberships and SPST and FCI Post-test Scores Results

		Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**p**	**η^2**	Observed Power(a)
SPST Analyze	Covariat	UEE	.185	1	.185	.023	.879	.099	.820
		SPST (Pretest)	67.032	1	67.032	8.472	.005	.000	.053
	Group memberships		271.812	1	271.812	34.352	.000*	.309	1.000
	Error		600.432	77	8.114				
	Total		933.295	81					
FCI Analyze	Covariat	UEE	.566	1	.566	.071	.791	.001	.058
		FCI (Pretest)	245.785	1	245.785	30.657	.000	.285	1.000
	Group memberships		122.421	1	122.421	15.270	.000*	.165	.971
	Error		617.324	77	8.017				
	Total		10871.000	81					

Table 4 shows that when the total pretest scores obtained from the SPST, FCI and UEE test are taken under control, it is found that there are significant results between SPST and FCI post test scores and group memberships. The LCM based laboratory approach produced significantly greater science process skills and conceptual achievement than did the VL approach. When the η^2 values are examined, it can be inferred that size effect for these skills are high in both test. On the other hand, Hake (1998) reported that the interactive-engagement (IE) methods can increase mechanics-course effectiveness well beyond that obtained in traditional methods and he found that the average FCI gain score of IE methods is .48 ± .14. (in the medium-g region). In this study, although LCM laboratory is to be much more effective than VL, FCI gain score of LCM (.24 ± .19) laboratory is in the *low-g* region (Table-3). The cause of this case can be that in laboratory tasks the students are concentrated on data collection and table formation, briefly on carrying out the experiment. Also, the students reported in the interviews that up to their present levels they have generally dealt with mathematical questions and that they find the conceptual questions of this sort different and difficult.

Conclusions and Implications

“In good labs, students discover concepts; they don’t just verify them...”(Renner, 1986).

Although inquiry-based science is popular, many curriculum materials, textbooks, laboratory guides and other materials are still prepared on traditional approaches. In a review of the literature, researchers found that inquiry-based laboratory approaches are more effective than verification or traditional laboratory approaches (Pavelich and Abraham, 1979;

Allen et. al. 1986; Volkman and Abel, 2003). The lab activities, lab guides or manuals and instructor must maintain interest and curiosity in science and develop students'conceptual understanding, creative thinking, problem solving ability, scientific thinking. Students should design their experiments theirselves, establish their hypothesis and test them, determine the variables about the experiment theirselves, decide which data to save, create their own tables, conclude results; briefly, students should not try to exactly perform passively what was written in laboratory guide or the instructions which was given to them by the teacher. "Many of students enjoy laboratory workand prefer it to other modes of learning. This is not, of course, the universal reaction of all students at all times" (Gardner and Gauld, 1990; Chiappetta and Koballa, 2002). According to Campell et. al. (2000), students' perceptions of the purpose of a laboratory task and understandings of laboratory procedures greatly influence their decisions on what to report and on how much detail to include in a report. The teachers should provide students with an environment in which they will feel interested in facts, events and subjects; briefly, an environment in which they may think and discuss like a scientist.

The result from this study showed that the use of 7E Learning Cycle Model based laboratory approach applications are more effective than the verification laboratory approach applications in terms of students' science skills and conceptual achievement. Moreover, at the interviews that are made with students after application, experiment group students stated that the laboratory enviroment excited them and that other laboratories (basic biology, basic chemistry that are operated with traditional approaches) should be operated like it.

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