Investigation of the Effect of Inquiry-type vs. Expository Chemistry Labs on Learning and Attitude for Iranian High School Students of 10th.Grade

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Abstract. *The main goal of this research is to investigate the effect of inquiry-based vs. traditional laboratory work on learning and attitude of high school students. The samples of this research were 42 students who had studied in 10th grade and they were divided into two 21 potentially similar member groups.*

The obtained data showed that in the knowledge domain, there was no significant difference between inquiry and expository approaches $(P\langle 0.05)$ *; but inquiry style was very effective in increasing chemistry attitude* $(P\langle 000)$

Therefore, it seems that entering the inquiry-type experiments in high school books, not only can develop the attitude of students, but it can also improve the cognitive levels and critical thinking in them.

Keywords: Attitude, Expository style**,** Inquiry-type laboratory, Laboratory styles, Learning, traditional lab

1. Introduction

Chemistry is one of the branches of empirical sciences that a main part of its findings come through observing and doing experiments. Laboratory activities have long had a distinctive and central role in the science curriculum, and science educators have suggested that many benefits accrue from engaging students in science laboratory activities (Garnett et al. 1995, Hofstein, Lunetta 2002, Lunetta 1998, Tobin 1990) [1-4].

Hands-on activities are a set of hand and mind purposeful activities that performing them will improve the students' knowledge, attitude and scientific skills. Laboratory activities are not only able to stabilize learning and increase the retention of learnt concepts; they can also lead to attaining skills which will be applied in daily life [5].

Domin (1999) presented four styles to implement laboratory activities. In fact, these styles are the approaches of a laboratory-based curriculum. The best known of them include: expository, discovery, problem-based and inquiry styles [6]. At present, chemistry labs in our high schools are taught in a traditional expository style.

Teachers have recognized the limitations of traditional laboratory work. In traditional laboratory classes, students follow step-by-step instruction to complete an experiment. As students concentrate on the completion of individual steps, they often do not have a deep understanding of the experimental design. For many of them, laboratory work means manipulating equipment but not manipulating ideas [7].

Science educators believe that when properly developed, inquiry-centered laboratories have the potential to enhance students' meaningful learning and conceptual understanding of the nature of science [1, 3].

The benefits of inquiry-based laboratory work are well documented in the literature. It is an effective mode of learning to improve students' content knowledge (Lord and Orkwiszewski, 2006), scientific process skills (Deters, 2005; Hofstein, Shore & Kipnis, 2004), attitudes toward school science (Gibson & Chase, 2002; Gott & Jarman, 2000; Lord& Orkwiszewski, 2006) and communication skills (Deters, 2005) [8]

Tobin (1990) suggested that meaningful learning is possible in the laboratory if the students are given opportunities to manipulate

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equipment and materials so as to be able to construct their knowledge of phenomena and related scientific concepts. However, he claimed that, in general, research has failed to show evidence that such opportunities really exist [4].

Nevertheless, few chemistry teachers in our country use inquiry-based laboratory work as a teaching aid. Recently, Deters (2005) surveyed 571 high school chemistry teachers in the United States and found that 45.5% of the teachers did not provide students an opportunity to write experimental procedures [9]. In Australia, Hackling, Goodron and Rennie (2001) surveyed 2802 secondary science students. They found that 33% of the students had never planned their own experiments [10].

These findings indicate that even in developed countries such as the United States and Australia, inquiry-based laboratory work is still not popular in schools [8].

Several research studies have been conducted to investigate the reasons why most of chemistry teachers prefer expository lab in contrast with other lab styles (especially inquiry style). Some factors such as: lower price, more safety, waste less time to perform an experimental procedure, easy to control the class and the instruction process and so on were declared to explain the advantages of traditional laboratories.

On the other hand, "lack of time, management problems, material demands, large classes and assessment issues" were the most obstacles they accounted for not to implement inquiry-based laboratories [11].

In this project, we selected the experiments which were about the solutions and the ways to measure the solubility of some familiar species. To do the experiments, we used some kitchen compounds which are cheap, safe and available. We could manage our chemistry laboratory inquiry group by implementing the guided inquiry method.

The guided inquiry is a student-centered method and can be defined as a set of stages in which the learners construct their own knowledge with the aid of experimental data.

The main purpose of this paper is to investigate the effectiveness of inquiry-based laboratory in comparison with expository chemistry lab in learning and attitude of high school Iranian students.

The project was guided by the following two major questions:

1. Does inquiry-based laboratory indicate a meaningful increase in learning of Solution conception in students compared to expository (traditional) laboratory style?

2. Does inquiry-based laboratory indicate a meaningful increase in the attitude of students compared to expository (traditional) laboratory style?

2. Laboratory Instruction Styles

Laboratory instruction is a cornerstone of most science programs because it allows students to be actively involved in their learning [12].

A lab-based curriculum must implement the ways in which the students can experience both of learning and understanding the concepts.

Many researchers have tried to describe a laboratory characteristic and the learning qualifications in it. Hodson (1993) believes that: "Laboratory must be like a puzzle, not a place to review the previous known. The things that students have already understood must not be examined in the laboratories. Furthermore, a laboratory must not be a place to investigate accuracy or inaccuracy of the chemical laws and concepts. If doing an experiment must show something, that thing must be the scientific method. Let's lab be a place where scientific findings and earning experience have priority "[13].

Acquired experiences in a laboratory must include employing logical and creative reflections; meanwhile they must be free from tied manuals existing in traditional way of chemical education.

Domin (1999) by investigating the common ways in laboratory instruction, presented four different styles to perform hands on activities:

"Four distinct styles of laboratory instruction have been utilized throughout the history of chemistry education: expository (traditional), inquiry, discovery and problem-based. Although these instructional styles share many commonalities and oftentimes their labels are used interchangeably, each style is unique and can be distinguished from the others by a set of three descriptors: outcome, approach, and procedure" [6].

Table 1 shows the descriptions of the laboratory styles:

Table1. Description of the laboratory instruction styles

Style	Descriptor		
	Outcome	Approach	Procedure
Expository	Predetermined	Deductive	Given
Discovery	Predetermined	Inductive	Given
Problem-based	Predetermined	Deductive	Student generated
Inquiry	Undetermined	Inductive	Student generated

Although many educators value the laboratory's instructional potential, but laboratory has also been the focus of considerable criticism concerning the lack of student learning in laboratory [13].Therefore, there has been increased interest in alternative laboratory instruction styles, such as inquiry-based or problem-based laboratory experiments.

In current issue, we have selected expository and inquiry type experiments to investigate. So, we explain more about these two styles as follows:

2.1. Expository type experiments

The conventional style of laboratory instruction is the expository one, which is instructor-centered, has a 'cookbook' nature, and has been criticized for placing little emphasis on thinking [14].

In traditional laboratory classes, students follow step-by-step instruction to complete an experiment. The instructor supervises students' work in every step and guides them directly. The outcome is predetermined. In this type of experiments, as students concentrate on the completion of individual steps, they often do not have a deep understanding of the experimental design. For many of them, laboratory work means manipulating equipment but not manipulating ideas.

Meaningful and purposeful learning randomly occurs in this style of laboratory-based activities; and just the lower levels of cognitive skills will improve.

Considering the cognitive levels of Bloom's taxonomy of behavioral objectives, using the expository type laboratory activities can just cover the three initial levels which are knowledge, comprehension and application; and it's unable to develop the higher cognitive levels include analysis, synthesis and evaluation [5].

Experimental planning and management and the procedure is less important in this type of experiments.

However, expository type of laboratory instruction, as was said, is still the most common style of laboratory in high schools and even universities.

Domin suggests that the most popular, though most criticized form of laboratory instruction is the expository or "cookbook" style. It has evolved into its present form from the need to minimize resources such as time, space, equipment, and personnel [6].

2.2. Inquiry type experiments

Inquiry-based laboratories include a set of continued and related activities. These experiments are designed to resolve the issues of scientific phenomena existing in nature or are caused by everyday life and students try to solve them by inquiring [15].

In this style, teacher is a facilitator and does not introduce an explicit procedure to students. In inquiry-type laboratories which are in accordance with scientific methods, students pose hypothesis and try to design experiments and perform them by taking advantage of their own creativity and innovation.

Science educators believe that when properly developed, inquiry-centered laboratories have the potential to enhance students' meaningful learning and conceptual understanding of the nature of science.

In inquiry-based laboratories the students are involved in more open-ended type experiences such as asking relevant questions, hypothesizing, choosing a question for further investigation, planning an experiment, conducting the experiment and finally analysing the findings and arriving at conclusions. It is thought that this type allows the students to learn and experience science with understanding. Moreover, it provides them the opportunity to construct their knowledge by actually doing scientific work [16].

Since the output of this style leads to creativity and innovation, most developed countries stress on applying inquiry style of laboratory instruction in science education, especially chemistry.

3. Methodology

3.1. Research design

This investigation was done in Iran, Tehran with 42 students of 10^{th} grade in 2009_2010 academic year which were randomly selected from one of Tehran's high schools. Students were equated by their first semester's total average and chemistry scores and divided into two 21 member groups. 21 students were determined as the ' inquiry group' and the other group was 21 students that they do the experiments by traditional expository style and were dominated as the 'control group'. The methodology was an equivalent posttest control group design.

We grouped the students to 3-person groups. Students were taken at two intervals to the laboratory. We gave them analogous contents. The selected experiments were about the solutions and solubility.

To assess the students' achievement and progress during the performance, the check lists (for each phase: expository and inquiry) were designed and the teacher marked her observations in them.

After the execution of desired experiments, we took post-test from each group and then we evaluated the dependent variables after exposure to the independent variable.

3.2. Instruments

The purpose of this project was to compare the two laboratory styles: inquiry and expository. In this research, there were dependent variables (learning progress) and (attitude); and independent variable was laboratory style instruction. So, learning test and chemistry attitude questionnaire was used to collect data.

The learning test consisted of different kinds of questions, such as multiple choice questions, restricted questions and fill in the blanks questions aiming to measure all attainments from the given topics. Ten chemistry teachers examined the instrument for content validity. The reliability of the instrument based on Cronbach's alpha was 0.78.

The chemistry attitude questionnaire was a set of 30 standard questions and was designed by Likert-type scale.

3.3. The Laboratory performances

The considered experiments were about: 1.The factors affect on the rate of dissolution 2.Saturated solutions and 3.Determining the solubility of some familiar chemical compounds such as sodium chloride and sugar. (Our chosen experiments were simply performable at a kitchen and that's because we wanted to show the relation between chemistry and daily life and also we tried to use materials which are as safe as possible).

I. At first interval, the students of Inquiry group (experimental group) were taken to the laboratory. They were divided to seven 3-member groups. Our lab process was as follows:

"Good question is the heart of good inquiry" and motivation has a central role in posing good questions.

To motivate the students, we showed them some experiments that were about how to prepare a saturated solution and the effect of temperature on it and they were indirectly guided to the topic. Then, some background information was presented. In this phase, the pre-prepared sheets were provided. In these sheets, the inquiry purposes were defined and the students must hypothesize, plan, design experiment(s), implement experiment(s), collect data or evidences and finally arrive at conclusions. We also asked them to share their group's findings with the members of another groups and discuss about them and develop their inquiry. We can summarize the inquiry sequences by figure 1.

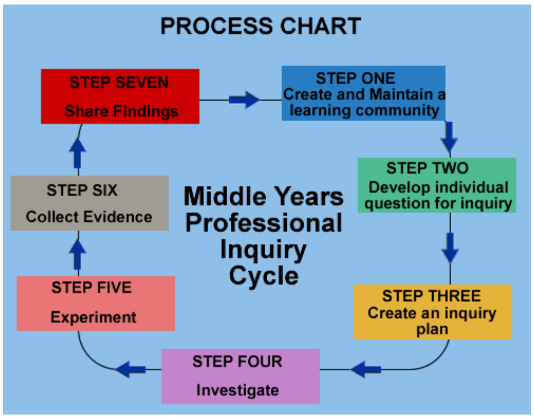

Fig.1. Inquiry cycle

The students must write their laboratory reports include the following parts:
1. Topic 2. Purpose 3. Materials and apparatuses 4. Hypothesizes 5. Procedure (in detail) 6. Data table 7. Results 8. Conclusion

9. The results obtained from sharing the findings and new findings.

The students' achievement and progress during the performance was assessed by the check list that was designed for inquiry phase and the teacher marked her observations in it.

II. Then the students of Expository group (control group) were taken to the laboratory. They were seven 3-person groups, too.

The experimental procedure was given to the control group. The instructions for the experiments were explicit and detailed. The students knew about what materials to use, how to conduct the experiments, how to collect the data and how to analyse the data. This phase which was largely closed, the students were asked to conduct the experiment based on specific instructions given in the laboratory manual.

Their laboratory reports must include the following parts:
1. Title 2. Purpose 3. Materials and apparatuses 4. Procedure (in detail) 5. Data and results 6. Conclusion

In this phase, expository lab check list was designed and we used it to assess the students' achievement and progress during the performance.

The exams as post-tests of learning and attitude were taken from the students of both groups (Inquiry and Expository) after the laboratory activities were finished.

4. The analysis and discussion

The analysis of the results was based on a comparison between the inquiry and the expository groups regarding knowledge and attitude post-tests scores. Both of two groups were equated on the averages and chemistry scores. Descriptive and inferential statistics were applied to analyse the quantitative data. Both data groups were analysed quantitatively by the SPSS (version 17) software.

Table 2 shows the descriptive data of two groups in learning exam.

Table2. Paired samples statistics

Lab style	Mean*	N	Std. Deviation	Std. Error Mean
Exp.	7.2381	21	2.38023	.51941
Inq.	7.3095	21	1.54496	.33714

***Scale Score = 10**

Table 3 shows the results of t-Test for two groups.

Table3. t-Test analysis results of leaning post-tests

Paired Differences					t	df	Sig. 2-tailed
Mean Diff.	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
-.07143	1.04026	.22700	-.54495	.40209	-.315	20	.756

When we compare the results of two groups, we found that although the students of inquiry group had a better performance in the learning exam, but the results from t-Test showed that there is no significant difference (p=0.756) between the mean scores of two groups at the significance level of 0.05. In another word, inquiry-based and expository laboratory has the same effect on knowledge domain.

Table 4 and Table 5 indicate the data analysis of attitude posttests of two groups:

Table4. Paired sample statistics for Attitude post-tests

Lab style	Mean*	N	Std. Deviation	Std. Error Mean
Inq.	3.6219	21	.48798	.10649
Exp.	3.0700	21	.59587	.13003

Scale Score=5 *

Table 5. t-test analysis results of Attitude posttests

Paired Differences					t	df	Sig. 2-tailed
Mean diff.	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
.55190	.20238	.0441	.45978	.64403	12.49	20	.000

As can be seen, the students in Inquiry group had a better sense during lab work and got higher degrees in attitude test than Expository (traditional) group. The grades of students were reported by using a Likert – type scale. According to t-Test results, the difference between two groups was significant (p = 000) and it indicates that Inquiry style laboratory can develop students' positive attitudes toward chemistry.

5. Conclusion

An inquiry-oriented, "hands on" approach to science instruction stimulates the natural curiosity and theory-building inclination of students while providing a solid conceptual framework for supporting the development of accurate concepts. Such experiences provide the raw material from which mature scientific theories are constructed. To increase a "minds-on" factor to a "hands-on" approach, teachers should decrease the "cookbook" nature of whatever labs they conduct and sequence the hand-s on activities before any readings or lectures so that students can explore topics before learning the terms [17].

The purpose of this research was to investigate the effectiveness of inquiry style of chemistry laboratory on high school students. From the findings of this study, we concluded that laboratory activities by implementing inquiry style had positive effects on students. At first the students of inquiry group were anxious; they faced with an unknown situation that was very different from previous sections of chemistry labs. They were confused because they should perform the experiments without any recipe. But, very soon they initiated to consult with their peers, pose hypothesis and plan their practical works. They provided a list of their essential materials and apparatuses and work began. Even, some of hypothesizes were new for instructor and she encouraged the students to test their ideas by performing experiments. The students continued their works with enthusiasm and time was not important for them. We were satisfied with this method, too.

After this project, the students who had participated in the inquiry-type laboratories claimed that the lab experiments, in which they are engaged, were very interesting and challenging; and gave them the opportunities to develop their scientific skills, share ideas and cooperate with their peers in the group and construct their knowledge individually. In addition, they felt that each member in the group had the opportunity to contribute to the discussion in order to achieve a common goal.

It should be noted that, in general, students who were involved in traditional expository lab described this type of laboratory boring and without excitement. Some of them had no desire to continue working, because they claimed that: "We should follow a procedure in recipe-like fashion, all doing the same things. We know the activities are contrived, and we know that we are expected to come up with a particular right answer. There are no surprises for us or for you."

To sum up, based on these quotes, it is seen that the students who were involved in inquiry style, are aware of the meaningful contribution of the inquiry method to their learning of chemistry.

In according to research results in attitude test, there was significant difference between expository and inquiry styles. Inquiry method had benefits for students such as: learning by doing, self-confidence, satisfaction, interest and experience, motivation, being active, curiosity, learning with pleasure, meaningful learning and so on. "Introducing inquiry-type experiments into the chemistry laboratory is a 'breath of fresh air' in the way chemistry is taught and learned, in the way students are assessed, and in our attempt to improve teachers' professional development" [18].

6. References

[1] GARNETT, P. J., GARNETT, P. J. and HACKING, M. W., refocusing the chemistry lab: A case for laboratory-based investigations. Australian Science Teachers Journal, 1995; 41, 26–32.

[2] HOFSTEIN, A. The laboratory in science education: the state of the art, Chemistry Education Research and Practice 2007; 8:105-107.
[3] LUNETTA, V. N. The school science laboratory: historical perspectives and context for contemporary teaching. In B. Fraser and K. Tobin (Eds.), International handbook of science education (Dordrecht: Kluwer Academic); 1998.
[4] TOBIN, K. (1990). Research on science laboratory activities: in pursuit of better questions and answers to improve learning. School Science and Mathematics, 1999, 90, 403–418.
[5] Reid, N., A Scientific approach to teaching of chemistry, Chem Educ. Res. Pract., 2008;9,51-59.
[6] Domin, D.S. Review of laboratory instructional styles. Journal of Chemical Education, 1999; 76,543-547
[7] Hofstein, A. & Lunetta, V.N. The laboratory in science education: foundation for the 21st century. Science Education 2004; 88, 28-54.
[8] Cheung, Derek, Facilitating Chemistry Teachers to Implement Inquiry-based Laboratory Work, International Journal of science and Mathematics Education 2007; 6: 107-130.
[9] Deters, K. Inquiry in the chemistry classroom, the science teacher 2005; 71(10), 42-45.
[10] Hackling, M. W. Goodrum, D. & Rennie, L. J., The state of science in Australian secondary schools. Australian Science Teachers' Journal 2001; 47(4), 6-17.
[11] Childs, P. E. Improving chemical education: turning research into effective practice, Chem. Educ. Res. Pract. 2009; 10, 189-203.
[12] Herrington, G. and Nakhleh, B., What defines Chemistry laboratory instruction? Journal of chemical Education, 2003, vol. 80, no. 10
[13] Hodson, D. Rethinking old ways, Studies in Science Education, 1993; (22):85-142
[14] Tsaparlis, Georgios and Gorezi, Marianna, Addition of a project-based component to a conventional expository laboratory, Journal of Chemical Education, 2007; 84(4), p668.
[15] Wenning, Carl, Contrasting Cookbook With Inquiry-oriented Labs, 2004: http://www.phy.ilstu.edu/pte/312content/inquiry_vs_cookbook_lab.pdf
[16]http://www.usask.ca/education/coursework/mcvittiej/methods/inquiry.html
[17] Pine, Jerome; Aschbacher, Pamela et.Al, Fifth graders' science inquiry abilities: A comparative study of students in hands-on and textbook curricula, 2006; vol. 43, issue: 5. pp.467-484
[18] Hofstein, Avi; Shore, Relly; Kipnis, Mira; Providing high school chemistry students with opportunities to develop learning skills in an inquiry-type laboratory: a case study, INT. J. SCI. EDUC. 2004; vol. 26, No. 1, 47-62