Science Education International
32(1), 23-33
https://doi.org/10.33828/sei.v32.i1.3

ORIGINAL ARTICLE

Problem-based Scenario Method with Experiments: Determining the Prospective Science Teachers' Biology Self-efficacy and Critical Thinking Tendency

Huriye Deniş Çeliker*

Department of Science Education, Education Faculty, Burdur Mehmet Akif Ersoy University, Burdur-Turkey

***Corresponding author:** huriyedenis@mehmetakif.edu.tr

ABSTRACT

The purpose of this research was to investigate the effect of problem-based scenario method with experiments on the biology self-efficacy and critical thinking tendency of the prospective science teachers. In the study, pre-test and post-test experimental design without any control group was used. The participants of the research were 108 second-grade prospective science teachers in an university in the west of Turkey. Throughout 12 weeks, prospective teachers were given scenarios and they designed experiments based on these scenarios in the Biology Laboratory II course. The biology self-efficacy scale and critical thinking tendency scale were used as a pre-test and post-test. In the analysis of data, Wilcoxon Signed-Rank Test for paired samples was used through SPSS-21. The findings showed that there was a statistically significant difference between biology self-efficacy scale pre-test and post-test of prospective teachers in favor of the post-test. There was also a statistically significant difference in critical thinking tendency scale in favor of the post-test. In the biology self-efficacy scale sub-factors of learning levels and problem-solving, there was a statistically significant difference on behalf of the post-test. However, there was not a statistically significant difference between pre-test and post-test concerning the laboratory activity sub-factor of the biology self-efficacy scale. On behalf of post-tests, there was also a statistically significant difference in critical thinking tendency scale's sub-factors as inquisitiveness, self-confidence, and systematicity. The results show that the problem-based scenario method with experiment certainly contributed to the biology self-efficacy and critical thinking tendency of pre-service science teachers. Based on these results, it is recommended that the problem-based scenario method with experiment be used in the laboratory lessons of prospective teachers.

KEY WORDS: biology self-efficacy; critical thinking; problem-based scenario method; prospective science teachers

INTRODUCTION

The perception of critical thinking and self-efficacy is important concepts for prospective teachers regarding 21st century skills. In the educational field, the perception of self-efficacy can be used to explain individual differences in teacher activities and contribute to understanding and developing teacher behaviors (Enochs and Riggs, 1990). The perception of teachers' self-efficacy is defined as a belief that teachers would show necessary behaviors on successfully performing the teaching function. Depending on self-efficacy perceptions, teachers' efforts, aims, and desire levels on teaching may be variable (Tschannen-Moran and Hoy, 2001).

The self-efficacy relevant to this study is Social Cognitive Theory. This is defined as "a judgment for himself/herself about designing necessary activities to show a certain performance and applying successfully" (Bandura, 1997, p. 3). The belief of biology self-efficacy may be defined as those decisions about successfully learning the biology field (Ekici, 2009). Bandura suggests that intense self-efficacy has a positive influence on the successes and happiness of individuals. When the individuals, who have an intense self-efficacy, encounter a hard task, they approach the situation as a work that had to be overcome (Askar and Umay, 2001).

It has been revealed that there are differences between teachers, who have high and low self-efficacy, on behaviors about classroom arrangement, using new methods, feedback for students with learning disabilities, and these differences affect students' motivation and successes (Tschannen-Moran and Hoy, 2001). The teachers, who trust their teaching abilities and believe that learning may be led by active teaching, show greater patience and give different feedback (Gibson and Dembo, 1984). This relationship between teachers' self-efficacy and student success has been examined by several researchers. It is concluded that teachers' self-efficacy has a positive effect on student success and behavior and is directly associated with teachers' behaviors in the classroom, being open-minded, developing positive attitudes on teaching (Tschannen-Moran et al., 1998). It has been noted that between teachers who have high and low self-efficacy there were significant classroom behavior differences on skills such as classroom arrangements, feedback for students with learning

disabilities, and these differences caused differentiations on student's success (Ozturk et al., 2002).

Bandura (1997) indicated that a teacher's self-efficacy and his/her perception had an important role in preparing a teaching environment that aimed to develop students cognitively. According to Aston (1984), teacher training programs can benefit from self-efficacy tools to explain prospective teachers' beliefs for supporting them. Yet, teacher training programs should provide the content of a certain field and more than the methods which can be used (Enochs and Riggs, 1990). One of the most important factors for forming the abilities teachers have is pre-service education. It has been argued that the teacher will be as adequate and efficient as the program taken (Gokce, 1999). Therefore, prospective teachers who are educated with an adequate and effective education process will increase the quality of education in the future. With the basic skills required by the age, prospective teachers can apply various methods in their teaching processes (Sarac, 2002). This means that teachers' interpretations about the situations they encountered in professional life can be affected by their educational experiences to include university (Dalal and Singh, 1986). The problem-based scenario is one of the methods that can improve prospective teachers' self-efficacy and different skills should be applied in their teaching processes.

The problem-based scenario method can help individuals to understand how to be specialized, to take advantage of the lives of themselves and others, and to make reasoning and learning explicit (Schank, 2002). Some universities aim to adapt students to life and their profession, to find solutions for the situations they might encounter using the education method based on learning with scenarios (Erduran-Avci and Bayrak, 2013). In learning based on scenarios, stories containing people and events are presented for a learning purpose (Caroll, 2000). There are four different scenario types: (A) Skills-based scenarios, (B) problem-based scenarios, (C) speculative-based scenarios, and (D) issues-based scenarios according to the content of the target aimed to be gained (Errington, 2003).

Research has shown how the problem-based scenario method is more effective than traditional teaching methods in terms of students' ability to be effective and to learn by doing and experiencing (Mariappan et al., 2003). Problem-based learning (PBL) aims to encourage student-centered learning and improve students' higher-order thinking skills (Azer, 2009). PBL is an approach that places the student at the center of the learning process, offers scenarios for groups to research and provide appropriate solutions, and scenarios have problems (Wyness and Dalton, 2018). The main tool of PBL is scenarios. These scenarios have events that increase students' curiosity, make them think about their reasons, and keep students' motivation at a high-level while reaching the gains (Hatisaru and Kucukturan, 2009). The scenarios should be associated with the real world so that students have a connection with the implementation that they will encounter in their professional life in the future (Sheridan and Kelly, 2012). In such an implementation, classes are designed by focusing on the process of gaining ability and behavior. The scenarios are set and produced for learning by experience (Errington, 2003). The scenarios can be chosen from events that have happened or are likely to happen, or they can be chosen from events that have not been experienced and associated with real life (Acikgoz, 2003; Brock, 2003; Dahlgren and Oberg, 2001). Learning based on the scenarios provides an educational environment in which attendants are carefully selected; solve genuine work tasks or problems (Clark, 2009). The approach of learning based on scenarios is a quite significant method requiring first the transferring of thought into the action, second turning the act into life, and final the individual acquiring this information from their own life (Cautreels, 2003; Ozerbas and Somuncuoglu-Ozerbas, 2015). There are studies based on a problem in a way of providing the student a role at this point (Stewart, 2003). The scenarios have the characteristics of living experience for students by making them feel probable situations they may encounter in real-life (Yan, 2006). In this way, it improves their ability in critical thinking (Torp and Sage, 2002).

A well-designed scenario should provide students a chance to reflect. It lets them exhibit, test, and evaluate their values (Ribchester and Healey, 2019). Research shows that not all students use what they have learned to solve problems of the real world (Waterman, 1998). Learning based on a scenario fills the gap between theory and implementation (Meldrum, 2011; Ahmed, 2019). Furthermore, every detail that students need on advancing in the scenario should be planned. On planning the scenario, it is necessary to work with leading experts in their areas related to learning targets (Akins and Crichton, 2003).

It is considered that the learning method based on the scenario, which activates the student, improves high-level thinking abilities and is beneficial for teachers on teaching hard topics (Rybarczyk et al., 2007). The most significant benefits of scenarios are to provide meaningful solution ways and interaction between learners (Garrison and Vaughan, 2008). Researchers and teachers, who studied learning based on scenarios, describe it as an approach that improves learners' creative thinking, imagination, creative solutions for problems, and contains planning for the future by regarding the mental process (Snoek, 2003; Viebahn and Hilton, 2006). They argue that these classroom interactions are factors working in conjunction with each other to support teacher and student performance (Wilson et al., 2002). The teaching approach of problem-based scenario, which activates the imagination of students and teachers, provides a delighted learning and teaching process for both teachers and students. This satisfaction is one of the conditions which are necessary for effective teaching. The scenario awakes the interests and imagination of people (Stomp, 2003). Those who have an education with scenarios learn in more detail and deeper than others (Ertl et al., 2006). Furthermore, the underlying logic of the approach is to learn and improve some skills through genuine activities (Schank et al., 1993). One of these skills may be critical thinking ability.

Critical thinking is a logical and reflective way of thinking that focuses on what to do and what to believe (Ennis, 1985). Critical thinking has been defined as the ability to control our own mind and take responsibility (Paul, 1996), the ability to interpret and evaluate observations, communications, information, and arguments (Fisher and Scriven, 1997). Critical thinking is to think about thinking while performing the act of thinking in an attempt to improve his/her thinking (Paul and Elder, 2012). Critical thinkers believe that thinking deeply and reasonably are the best way to decide what to believe, and they tend to use these methods in a variety of appropriate situations (Fisher, 2011). While critical thinking abilities are containing some high-level thinking abilities, critical thinking tendency is the motive and tendency of using critical thinking of individuals who use this kind of thinking (Facione, 2015). Critical thinking is a purposeful judgment that requires self-regulation, resulting in interpretation, analysis, evaluation, and inference (Hajrezayi et al., 2015). PBL supports the development of students' critical thinking skills (Al-Najar et al., 2019). It was found that students are more inclined to critical thinking when their self-efficacy evaluations are high (Phan, 2010). Kezer et al. (2016) stated that there was a correlation between critical thinking tendency and self-efficacy perception of university students. Phan (2009) found out a positive and significant relationship between self-efficacy and critical thinking. Wanga and Yi-Wub (2008) found out that the predictive power of self-efficacy was high on using high-level learning opinions such as critical thinking. Bandura and Lock (2003) defended that self-efficacy creates motivation and develops performance. Leung and Kember (2003) found a positive relationship between motivation variables such as aim tendency with critical thinking, self-efficacy belief, and effort. Furthermore, Kuiper (2002) expressed that improving of critical thinking benefits to confidence and developing self-efficacy. In the related literature, it was stated that there is a significant and positive correlation between self-efficacy beliefs and critical thinking tendency of prospective teachers (Cansoy and Turkoglu, 2017; Dehghani et al., 2011; Zangenehvandi et al., 2014). It was predicted that the implementations of problem-based scenarios method with experiments in laboratory classes of biology would contribute to the biology self-efficacy level and critical thinking tendency of prospective science teachers.

There are several studies in different learning levels of problem-based scenarios method. Hursen and Gezer-Fasli (2017) set forth that learning based on the scenario is more effective than reflective learning in a way of academic achievement of prospective teachers. Yet, a significant difference could not be found between self-efficacy perceptions of groups with learning based on the scenario and reflective learning. Dori et al. (2002) concluded that a significant improvement occurred in the knowledge level and high-level thinking abilities of students by learning based on the scenario. Bardach et al. (2020) found out a significant effect on self-efficacy of the experimental group that was implemented feedback and reflection with learning based on the scenario. Peranginangin et al. (2019) PBL with Karo culture context has increased the mathematical problem solving skills and self-efficacy of its application. Similarly, Rokhmawati et al. (2016) concluded that the PBL model improves students' problem solving skills and self-efficacy.

When considering the related literature, it is observed that the PBL is used with different techniques and educational environments. Unlike others, this study expects prospective science teachers to specify the problems in the problem-based scenario and design an experiment as a solution. This study provides an example of how to use the process of problem-based scenarios method with experiments in teacher training in the biology laboratory class. It was aimed to research the effect of performing biology laboratory course with the process of designing an experiment based on scenarios on biology self-efficacy and critical thinking tendency of prospective teachers.

Research Questions

1. What is the effect of problem-based scenarios method with experiments in biology laboratory course on biology self-efficacy of prospective science teachers?
2. What is the effect of problem-based scenarios method with experiments in biology laboratory course on critical thinking tendency of prospective science teachers?

METHODOLOGY

Research Design

In the study, a pre-test and post-test without any control group was used as a quasi-experimental design (Cook and Campbell, 1979). In this design, the effect of the process is tested with research on a single group. Measures of subjects for the dependent variable are obtained using the same subjects and tools as a pre-test before the implementation and post-test after. Within this respect, this design can be described as a single factor design or recursive measuring design. The significance of the difference between the pre-test and post-test scores of a single group in the pattern is tested (Buyukozturk et al., 2014). In the study, the process of problem-based scenarios with experiments is used as an experimental application. As pre-test and post-test, critical thinking tendency scale and biology self-efficacy scale are used.

Participants

The potential participants of the research were 110 second-grade prospective science teachers in a faculty of education of a state university in the west of Turkey. This study was conducted with 108 of the prospective teachers because two prospective teachers did not attempt the post-tests. Biology laboratory is a compulsory course for science teaching. There are Biology Laboratory I (2 credits) in the fall semester and Biology Laboratory II (2 credits) in the spring term of second grade as an applied course. When the distribution of prospective teachers according to gender was examined, 78 (72.2%) were women and 30 (27.8%) were men.

Science Education International
32(1), 23-33
https://doi.org/10.33828/sei.v32.i1.3

Data Collection Tools

Biology self-efficacy scale

The biology self-efficacy scale which was developed by Woo (1999) and adapted into Turkish by Ekici (2009) was used. The scale has three factors. The first one is laboratory activities, the second one is the learning level, and the third one is the solving problem. Cronbachs' alpha coefficient of the inventory, which is formed by 40 Likert-type items, was found to be 0.94. The Cronbachs' alpha value was calculated as 0.95 for the pre-test of present study, and 0.96 for the post-test. Cronbachs' alpha values of each sub-factor of the scale are shown in Table 1.

As shown in Table 1, the Cronbachs' Alpha reliability coefficient of the laboratory activity sub-factor of the original biology self-efficacy scale was 0.93, the Cronbachs' Alpha value of the learning level sub-factor was 0.90, and the Cronbachs' Alpha reliability coefficient of the problem solving sub-factor was 0.88.

Critical thinking tendency scale

The adaptation into Turkish Culture of the scale which was developed by Facione et al. in 1998 was made by Kokdemir (2003). The final form consists 51 items and six factors as "Analyticity (ten articles)," "Open-Mindedness (12 articles)," "Inquisitiveness (nine articles)," "Self-confidence (seven articles)," "Truth-Seeking (seven articles)," and "Systematicity (six articles)." Cronbachs' alpha coefficient of the inventory, which was formed by 51 Likert-type items, was found to be 0.88. Cronbachs' alpha value for the pre-test of present study was calculated as 0.76 and the Cronbachs' alpha value for the post-test was calculated as 0.82. Cronbachs' alpha values of each sub-factor of the inventory are shown in Table 2.

In Table 2, the reliability coefficient of the analyticity sub-factors of the critical thinking tendency original scale was 0.75, the Cronbachs' Alpha value of the open-mindedness factor was 0.75, the inquisitiveness sub-factor's Cronbachs' Alpha value was 0.78, the self-confidence sub-dimension was 0.77, the truth seeking Cronbachs' Alpha value of the sub-factor was 0.61, and the reliability value of the systematicity sub-factor was 0.63.

The Model of Problem-based Scenarios with Experiments

Problem-based scenarios were used in this study. Hafler (1997) expresses that a scenario should be prepared in four phases such as planning, writing, applying, and improving. Brock (2003) defined a model with eight phases (purpose; integration; authenticity; prevalence and relevance; resources and format for delivery; impact and interest; sequence; brevity and complexity; and modality). Scenarios were written after the specified models had examined.

The PBL process and its stages have been studied from different sources (Alrahlah, 2016; Hmelo-Siver, 2004; Wurdinger and Carlsen, 2010). Since problem-based scenarios applied together with the experiments in the biology laboratory course, the experiment phase was added to the process, and the application was made according to the stages indicated in Figure 1.

According to Figure 1, scenarios based on real or probable events were prepared in line with the learning objectives, based on the problem-based scenario method. Second, prospective teachers read the scenario to understand the content of the scenario and the topics. The third stage was the determination of the problem. At this stage, the prospective teachers could write notes to identify the problem after reading the scenarios. Prospective teachers could analyze the topic with group discussion. In this way, the problem was determined and could be defined. In the fourth stage, the solution of the problem, the solution was searched, examined and the information was described within the reference and resources. Various resources and materials have been provided for prospective teachers to conduct research. In the fifth stage, prospective teachers design and implement an experiment based on the data they have obtained as a result of their research. They tried to explain the problem situation in the scenario by experiment. In the last stage, the researcher and prospective teachers evaluated the learning process together. In this process, group observation

Table 1: Sub-factors, examples of items and Cronbachs' alpha values of biology self-efficacy scale

Sub-factors of biology self-efficacy scale	Examples of items	Original cronbachs' Alpha
Laboratory activity sub-factor	In the biology lesson, I can carefully observe and define the result of the experiment	0.93
Learning level sub-factor	I can understand the important terms and concepts in the biology book	0.90
Problem solving sub-factor	I can help my friends to solve problems related to biology	0.88

Table 2: Sub-factors, examples of items and Cronbachs' alpha values of critical thinking disposition inventory

Sub-factors of critical thinking tendency scale	Examples of items	Original cronbachs' Alpha
Analyticity	It disturbs me that people rely on weak ideas to defend a good thought	0.75
Open-mindedness	Exams that require thinking are better for me than those that require only memorization	0.75
Inquisitiveness	It would be great to study new things all my life	0.78
Self-confidence	I am proud to be able to think with great clarity	0.77
Truth-seeking	It is impossible to be neutral when discussing my own ideas	0.61
Systematicity	I am known for my regular approach to complex problems	0.63

Science Education International
32(1), 23-33
https://doi.org/10.33828/sei.v32.i1.3

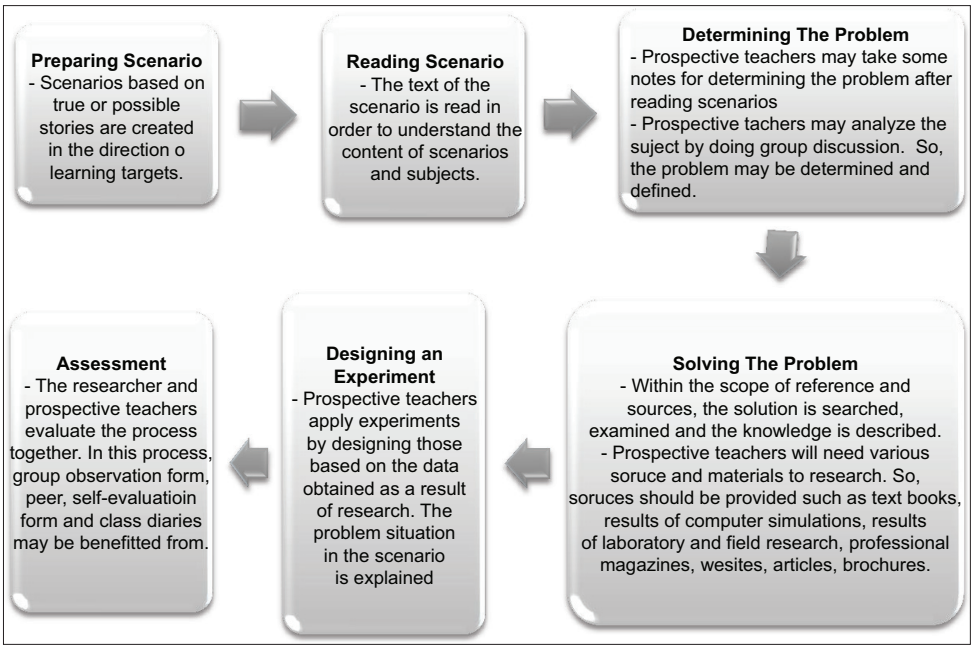

Figure 1: The stages phases of problem-based scenarios with experiments

form, peer, self-assessment form, and course diaries could be used.

As noted, this research was conducted with 108-second grade prospective science teachers who had been taking Biology Laboratory II course in a faculty of education. On the experimental group, Biology Self-efficacy Scale and Critical Thinking Tendency Scale were performed pre-test and post-test. During the implementations, there was no change in the routine of Biology Laboratory II course and it was conducted 2 h a week. The experimental study was continued for 12 weeks. It lasted 14 weeks with pre-test and post-test. In the groups, worksheets related to learning based on the problem were used. In the activity sheets, there were 14 stories including daily life problems which designed by students' interest and curiosities and make them research and investigate. According to the subject content, one or two scenarios were given to prospective teachers in each week. The scenarios were prepared in the context of these topics: Diffusion-osmosis; structure of blood; blood groups; muscles tissue, adipose tissue; observing growth; and development in living things; characteristics of vertebrates and invertebrates; digestive system organs, nutrients and ingredients; respiratory system organs; circulatory system organs; excretory system organs; and sensory organs: Tongue and taste; sense organs: Eye and its structure. Below is a sample scenario for osmosis:

> *Merve and her friends had gone to the sea. They had a very enjoyable day swimming in the sea for a long time. When they got out of the sea, they all noticed that their skin was wrinkled. After waiting for a while on the beach, the wrinkles on the skin of their hands disappeared. Merve and her friends decided to have a picnic on the way back from the sea. They were preparing their meals on a table on the watered grass. Merve's friend Irmak accidentally spilled the salt on the floor while trying to add salt to the salad. When the salt reached the grass, the slug in the grass had already died. This situation made them very sad.*

The following questions were given to prospective teachers along with the scenario.

1. *What are the problem/s to be addressed in the scenario? What could be the reason for the incident occurring on the skin of the hands of Merve and her friends? Why is the slug dead?*
2. *What do we know about this topic?*
3. *Report your research on the topic.*
4. *Design an experiment that can demonstrate this topic context*
5. *Present your research and experiments on the subject in any way you want.*

Experiments conducted by prospective teachers regarding this scenario are given below. The prospective teachers worked in groups. Some experiments were preferred and conducted by more than one group.

Experiment 1: The prospective teachers used dried semi-permeable animal intestines, distilled water, lugol solution, benedikt solution, starch solution, glucose solution, two beakers, a standing holder and a spirit stove, and after waiting 24 h, they were informed about diffusion have done their experiments.

Experiment 2: The prospective teachers carried out their experiments in which they observed plasmolysis and deplasmolysis phenomena with onion skin, pure water, concentrated saline solution, slide, coverslip, and microscope.

Experiment 3: With the osmosis experiment in potatoes, prospective teachers; they carved the inside of boiled and two

raw potatoes. They concentrated the environment by putting salt into one of the boiled potatoes and one of the raw potatoes. They did not add salt to the third raw potato. They placed three potatoes in their water baths. They observed the passage of water according to the density difference because of osmosis, and the osmosis phenomenon in living and non-living cells.

Experiment 4: The prospective teachers kept the outer shell of an egg made up of calcium in vinegar to dissolve it. It is a concentrated solution of protein and water in the egg membrane, whose shell has disappeared. They observed osmosis by doing the experiments in which they observed the volumetric change of the egg in distilled water and concentrated salt in water.

Experiment 5: The prospective teachers filled a container with pure water. Then, they dipped a funnel with sugar water inside this container, which they sealed with selectively permeable animal intestine in a wide part. They observed the liquid passage in the narrow section of the funnel.

Experiment 6: The prospective teachers observed the jellybeans by waiting in water. Here, the gelatin of the sugar acts as a semi-permeable membrane, so water can enter the sugar, but the sugar and the dye are much more difficult to get out of the sugar.

Experiment 7: The prospective teachers used one (or two) jars, paper towels, rubber bands, and food coloring for this experiment. They filled a jar with water and attached a paper towel (with a rubber band) to the mouth of the jar. Hence, they made a water-filled reservoir that would hang over the water and add food coloring. They dropped a few drops of food coloring into the chamber and observed.

Experiment 8: The prospective teachers put the vanilla into the balloon and inflated it. They placed this balloon in a box and closed the lid. They asked their classmates to guess what was inside the bubble. After waiting for a while, when they opened the lid of the box, the whole class knew that the substance in the balloon was vanilla and related the experiment with the concept of diffusion.

Prospective teachers, who studied in cooperative groups of 5–6 people, read the scenarios which were given them, and then discussed the questions "What is/are the problem/problems which should be handled? What do we know about it?" They reported their research about the subject in a week and designed experiments that reveal the subject in the scenario. In the 2nd week, they performed their experiments and filled peer and self-efficacy evaluation forms related to the process. After this process, they were given the scenarios about the next week and discussed as a group again. Since the beginning of the process, prospective teachers were tried to bring as many sources as possible which provides them an opportunity to research the subject by giving them the main theme of the next week. Prospective teachers designed and performed experiments related to the problems in scenarios for 12 weeks.

Data Analysis

The data were analyzed through SPSS software package (version 21). The Kolmogorov–Smirnov Test (n = 108) was used to determine the normality of this research. In the Kolmogorov–Smirnov test results of the biology self-efficacy scale post-test scores (ρ = 0.048) and the post-test problem solving factor (ρ = 0.009), ρ values were found to be <0.05. Although the Kolmogorov–Smirnov test pre-test and post-test scores of the critical thinking tendency scale did not show excessive deviation from normal, the sub-factors of the scale, analyticity pre-test (ρ = 0.000) and post-test scores (ρ = 0.001), open-mindedness post-test scores (ρ = 0.001), inquisitiveness post-test scores (ρ = 0.045), self-confidence pre-test (ρ = 0.004) and post-test scores (ρ = 0.017), and truth-seeking pre-test scores (ρ = 0.015) deviated from the normal distribution.

The Wilcoxon Signed-Rank Test for paired samples which is one of non-parametric analysis was used comparing pre-test and post-test scores of biology self-efficacy and critical thinking tendency scales. Analyzes were done on total scores.

FINDINGS

Means and standard deviations of pre-test and post-test scores of the prospective science teachers had achieved from the biology self-efficacy scale and its sub-factors are given in Table 3.

As shown in Table 3, the pre-test average of the total scores of the biology self-efficacy scale was 152.33 while the post-test average increased to 168.56. The pre-test average of the laboratory activity sub-factor of the biology self-efficacy scale increased from 50.94 to 51.44 in the post-tests. The pre-test average of the learning level sub-factor was 56.40, and the post-test average was 62.17. The pre-test average of the problem solving sub-factor of the scale increased from 45.00 to 50.12.

Means and standard deviations of pre-test and post-test scores of the prospective science teachers have achieved from critical thinking disposition tendency and its sub-factors are given in Table 4.

As shown in Table 4, the critical thinking tendency scale pre-test total score average increased from 221.78 to 226.56. Post-test averages of the inquisitiveness, self-confidence and systematicity sub-factors of the critical thinking tendency scale increased according to the pre-test averages. However,

Table 3: Means and standard deviations that the prospective teachers had achieved from biology self-efficacy scale and sub-factors

Biology self-efficacy scale and sub-factors	Pre-test		Post-test	
	Mean	SD	Mean	SD
Laboratory activity sub-factor	50.94	6.33	51.44	5.10
Learning level sub-factor	56.40	7.57	62.17	7.87
Problem solving sub-factor	45.00	6.38	50.12	6.45
Total Inventory	152.33	18.68	168.56	19.25

Science Education International
32(1), 23-33
https://doi.org/10.33828/sei.v32.i1.3

Table 4: Means and standard deviations that the prospective teachers had achieved from critical thinking disposition inventory and its sub-factors

Critical Thinking tendency scale and sub-factors	Pre-test		Post-test	
	Mean	SD	Mean	SD
Analyticity	47.97	5.52	47.89	6.20
Open-mindedness	52.64	7.27	52.44	8.77
Inquisitiveness	39.94	5.37	41.59	6.43
Self-confidence	28.25	4.87	30.23	4.87
Truth-seeking	26.18	5.53	26.40	5.87
Systematicity	26.80	3.89	27.99	4.58
Total Inventory	221.78	21.39	226.56	24.97

pre-test-post-test averages of the analyticity, open-mindedness, and truth-seeking factor of the scale are very close to each other.

The results of the Wilcoxon Signed-Rank Test for paired samples, which are conducted for the significance of the difference between pre-test and post-test average scores belonging to the biology self-efficacy scale and its sub-factors, are given in Table 5.

Wilcoxon Signed-Rank test results are given in Table 5 that is about if biology self-efficacy of prospective science teachers showed a significant difference before and after the process of problem-based scenarios with experiments in a biology

Table 5: Biology self-efficacy scale scores of Wilcoxon signed-rank test results of pre-test and post-test

Biology Self-efficacy Scale and Sub-factors	Post-test-Pre test	n	Mean Rank	Sum of Ranks	z	ρ
Total of Biology self-efficacy scale	Negative ranks	16	25.50	408.00	7.71*	0.000
	Positive ranks	91	59.01	5370.00		
	Ties	1				
Laboratory activity sub-factor	Negative ranks	43	49.74	2139.00	1.18*	0.240
	Positive Ranks	56	50.20	2811.00		
	Ties	9				
Learning level sub-factor	Negative ranks	16	27.63	442.00	7.43*	0.000
	Positive ranks	88	57.02	5018.00		
	Ties	4				
Problem solving sub-factor	Negative ranks	17	37.65	640.00	6.78*	0.000
	Positive ranks	87	55.40	4820.00		
	Ties	4				

*Based on negative ranks

Table 6: Critical thinking scale scores of Wilcoxon signed rank test results of pre-test and post-test

Critical thinking tendency scale and sub-factors	Post-test-pre test	n	Mean rank	Sum of ranks	z	ρ
Total of critical thinking tendency scale	Negative Ranks	37	51.03	1888.00	2.99*	0.003
	Positive Ranks	69	54.83	3783.00		
	Ties	2				
Analyticity	Negative Ranks	50	49.97	2498.50	0.082**	0.934
	Positive Ranks	49	50.03	2451.50		
	Ties	9				
Open-mindedness	Negative Ranks	45	52.58	2366.00	0.211*	0.833
	Positive Ranks	53	46.89	2485.00		
	Ties	10				
Inquisitiveness	Negative ranks	36	48.63	1750.50	3.18*	0.001
	Positive ranks	68	54.55	3709.50		
	Ties	4				
Self-confidence	Negative ranks	30	46.65	1399.50	4.11*	0.000
	Positive ranks	72	53.52	3853.50		
	Ties	6				
Truth-seeking	Negative ranks	43	50.42	2168.00	1.07*	0.283
	Positive ranks	56	49.68	2782.00		
	Ties	9				
Systematicity	Negative ranks	28	41.79	1170.00	3.67*	0.000
	Positive ranks	63	47.87	3016.00		
	Ties	17				

*Based on negative ranks. **Based on positive ranks

laboratory course. The analysis result showed that there was a significant difference between prospective science teachers' pre-test and post-test the biology self-efficacy scale, $z=7.71$, $\rho < 0.05$. When the mean rank and sum of ranks were considered, it had shown that this difference was in support of the post-test score. The same results were available for the learning level of the biology self-efficacy scale and its sub-factor problem-solving. Yet, it had also shown that there was not a significant difference between pre-test and post-test scores in a sub-factor of activities of the scale. According to these results, the process of problem-based scenarios with experiments affects improving biology self-efficacy of prospective science teachers.

The results of the Wilcoxon Signed-Rank Test for paired samples, which were conducted for the significance of the difference between pre-test and post-test average scores belonging to the critical thinking scale and its sub-factors, are given in Table 6.

The results of the Wilcoxon signed-rank test for paired samples are given in Table 6 about if prospective science teachers showed critical thinking tendency differences before and after the process of problem-based scenarios with experiments. It showed that there was a statistically significant difference between prospective science teachers' scores which they had from the critical thinking tendency scale before and after the experiment, $z=2.99$, $\rho < 0.05$. When the mean rank and sum of ranks were considered, it had shown that this difference is in support of the post-test score. There was a statistically significant difference in support of post-tests in dimensions of inquisitiveness, self-confidence, and systematicity of the scale. Yet, there was not a statistically significant difference between pre-test and post-tests in dimensions of analyticity, open-mindedness, and truth-seeking of the scale. The results show that the problem-based scenario method certainly contributed to the biology self-efficacy and critical thinking tendency of pre-service science teachers.

DISCUSSION AND CONCLUSION

When the findings of this research, which aimed to reveal the effect of the prospective science teachers on biology self-efficacy and critical thinking tendency during the process of problem-based scenarios with experiments in a biology laboratory course, were examined, a significant increase could not be found in laboratory activity sub-dimension as there was a significant increase in their biology self-efficacy and learning levels of biology self-efficacy scale and its problem-solving sub-factors. The prospective teachers determined the problems in scenarios given to them and researched about learning field related to this problem. They designed experiments in which they could reveal the problem in the scenario. Authentic learning environments that make students take more responsibilities to improve self-efficacy (Mataka and Kowalske, 2015). Scenarios must be realistic and reflect the experiences of attendants (Hmelo-Silver, 2004). The self-efficacy belief is related to experiential learning (Scott, 2014). In the process of problem-solving, students visualized the problem and decided how to solve it. In this way, the problem-solving process increased the awareness of cognitive qualities (Mohamed and Nai, 2005). The individuals, who had a low level of problem-solving, made mistakes on deciding how to use the knowledge (Lucangeli et al., 1997). Cognitive awareness increases the success of problem-solving (Howard et al., 2000). Using scenarios in a learning method based on problem improved students' confidence and self-efficacy besides their knowledge and abilities (Cerezo, 2004; Mayer, 2002; Morales-Mann and Kaitel, 2001). The programs which provided opportunities such as real learning experiences, relations, motivation, and leadership experiences support individuals' self-efficacy (Versland, 2009). At the end of the class performed appropriate to problem-solving strategies, Posnanski (2002) reached similar results that it had positive effects on teachers' self-efficacy. Kaptan and Korkmaz (2002) revealed that the implementations based on a problem conducted with scenarios increased prospective science teachers' self-efficacy beliefs for science.

It was suggested that a learning environment based on the problem, which based on the web, had a positive effect on learners' self-efficacy beliefs (Brown et al., 2013). Similarly, there was a significant change in self-efficacy related to confidence and new learning of attendants in the workplace after learning application based on a problem in which scenarios are used (Dalby, 2005). Hsu et al. (2015) concluded that simulation course based on scenarios improved nurses' confidence. When students analyzed daily life problems, science classes become more interesting and entertaining. In conclusion, enjoying the learning affected students' self-efficacy (Saputro et al., 2019).

There was a significant increase in the prospective science teachers' critical thinking tendency of problem-based scenarios with experiments, and its sub-factors as inquisitiveness, confidence, and systematicity. Yet, there was not a statistical increase in analyticity, open-mindedness, and truth-seeking dimensions of the scale. Being asked questions during problem-solving processes made students think and improve their critical thinking abilities (Cooke and Moyle, 2002). Similar results were reached in different areas. Learning methods based on a problem with scenarios, which were used in social science class and nursing students, improved students' critical thinking abilities (Lee et al., 2004). The implementation of a professional development program had gained speed because implementing real-life scenarios in learning based on problem provides a hands-on experience or deciding skills, leadership skills, and critical thinking abilities (Brownell and Jameson, 2004). Learning based on a problem with scenarios was a student-centered method which provides transferring students' critical thinking and knowledge into implementation (Crawford, 2011; Savery, 2006; Wilder, 2014). Canturk-Gunhan and Baser (2009) revealed that the learning method based on a problem with scenarios improves students' critical

thinking abilities in math class. It is originated from problems about daily life making each knowledge permanent (Gunter and Alpat, 2017) and improves their critical reasoning (Saputro et al., 2020). PBL has great potential to improve students' higher-order thinking skills, especially critical thinking skills (Masek and Yamin, 2011). Although there are studies revealing that PBL improves critical thinking skills (Gholami et al., 2016; Ismail et al., 2018; Ozturk et al., 2008; Seibert, 2021; Semerci, 2006; Sendag and Odabas, 2009; Tiwari et al., 2006; Zhou, 2018), there are also researches revealing that it does not increase critical thinking skills (Choi et al., 2014; Yuan et al., 2008). It is noteworthy that most of these studies are in the field of nursing. More research is necessary to explore the effect of PBL on critical thinking in different cultures, study groups, and disciplines (Sommers, 2014).

LIMITATIONS AND SUGGESTIONS

This study provides evidence that the prospective teachers' problem-based scenarios with experiments in biology laboratory course contributed to improving biology self-efficacy and critical thinking. It was quite important to apply experiments about biology subjects in science class to prospective science teachers who will conduct these with different methods and techniques. The results showed that the processes of problem-based scenarios with experiments were useful to prospective teachers for laboratory courses. There were some limitations in the study because it was applied to the formal education program. The study was conducted with second-grade prospective science teachers. Hence, the generalizability of the study is an important limitation. A control group could not be selected not to cause differences between the classes. The application can be repeated by experimental and control group in different studies. Non-parametric statistics were used. By choosing wider participants to form different universities, the data which are closer to normal distribution can be reached and some parametric tests, which can give statistically stronger results, can be used. Data collection tools, which were used in the study, are the scales that are adapted to Turkish, tested in a way of validity and reliability. A similar study can be used by developing a more up to date biology self-efficacy scale and critical thinking tendency scale. Data variety can be provided by including qualitative data collection tools as observation and interview into the process. The process of problem-based scenarios with experiments increased in the biology self-efficacy scale, laboratory activity sub-factor, critical thinking tendency scale, analyticity, open-mindedness, and truth-seeking sub-factors of prospective science teachers. These reasons can be researched in detail. In different studies, another research can be conducted to develop these sub-factors.

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