The effect of creative and critical thinking based laboratory applications on creative and logical thinking abilities of prospective teachers

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Contents

Abstract

The purpose of this study was to examine the effect of creative and critical thinking based laboratory method on prospective primary teachers' creative and logical thinking abilities. This research was conducted with 90 prospective elementary school teachers who were enrolled in two classes of education faculty during the spring semester of the 2004–2005 academic year. Creative and critical thinking based laboratory applications were conducted in the experimental group, and traditional laboratory applications were conducted in the control group. As a result of the investigation, it was determined that the experimental group was more successful than the control group in terms of the logical thinking ability and creativity. Implications for science education at the teacher education level were discussed.

Keywords: Creative thinking, critical thinking, logical thinking, creativity

Introduction

People have to improve their creative and logical thinking in order to develop technological improvements and utilize them in today's continuously changing and developing world. These two abilities are necessary to create new products and to find effective and productive solutions for potential problems as the world develops. The individuals who are key in determining development of the world and have high-levels of creative and logical thinking abilities may provide better life for their societies; therefore, concepts of logical thinking and creative thinking have importance for the scientific world and have still been used in different fields (Koray, 2003). To know the meanings of the creative thinking and logical thinking may be useful to determine aims of applications in education.

Creative thinking has been considered as an intuitive process. The components of creative thinking include understanding incomplete parts, gaps in intuitively getting knowledge, problems and difficulties, to conjecture about these parts, gaps, difficulties and problems, to set hypotheses about them, to test the hypotheses, to compare the results of test, to set and evaluate new hypotheses if needed and lastly, to explain the final results (Saeki et al. 2001:25). The ability of creative thinking has an important role for many scientific applications, especially when used for setting the hypotheses and problems and for constructing an action plan to resolve them (Koray, 2003). The process of the creative thinking is hard to evaluate and has a complex structure requiring deep experiences, to be open-hearted, to accept ideas, to experience new approaches, to be curious, to have high level self-confidence, to be dissipated and have high energy, to be an idealist, to like loneliness, to be humorous, to obtain knowledge about aesthetical artistic interests, to behave suddenly and to be interested in new, mysterious and complex things (Özden, 2004:174-175, Enger & Yager, 1998:10). Özden (2004:176-178) stated that certain skills contribute to creative thinking in literature. These skills include fluidity, flexibility, originality, sensitivity to problems, ability to determine problems, to imagine deeply, to be childlike, to think analogically, the ability to evaluate situations, to be analytical, to synthesize anything well, to have ability to transform something, to go beyond the common boundaries, to think intuitively, to make predictions, follow-through on job completing, concentration on goals, logical thinking, ability to provide extraordinary conjunctions, to be spontaneous, to be courageous against uncertainty and to have autonomy. In the existing literature, there are some studies showing the effectiveness of creativity programs on development of the creative thinking ability (Parnes and Reese, 1970; Sandwith, 1978). Studies on creativity based applications in labs are hard to find in the existing literature. There is one study on creative and critical thinking based lab applications with the dependent variables out of creativity (Koray et al. 2007). Therefore, there is a gap in experimental studies of science lab activities.

As the other ability focused in this study, logical thinking as an aim of higher order education is mirror of thought that come about in formation of operations in child. The essential characteristic is to be operational and extend the action scope through internalization (Piaget, 1950; 30, 37). In addition, logical thinking comprises both thinking about thought and reversal association between what is possible and what is real (Inhelder & Piaget, 1958; 341). Logical thinking is the highest form of thinking for Piaget, and in his stages of cognitive development, this type of thinking develops towards higher stages. He showed the development of logical thinking as in concrete operational stage, but he made discrimination between stages of logical thinking on concrete objects and multifactor situations. Therefore, development of logical thinking is explained in concrete and formal operational periods beginning from 7-8 ages to older ages (Gredler, 2005). In the literature on science lab activities, it is a difficult task to find critical and creative thinking based experimental studies including logical thinking abilities as dependent variables. In addition, there is only one study in the national literature on the variables out of logical thinking (Koray et. al, 2007)

The Aim and Importance of the Study

It is a clear fact that the laboratory method is one of the most important teaching methods for providing effective and meaningful learning in science education. It is the foundation for scientific and technological development. The laboratory method that is based on students' active participation in the process of data collection and analysis of the facts can provide students an understanding of the nature and ways of science. In addition, it can also provide students opportunities to improve their problem solving and investigation skills, to do appropriate generalization about important points in science, to get scientific knowledge and to hold positive attitudes towards science (Tamir, 1997). Integration critical and creative thinking processes with the laboratory method, which is one of the most important methods in effective science education, may contribute to science content learning and logical thinking on scientific issues. Jackson (2000) showed requirement and importance of critical thinking in development of problem solving ability. In addition to problem solving, Koray et al. (2007) presented the effectiveness of creativity and critical thinking based applications on science process skills. The laboratory method frequently requires usage of problem solving and science process skills and is mainly based on experiments. Therefore, it includes the examining of events, processes and facts in nature using experimental studies. When the descriptions of creative and critical thinking concepts are taken into consideration, it can easily be seen that activities about creative and critical thinking abilities should be part of the laboratory method in order to explain and study the structure of natural events, which are complex, open-ended and multifaceted. Again, the research method used in the study, the experimental method, is only way to construct a cause-effect relationship that might provide important knowledge about practical importance of the applications. In this study, it was hypothesized that critical and creative thinking based activities are effective on the development of logical thinking and creative thinking. The effect of applications on creative thinking was thought to be a direct influence, while the effect of applications on logical thinking was thought to be mediated by the effectiveness of the applications on problem solving and science process skills, which are tools of logical thinking ability. With all these considerations, the aim of the study was to investigate the effectiveness of creative and critical thinking based laboratory applications on creative and logical thinking abilities of prospective teachers

Problem Question of the Study

Does the scores of the sophomores enrolled in labs including critical and creative thinking based applications on logical and creative thinking abilities tests show significant statistical differences from the scores of the sophomores enrolled in traditional lab applications?

Method

This research is a quasi-experimental study with non-equivalent groups, which includes pre and post-test design with the control group (Fraenkel & Wallen, 2003). This research was conducted with 90 prospective elementary teachers in Eregli education department at the Zonguldak Karaelmas University in the spring semester of the 2004-2005 academic year. The course lasted 3 hours for each week over a period of twelve weeks with the pre and post-test applications. The investigation was conducted in the science laboratory as a one-semester course by the researchers. There were two randomly assigned groups in which one group of students was exposed to creative and critical thinking based lab instruction, and the other was exposed to traditional lab instruction. Data was collected through creative and logical thinking tests.

Instruments

Torrances's Creative Thinking Test

The test consists of two types. In this study, Figural Form A, as a type of the test, was used to measure the creative thinking skills of the participants. Another type of the test is the Verbal Form. The test includes three parts. Each part has a different activity sets which include picture drawing activities, picture drawing completion activities and the parallel line activities. The test measures the different aspects of creative thinking skills. These are fluency, originality, flexibility and elaboration. The determination of the score on each aspect was carried out by scoring the following criteria:

Fluency: total number of pictures completed.

Elaboration; how well the person is able to draw detailed pictures.

Flexibility: the number of pictures about the topic.

Originality: the number of the pictures drawn which are not imagined by others (Sternberg and Lubart, 1999:7).

In this study, Figural Form A was used with its sets of picture drawing, picture drawing completion and parallel line activities. The adopted subtests were composed of four aspects of the test (see Table 1). The appropriate time for the application of the test is 30 minutes. The Cronbach alpha reliability value of the test was found as .97. The Pearson product-moment correlation coefficients on test-retest reliability were calculated by Aksu (1988) and were determined in Table 1 (as citen in Korkmaz, 2002).

***Table 1** Test-retest reliability values for the aspects of the test*

Aspect of The Test	The Pearson Product-Moment Correlation Coefficient
Fluency	0.62
Flexibility	0.68
Originality	0.43
Elaboration	0.34
Total	0.58

The test was considered as reliable instrument for the study

The Logical Thinking Test

The logical thinking ability test (GALT) developed by Roadrangka, Yeany and Padilla (1982) and adapted by Korkmaz (202) was used in the study. The test includes 21 items and measures 6 logical processes. These processes are conservation, mass, length, volume, proportional comparison, controlling the variables, consolidative comparison, probabilistic comparison and relational comparison. The following table summarizes the number of items corresponding to each process.

***Table 2** Logical processes in the test and corresponding item numbers*

Process	The number of items
Conservation	1
Mass	1
Length	1
Volume	1
Proportional comparison	6
Controlling the variables	4
Consolidative comparison	3
Probabilistic comparison	2
Relational comparison	2
Total	21

In the test, participants are asked to answer each question and to write down their reasoning. According to past studies, the test was found to be appropriate for students at the 6th grade level and above. The time required for completion of the test is 45 minutes (Korkmaz, 2002). The alpha reliability of the test is 0.71. In the scoring process, one point is given to each true answer and satisfactory reason for the first 18 items, and one point is given to each true answer for the other questions.

Data Analysis

In the study, the data about logical and creative thinking abilities were gathered by two instruments, and then the data obtained from the instruments was recorded in an SPSS sheet. Finally, a one-way MANOVA was conducted to analyze the data by the SPSS version 13.

Procedure

1) The study was conducted in each group by researchers and was applied in the weekly three-hour science laboratory course. The study lasted for one semester.

2) In the first stage of the study, basic knowledge about biology, chemistry and physics experiments was included in the lab studies. In the experimental group, how to use creative and critical thinking abilities during the experiments and reporting the results was discussed. The basic focus of the study was to develop general creativity and logical thinking abilities of the students. Creative and critical thinking based applications were embedded in an open inquiry context. A basic constructivist approach towards curriculum was utilized for the purpose of the study, which is in line with constructivist curriculum reforms across the country. However, in the control group, experiments were introduced using traditional experimental methods and reporting the results were explained. In the control group, only titles of the experiments were given, and the students were driven to their textbooks for detailed information about processes and materials required for experiments. During the process, instructors asked content and experimental designs. Students relied on textbooks the majority of the time. Students were not asked any questions about the meaning of experimental results or methodology, but instructors provided feedback through lab report evaluations and answers to students' questions. There was no limitation on feedback. The instructors had always been providing support and guidance. Additionally, the instructors were same for both of groups using the same topics and same amount of instruction time.

3) During the second stage, the groups with two or three members determined their own experiments for 12 weeks. Then, determined experiments for 12 weeks by students were assigned for each group in experimental and control groups. In the assignment, order of groups of experiments for each week was considered; since each group should have conducted different experiments from other groups in each week and should have completed all experiments in the classroom during semester. Therefore, rotation way that was based on groups of experiments for each week was used. In this stage, creative and logical thinking tests were applied to the sophomores as pre-tests. The students had no prior instruction on creativity and logical thinking. Both groups were not given the expectations of the instructors for the study or involved in any activity which might give clues about the expectations. To decrease the interaction effect, feedback and corrections were generally indicated in the reports.

4) During the experimental stage of the study, the participants in the experimental group were given only the title and aim of the experiment. They designed the experiments by investigating the visual and written resources about the experiments, whereas the participants

of control group, conducted their experiments, using the lab textbook. In the experimental and control groups, the same experiments were studied in the same order.

5) In the fourth stage of the study, the participants of the experimental group have used their critical thinking abilities by analyzing all parts of the experiments. They found missing steps and have suggested innovations during the last part of the experiment. By using creativity, they have designed new, original experiments and have applied them in the lab. In addition, they have used different tools than the original experiments or found new use areas for old tools. Then, they reported their findings by using the lab report format. During all processes, instructors gave feedback, guidance and support in each group when it was required. To decrease interaction effect, all of these actions were generally provided in a written format as answers to lab reports or basic question-answer format. In the experimental group, students were challenged by writing questions and answers to analyze the experiment, making critics about the experiment and adding innovations about the experiment. A majority of the students in the experimental group asked for more help and allowed more time for these parts of the process. In the control group, the participants used traditional lab experiments found in the textbook. They have conducted studies with the procedure included in the textbook and observed the results of their studies.

6) After the each week, all of the participants submitted their lab reports to the researchers and received feedback.

7) At the last stage of the study, creative and logical thinking post-tests were applied to the sophomores. The lab report formats for the experimental and control groups can be seen in the Appendix.

Results

Under this title, the results of descriptive and inferential statistics analyses will be presented. For the analysis, total scores on the subtests of both tests were used for comparisons.

Table 3 *The Result of Independent t-test for pre-test scores of the participants at each group on the logical thinking and the creative thinking test*

Pre-tests	**Groups**	**n**	**Mean**	**SD**	***t***	***p***
Creative Thinking Test	Experimental	44	49.14	14.75	.66	.51
	Control	46	47.24	12.56		
Logical Thinking Test	Experimental	44	10.82	3.39	.56	.58
	Control	46	11.24	3.75		

As seen in Table 3, there is no statistically significant difference between pre-test scores of the sophomores on creative thinking and logical thinking tests (t=.66, p<0.05, t=.56, p<0.05). This result shows that the groups of the study are equivalent in terms of creative and logical thinking parameters before the implementation.

Table 4 *Experimental Design (MANOVA)*

Independent Variable	Dependent Variables	Groups
Creative and Critical Thinking Based Laboratory Applications and Traditional Lab Applications (Method)	Logical Thinking Skill	Experimental
		Control
	Creative Thinking Skill	Experimental
		Control

Table 4 shows that the design of the study includes one independent variable and two dependent variables within the two groups. The normality assumption was investigated by looking at skewness and kurtosis values for each cell. The values for skewness and kurtosis range from -1 to +1. Therefore, the assumption was accepted to be provided. The assumption of equality of variances was tested by considering Levene's Test results. The test showed that the assumption was provided with the statistically non-significant results for the equality of error variances.

Table 5 *The Results for the Test of Equality of Covariance Matrices*

Variable	F	df1	df2	*p*
Logical Thinking Skill	.02	1	88	.90
Creative Thinking Skill	1.21	1	88	.27

Table 6 *The Results for the Test of Equality of Covariance Matrices*

Box's M	5.36
F	1.74
df1	3
df2	1490495
Sig.	0.16

Table 6, shows Box's value and the significance shows it is one of the most important assumptions of the MANOVA analysis. Equality of covariance is not violated in the study (*Box's M= 5.36, p*<0.05).

Table 7 *The mean, standard deviation and frequency values of the participants of each group*

Dependent Variables	Groups	n	Mean	SD
Creative Thinking Skill	Experimental	44	57.61	9.64
	Control	46	51.52	10.36
Logical Thinking Skill	Experimental	44	13.75	2.93
	Control	46	10.43	4.12

Table 7 presents means and standard deviations of each group on the post-test scores. The experimental group developed higher scores on the creative and logical thinking abilities tests than the control group.

Table 8 *The result for one-way MANOVA*

Source of Variance	**Multivariate Test**	**Value**	**df1**	**df2**	**F**	**Multivariate η^2**	**p**
Group	Wilks' Lambda	.75	2	87	14.64	.25	.00

A one-way multivariate analysis of variance (MANOVA) was conducted to determine the effects of creative and critical thinking based laboratory applications and traditional laboratory applications on two dependent variables, the scores of the students on creative and logical thinking tests. Significant differences were found between the creative and critical thinking based laboratory applications and traditional laboratory applications on the dependent measures, Wilks's Λ= .75, F (2, 87) =14.64, p<0.05. The multivariate η^2 based on Wilks's Λ was moderately strong at .25. Table 7 contains the mean, standard deviations and frequencies on the dependent variables for each group. The mean of scores on the creative and logical thinking tests demonstrate that the creative and critical thinking based laboratory applications given to the experimental group were found to be more effective than the traditional laboratory activities in improving both the logical and creative thinking abilities.

Conclusion

The result of the study is an indication of the effectiveness of the applications based on critical and creative thinking. In fact, the critical thinking and creative thinking as higher-order thinking abilities are related to many important variables such as age, cognitive development, field of the study, etc. (Lin, 2004). The students in this study are at the stage of formal thinking so; they are able to think at the abstract level as a higher-order form of logical thinking. Creative and critical thinking also requires frequent logical thinking due to its more complex structure and products (Garrison & Archer 2000; de Bono, 1970). The applications based on this kind of thinking should increase the level of logical thinking due to the processes experienced by students engaged in creative and critical thinking based applications. This study showed the expected result occurred with a moderate level practical significance. The laboratory is the most important area for application in science education. The inquiry and other activities related to science processes include the logic of science as a form of logical thinking. Therefore, laboratories might also provide a rich context for using logical thinking together with creative and critical thinking abilities. As higher order levels of thinking, creative and critical thinking are helpful to reach to deeper understanding for scientists and so they increase effectiveness of laboratory to learn science related logical thinking as found in this study. Previous literature is consistent with this study. Parnes and Reese (1970), in their study with high school students, found that students' creativity increased significantly after participation in creativity based program. Again, Sandwith's (1978) study of college students demonstrated that short term creativity applications effectively increased participants' creativity scores. Sungur (1988), in Turkey, showed that a creative problem solving program was significantly effective in increasing problem solving abilities of university students. The increase in problem solving ability as a process for using logical thinking might be supportive evidence for this study. Jackson (2000) stated that critical thinking ability was an effective factor for mathematical problem solving that is an area requiring frequent use of logical thinking. As found in the literature, this study supported the idea that creative and critical thinking based laboratory applications, as tested on the experimental group, are more effective than the traditional laboratory activities in improving logical and creative thinking abilities.

The importance of the results of this study are due to the effectiveness of the research design to establish a cause-effect relationship and establishing variables used in preparing activities. Creativity and critical thinking are the two most important higher-order thinking abilities. In science labs, the development of such abilities might contribute to many other skills, such as logical thinking and science process skills as previously demonstrated by other studies (Koray et al. 2007). Considering the new constructivist curriculum, it can be said that creative and critical thinking based applications will become more concrete for teachers because of these studies.

Suggestions

The results of this study provided evidence for the effectiveness of the program. Because of the benefits found in this study, the pre-service teachers should be supported during their lab teaching experiences with critical and creative thinking based activities that explicitly model the process of creative and critical thinking. Integration of critical and creative thinking based applications into logical thinking processes should be made clearer future studies on the steps of logical thinking in common lab activities. The opportunity to critique the logical process of experiments should also be provided to pre-service students. In addition, the effectiveness of combining critical and creative thinking activities in different ways in lab studies should be further investigated.

Although the study provides experimental evidence to evaluate the effectiveness of the program, it is limited to the sample and the instruments used. The lack of a random sampling procedure in the study is another point to consider in interpreting the results of this study. The results of this study should be extended with qualitative and quantitative follow-up studies.

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Appendix

1. Lab Report Format (For Experimental Group)

Name of Unit:

Number of the Experiment:

Name of the Experiment:

Aim of the Experiment:

Theoretical Frame:

Scientific Concepts about Topic of the Experiment:

Tools Used in the Experiment:

Design of the Experiment:

Procedure:

Questions and Answers to Analyze Experiment (At least 20):

Critics about the Experiment (At least Three Points):

Innovations about the Experiment (At least Three Points):

Results and Conclusion:

Knowledge about Scientific and Technological Reflections of the Results of:

Original Experiment about Topic of the Experiment:

Resources:

2. Lab Report Format (For Control Group)

Name of Unit:

Number of the Experiment

Name of the Experiment:

Aim of the Experiment:

Theoretical Frame:

Tools Used in the Experiment:

Design of the Experiment:

Procedure:

Questions and Answers about the Experiment (At least 5):

Results and Conclusion:

Resources: