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Cover Page Footnote

This study was produced from the master thesis of the first author under the supervision of the second author.

Students' Conceptions of Learning Biology and Achievement after Stem Activity–Enriched Instruction*

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Abstract

Although there are many studies analyzing the effect of the STEM model on students' cognitive characteristics, no studies have focused on its effect on students' conceptions of learning (COL). It is necessary to determine how COL, which may vary depending on cultural features and learning environments, will take shape with STEM, which is a learning model of great importance. Therefore, the current study investigated the effects on Turkish high school students' academic performance and conceptions of learning biology (COLB) in STEM activity–enriched biology courses. The study implemented a true-experimental design and was carried out with 99 high school students. The COLB Scale was used to determine the students' COLB, and the Nervous System Achievement Test (NSAT) was used to determine their achievement regarding the structure, function, and mechanism of the nervous system. The data analysis was conducted using MANOVA. According to the results of the analysis, the STEM activity–enriched learning model had an effect on the students' academic performances; however, it made no difference in terms of their COLB.

Keywords: biology, conceptions of learning, STEM

Introduction

In today's educational research, it is important to identify variables that might affect students' academic performance and to reveal the relationships between these variables. Raising individuals with distinctive qualities in changing economic and technological conditions and training people with the desired profile are possible by manipulating these variables. Based on these factors, countries sometimes make educational reforms. The STEM (science, technology, engineering, mathematics) educational model emerged as a result of such a need and has been adopted in several countries. Although the STEM model was first integrated

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into the education system of the United States (Sanders, 2009), it also appears in the education systems of other countries, particularly China and India. In STEM centers established within universities and schools under the Ministry of Education in Turkey, studies have examined the implementation of STEM activities and the popularization of STEM studies. STEM education was developed to meet the need for individuals who can devise new ideas and contribute to the fields of science, technology, engineering, and mathematics or who are specialized in these fields. With STEM education, it is thought that scientists will emerge, engineers and mathematics and technology experts will make new designs, and progress in science and technology will be achieved. Therefore, experts claim that in this approach, which requires the interdisciplinary transfer of information, the unification of science, engineering, technology, and mathematics is possible and can cover in- and outside-class activities at every grade level from preschool to higher education (Gonzalez & Kuenzi, 2012).

With the importance given to the STEM model, several studies have been conducted within the scope of integrated STEM education, which is based on individuals' experiences and the integration of content and context for the implementation of STEM activities. Integrated STEM education means teaching a topic by integrating the learning outcomes and skills of the main discipline that the topic belongs to with those of at least one other discipline (Çorlu, 2017). Lamb et al. (2015) conducted a three-year study with 254 students from preschool, second, third, fourth, and fifth grade levels to determine the effects of integrated STEM education on students' cognitive and affective development. According to the study's findings, students' levels of self-efficacy toward science, interest, spatial imaging, mental rotation, and science content knowledge were higher in the experimental groups where STEM activities had been implemented, and the researchers observed that STEM activities were influential in students' cognitive and affective development. Similarly, an experimental study by Cotabish et al. (2013) investigated the effects on scientific process skills and content and concept knowledge in elementary students who participated in a STEM program. This study, which was conducted with 1750 students from second through fifth grades, lasted for a whole educational year. In the light of the findings, the authors state that a statistically significant increase was found in scientific process skills and concept and content knowledge in the students in the experimental group. Mutakinati et al. (2018) carried out a study with 160 secondary school first graders and analyzed project-based learning (PBL) with STEM education. They claimed that they achieved progress in the development of critical thinking ability. Other studies on STEM education have investigated the relationships between the academic achievement of Turkish students and variables such as motivation and interest in STEM occupations (Karcı, 2018), intelligence types, and learning styles (Onsekizlioğlu, 2018). The current study, however, in contrast to these frequently researched variables, analyzes whether STEM-based activities has an effect on students' conceptions of learning (COL). Therefore, our purpose in this study was to determine the effect of STEM activity–enriched instruction on Turkish high school students' academic performance in biology and their COL. For this purpose, we aimed to answer the following questions:

(1) What is the effect of a STEM activity–enriched learning method on Turkish high school students' biology achievement?

(2) What is the effect of a STEM-enriched learning method on Turkish high school students' conceptions of learning biology?

Conceptions of Learning

A COL is generally defined as a consistent knowledge and belief system regarding learning (Benson & Lor, 1999). It has also been defined as what a student thinks about the topics they have learned, or simply as the topics or content they have learned (Benson & Lor, 1999). According to another definition, a COL is an individual's personal learning goals, activities, or strategies or the learning process itself (Vermut & Vermetten, 2004). Buehl & Alexander (2001) and Tsai (2004) define COL as the knowledge that the student has acquired at school and their beliefs about learning—that is, their academic epistemic beliefs. Scholars have suggested that students usually conceptualize their learning experiences in different ways (Tsai, 2004).

One of the earliest studies on COLs was conducted by Säljö (1979), who examined students' COLs under the categories of increasing knowledge, retaining and using it when necessary, having the knowledge of reality, and abstraction of meaning, a process aiming at comprehension and understanding (Taşkın et al., 2015). Later studies mention these categories in different ways, such as memorizing, preparing for exams, calculating and practicing, increasing knowledge, understanding, applying, and seeing in a new way (Martin et al., 1993). Tsai (2004) defines the first three steps of this categorization as low-level COLs and the last four as high-level COLs. Students with low-level COLs take a passive role in learning and achieve learning through a narrow perspective, whereas students with high-level COLs are active in learning and adopt a wide perspective regarding learning (Tsai, 2004). When students with low-level COLs identify and learn the information that they consider important in their studies, they accept the information as it is since they do not attempt to search the meaning (Liang & Tsai, 2010). However, individuals with high-level COLs focus on understanding the topic, associate new situations with previous ones and their own experiences, and consider events from a critical perspective (Sadi & Lee, 2018). Studies have examined COLs and their relationships with both academic performance and self-efficacy as well as other variables, such as epistemic beliefs and learning approaches (Dart et al., 2000). For example, in his study on the relationships between the COLs, epistemic beliefs, and learning strategies of pre-service teachers studying at Hong Kong University, Chan (2003) highlights that there is a positive relationship between these variables. Dart et al. (2000) conducted a similar study aiming at investigating the effect of students' COLs on their academic selves and learning approaches. In total, 533 secondary school students participated in the study. According to the study's findings, a relationship was present among students' academic selves, learning approaches, and COLs. Another study by Tsai et al. (2011) investigated the effects of college students' science learning processes on their scientific epistemic beliefs, science COLs, and self-efficacy. According to the analysis results of the structural equality model, the authors emphasized that students' scientific epistemic beliefs definitely decreased and science COLs (e.g., memorizing, preparing for exams, calculating, applying) might trigger sophisticated scientific epistemic beliefs and high-level concepts (e.g., increasing knowledge, applying it, and understanding it). Other studies have stated that COLs may vary depending on cultural characteristics, learning environments, and domain-specific features (Sadi & Lee, 2017). In their study with Taiwanese and Turkish high school students, Sadi and Lee (2017) compared students' biology COLs. The results showed that there were differences between countries in the students' biology COLs. Specifically, there were meaningful differences between Taiwanese and Turkish students in the sub-dimensions of memorizing, calculating and practicing, increasing knowledge, and seeing a new way. Moreover, the authors observed differences between Taiwanese female and male students in the sub-dimensions of memorizing and understanding, while this difference did not exist between Turkish female and male students. In a similar study, Purdie et al. (1996) compared the COLs of Australian and Japanese students and found significant differences between the two cultures. In Australia, the students focused on superficial learning with a narrower perspective, while in Japan, the students preferred learning through a wider perspective.

In addition to the studies focusing on the differences in cultural characteristics, there are also studies that show the domain-specific characteristics of COLs (Buehl & Alexander, 2001; Li et al. 2013; Sadi, 2015). These studies highlight that the results may vary when students' COLs are considered not as science in general but as separate disciplines of physics, chemistry, and biology (Sadi & Lee, 2015; Liang & Tsai, 2010; Lee et al., 2008). For instance, in his phenomenographic study with 120 university students, Tsai (2004) examined the students' science COLs, highlighting that it is not possible to determine the students' physics or biology COLs by asking questions on "science." In her study on whether there is a difference in high school students' COLs in the physics, chemistry, and biology domains, Sadi (2015) found that students' preferred COLs change in certain sub-dimensions. Therefore, having considered the cultural and domain-dependent characteristics of COLs, the current authors believe that examining Turkish high school students' COLs and analyzing these, which have thus far been analyzed via phenomenographic or survey models, through an experimental model will make a significant contribution to the related literature.

The fact that COLs may vary due to domain-specific characteristics is explained above and, in this regard, the current study provides an analysis in the biology domain. Biology is a highly comprehensive discipline that investigates nature and natural events and examines the interaction between living and nonliving things. Especially in the Turkish educational system, high school biology curricula cover several topics and key concepts. Biology, by its nature, includes multiple domains, such as human physiology, evolution, and ecology, and it also interacts with other disciplines (e.g., biostatistics, biochemistry). Unfortunately, students' average biology scores in Turkey are low in nationwide exams like the central university entrance exam. Thus, different but effective methods and techniques should be applied in biology education, or the ways the students prefer to learn biology need to be determined. Within this context, the researchers prepared STEM activities that aim to teach concepts regarding the structure, function, and mechanism of the nervous system, which is covered in human physiology and has been observed to be a difficult topic for students to grasp.

Methodology

Quantitative research includes testing the problem cases determined by the researchers within the framework of the theory on which the study is based, making an interpretation by performing statistical analyses of the data, and moving from general to specific through deductive logic (Fraenkel & Wallen, 1996). Among the quantitative research methods, we used a true experimental design in this study to determine the effect of a biology lesson enriched by STEM-based activities on high school students' academic achievements in the structure, function, and mechanism of the nervous system and on their biology COLs. The true-experimental design uses a pretest-posttest control group with random design. Instead of designating already existing groups as experimental and control groups, the students in these groups were determined through random assignment. In this study, we gathered the names of the students in the sample in a pool and then randomly assigned each student to one of the four groups. Later, we again randomly chose experimental and control groups among these four groups. In this way, the possibility of being in any of the groups for a student was equal to the possibility for other students.

After we formed the experimental and control groups, we made the implementations before and after the experiment in both groups.

In the experimental groups, the study implemented a STEM activity–enriched learning method, whereas the control groups employed a learning method in which the course teacher was more active. The independent variable of the study was the learning method, which was different in experimental and control groups, and the dependent variable was the scores in the achievement test on the structure, function, and mechanism of the nervous system and in the post-test of the conceptions of learning biology scale. Within the scope of the study, after comparing the pre-test and post-test scores, the researchers attempted to determine the effect of the independent variables on the dependent ones.

Sample

The sample of the study was made up of 99 high school eleventh-grade students attending a public high school in an Anatolian city in the Central Anatolia Region in Turkey. The implementation was conducted with the participation of two biology teachers in two experimental and two control groups (four classes in total). The students were placed in their new classes, which were different from their own classes, through random assignment. In other words, the already existing groups of students in their own classes were not assigned as experimental and control groups. After the distribution of the students across classes through random assignment, of these four classes, we determined two classes as experimental groups and the other two as control groups, again through random assignment. There were 48 students in the experimental group and 51 in the control group.

Instruments

To determine the participant students' achievement levels in the structure, function, and mechanism of the nervous system, we used the Nervous System Achievement Test (NSAT), and to determine students' conceptions of learning biology, we used the Conceptions of Learning Biology Scale (COLB).

Nervous System Achievement Test (NSAT)

We applied the NSAT to both the experimental and control groups before and after the implementation of the experiment. We prepared the NSAT by reviewing the related literature so that the test would be suitable for the concepts regarding the structure, function, and mechanism of the nervous system in high school biology class. Although initially, we prepared 25 multiple choice questions to cover the key concepts of the unit—including neuron structure, impulse transmission, the central and peripheral nervous system, the brain and the spinal cord, reflex, and reflex bow— after the analyses, we decided for the final achievement test to have 20 questions. To ensure the content validity, we had two biology teachers, one academician working in the department of biology and one educationalist, evaluate the draft of the achievement test. The experts gave feedback on and made suggestions about certain points, such as whether the question roots and distractors were understandable, whether the questions were appropriate for the students' level, whether they met the learning outcomes mentioned in the related curriculum, and whether the distractors were sufficient and appropriate, as well as the scientific accuracy of the questions and distractors and the categorization of test items according to Bloom taxonomy. Based on their opinions, we made some corrections and adjustments and gave the achievement test its final shape before the pilot application. To carry out the item and internal validity analyses (item discrimination, item difficulty index, and reliability) of the achievement test, we conducted pilot applications with a group of 111 high school students (74 females and 37 males) attending a high school in the Karaman city center, which did not overlap with the study group. The item and reliability analyses of the data obtained from the pilot application were made via ITEMAN software. We conducted the calculations of item statistics to select the items, to make the necessary corrections on certain ones, or to leave out the items that were considered inappropriate. Based on the results of the item analysis, we removed the items with an item discrimination index below 0.2, which were items 6, 10, 15, 19, and 24. After removing these, we repeated the item analysis. According to the results of the new item analysis conducted on 20 multiple choice questions, the item discrimination index was 0.630 and the item difficulty value was 0.411.

In addition to the validity studies, we also carried out reliability studies for the measurements obtained through the test. Reliability is defined as the consistency of the responses to the test items. To measure reliability, we used Cronbach's alpha coefficient. The reliability coefficient for the NSAT was 0.724.

Conceptions of Learning Biology Scale (COLB)

We applied the COLB to determine the high school students' biology COLs before and after the implementation. Students from both the experimental and control groups completed the scale. The Conceptions of Learning Science Scale (COLS), which was developed by Lee et al. (2008) and translated into Turkish by Sadi and Uyar (2014), was revised for biology for the current study and applied to high school students as the COLB. The authors received permission to use the original scale in the current study and checked the appropriateness of it. In the original version of the scale, there are seven sub-dimensions and 35 items that measure these sub-dimensions. These seven factors are memorizing (five items), preparing for exams (six items), calculating and practicing (five items), increasing knowledge (five items), understanding (four items), applying (five items), and seeing in a new way (five items). These factors have a hierarchical structure, and the first three factors (memorizing, preparing for exams, calculating and practicing) are defined as low-level COLs, and the last four (increasing knowledge, understanding, applying, seeing a new way) as high-level COLs (Li et al., 2013).

Within the scope of the current study, COLS was revised for biology. Such implementations are evidenced in the related literature (Li et al., 2013; Sadi, 2017; Sadi & Lee, 2018). Similarly, in the current study, we used the same scale (COLS) to determine high school students' biology COLs after we made the necessary adjustments. Based on the adjustments, we applied COLB to a group of 111 high school eleventh graders who were not part of the study group. Confirmatory factor analysis was conducted with the data obtained from the pre-application. When we examined the t-values regarding the extent to which latent variables explain observed variables, those for items 10 and 11 were not found to be significant. In this case, error variances for these items were quite high. As a result, we decided that these items needed to be excluded from the analysis (Çokluk et al., 2014) and repeated the confirmatory factor analysis. According to the findings of the analysis, the p-value was found to be significant; however, since this value might vary depending on the sample size, a significant p-value is tolerated in many studies (Çokluk et al., 2014). We also considered the x^2/df value, which we found to be 1.60. An x^2/df ratio below 3 is considered good fit and is a desired value. When we calculated the RMSEA value, it was found to be .075, which is accepted as a good fit (Vieira, 2011). When other fit indices, including GFI=.90, CFI=.91, RMR= .070, and

NNFI=.90, were analyzed, we generally found them to be good fit index values (Brown, 2006).

For the reliability analysis of COLB, we calculated the internal consistency coefficient Cronbach's alpha (α). For the whole scale, the Cronbach's α value was found to be .86. For each sub-dimension, reliability coefficients were examined separately, and for memorizing, it was .83, for preparing for exams, .82, for calculating and practicing, .72, for increasing knowledge, .83, for understanding, .84, for applying, .72, and for seeing in a new way, .83.

Treatment

We conducted the present study to determine the effect of a STEM activity–enriched teaching method, which was applied to Turkish high school students as part of the 5E learning cycle model, on the students' academic achievement regarding the nervous system and on their biology COLs. In the related literature, there are several learning-teaching methods for the implementation of the STEM model. The current study used the 5E learning cycle model. Karplus and Their (1967) proposed the 5E learning cycle model, and in later years, it was developed by Roger Bybee as part of the Biological Sciences Curriculum Study (BSCS) (Bybee et al., 2006). The 5E learning cycle model, which aims at encouraging students to discover concepts during the learning period, to be responsible for their own learning, and to establish links between newly learned and previously learned information, has five stages: engagement, exploration, explanation, elaboration, and evaluation. In line with this, during the implementation of the learning cycle following these stages, STEM activities were used in the experimental group. An example lesson plan illustrating this implementation is explained below. Before the study, the researchers informed the participant students and course teachers about the topic, purpose, duration, and method of the study. The course teachers who would conduct the implementation received detailed information about STEM as well as the theoretical framework and the applications of the 5E model. To achieve a standardization of the implementations among the teachers and to conduct the study in line with its purpose, we prepared a teacher guide on STEM and the 5E learning cycle and gave it to the teachers. During the preparation of the lesson plans and the design of the STEM-based activities in the experimental group, we consulted the sources in the related literature. We focused on whether STEM implementations covered the structure, function, and mechanism of the nervous system in Turkish high school eleventh-grade biology curriculum, and by putting biology in the center, we paid attention to context integration of technology, engineering, and mathematics. Therefore, the lesson plans and activities did not have to include outcomes for each discipline separately or directly address the learning outcomes regarding the disciplines (Roehrig et al., 2012).

In the experimental group, the application for teaching the key concepts about neuron structure, types, and impulse transmission started with a short activity aimed to draw out the students' attention and to reveal their prior knowledge, following the first stage of the 5E model. As part of the activity, the students were asked to close their eyes. In the meantime, the teacher played various sounds, such as bird sounds, a traffic accident, or a siren, for a short period of time. Next, the students were asked to identify the sounds they heard and express the feelings triggered by the sounds. This activity highlights how an image in the brain is formed with the help of a sound a person hears. In this way, the students were reminded of concepts regarding the nervous system and nerve cells. At the same time, the students were shown a short cartoon emphasizing physiological symptoms developed due to the effects of the nervous system. The goal of this cartoon was to achieve a flow of thoughts about the role of the brain in managing our emotions. At the end of this entry stage, the students were asked to answer the first two questions of each section in the "What I know, What I want to know, and What I learned" (KWL) chart.

The second stage of the 5E model, exploration, is when students make observations, do research, propose hypotheses, plan various activities, and realize them. In this stage, the students formed groups of five. The students were asked to conduct a modeling study for a knowledge-based life problem in the worksheets. The knowledge-based life problem is as follows:

> *Mr. Ali is 76 years old. He states that there has been a loss of sensation in the area from the right-hand thumb to the wrist for a period of time. After the examinations, it is understood that the stimulus transmission has slowed down in one of the neurons. According to the problem that Mr. Ali is experiencing, what kind of a model would you design to prevent the loss of sensation in the neurons if you were a scientist working in the field of medicine?*

At this stage, the course teacher created a supply pool to enable the students to complete the STEM activity. During the activity, the course teachers did not tell the students which materials would be used in the activity. The students on their own chose the materials that they would need from the supply pool to test their hypotheses and create the model they designed. Any materials not in the supply pool but needed by the students were then added to the pool. The tools and materials in the supply pool included conductive wires, bulbs of different sizes, play dough, cotton, plastic foil, plastic tubes, test tubes, plastic gloves, lightbulb sockets, batteries, an electric motor, a motion-sensitive sensor, colored pencils, glue, and cardboard. The students were given two lesson hours to design and create their models. During this period, each group tried to create the best model possible using the tools and materials in the supply pool and presented a simulation of their models to the other groups. The groups were told to write on their worksheets the materials they used and the strategy they followed during the model design process. When the time was up, the model that was the most appropriately designed or created to solve the problem and the easiest to understand was again chosen by the students.

In the discovery stage, the students did various research and tried to gather information about the electrical and chemical occurrence of stimulus transmission through a neuron and between neurons. In this stage, the group members developed several hypotheses by putting forward different opinions to design and create a working model.

In the explanation stage, the third stage of the 5E model, students share the information they have gathered about the topic in classroom environment under the guidance of their teachers, and the concepts regarding the topic are clarified. Concepts and terms about the topic are highlighted and explained. The guidance of the teacher is crucial for the explanations of the concepts and generalizations to be scientific, correct, and valid (Tonseenon, 2017). At this stage of the present study, the groups shared with their peers the scientific aspects of the models they had created. They specifically explained the events that took place during the transmission of a stimulus through a neuron or from one neuron to the other by simulating it on their model. Moreover, the course teachers explained various concepts regarding stimulus transmission in neurons, such as polarization, depolarization, repolarization, and synaptic resistance. At the same time, the teachers covered related concepts about the topic.

In the elaboration stage, it is vital to make connections between the information acquired about the topic and, particularly, daily life. At this stage, teachers might ask new questions regarding the active use of the information or seek suggestions about the solution to a new problem case. In this stage, based on the models they had designed, the students were asked to give examples of daily life implications of the transmission in nerve cells and examples showing how important this transmission is for our vital functions. The students were asked to do research specifically about new applications that are or possibly will be in the field of medicine and to show them on the model they had designed.

In the evaluation stage, the last stage of the 5E model, learning regarding the topic is evaluated. The teachers may perform this evaluation, or the students may evaluate their own learning. At this stage, conventional and alternative assessment and evaluation tools can be used (Bybee et al., 2006). The criteria considered in the evaluation stage included whether the students had designed and operated their models by paying attention to the fact that there might be electrical and chemical changes in the stimulus transmission through a neuron or from one neuron to the other and whether they had considered the fact that the direction of the stimulus transmission is important. Moreover, each group's presentation of their own design and design processes in class using computer programs and their demonstration of the model by simulating it were also evaluated by the other groups, and each class chose the best-designed model. In addition, the evaluation used the Diagnostic Branching Tree Technique, which we prepared for the evaluation regarding the topic.

The students then completed the section titled "What I Learned" in the last section of the KWL scheme, the first two questions of which they had answered previously.

In summary, the above section explained a lesson plan implementing STEM activities addressing the learning outcome "the structure and types of neurons and impulse transmission are examined" by using the 5E learning cycle model. In the STEM activities, especially while the students were trying to design a working model, it was important for students to become familiar with the components of an electrical circuit and form a circuit, to determine the appropriate distance between neurons in impulse transmission by using the concepts of ratio and proportion, to use technology for visual and written communication, to work in harmony with team members in a joint project, and to share their opinions in terms of creating a context with the disciplines of technology, engineering, and mathematics.

The implementation process, which is briefly summarized above, occurred while teaching other concepts such as the central and peripheral nervous system and the reflex arc and its function. While the STEM activity was implemented in the experimental groups, in the control groups, the concepts regarding the structure of the neuron, neuron types, and impulse transmission were covered in the same way as other topics had been covered in class before. In other words, these topics were taught with a method in which the teacher is usually more active. During the lesson, the coursebook and various sources were used, a smart board was used for the visuals and video presentations, and the topic was covered through direct lecturing and question-and-answer technique. During the lesson, if the students had difficulty understanding a topic, they asked questions. The teacher answered their questions and repeated material previously covered.

Data Analysis

In the present study, the data from the NSAT and COLB pre-tests and post-tests were analyzed using the SPSS package. Before the implementation, to determine whether the experimental and control groups were equal in terms of their academic achievement and COLs, we used the independent group t-test. After the implementation, to determine whether a STEM activity–enhanced biology course had an effect on the high school students' academic achievement in the structure, function, and mechanism of the nervous system, we used multivariate analysis of variance (MANOVA).

Results

Descriptive Statistics

Below, we present the descriptive statistical analysis of the participant Turkish high school students' NSAT pre-test (PRE-NSAT) and post-test (POST-NSAT) data and COLB pre-test (PRE-COLB) and post-test (POST-COLB). Within the scope of these analyses, first, to decide whether the data displayed normal distribution, we considered the Kolmogorov-Smirnov and Shapiro-Wilk tests of normality, central tendency measures such as mean, median, and mode, and skewness and kurtosis values.

Table 1 displays the descriptive statistical analysis results of the NSAT pre-test and post-test data from both the experimental and control groups.

Table 1. Descriptive Statistics for the NSAT

	Experimental Group		Control Group	
Nervous System Achievement Test (NSAT)	Pre-test	Post-test	Pre-test	Post-test
N	48	48	51	51
mean	5.06	15.81	5.39	13.80
median	5.0	16.0	5.0	15.0
mode	4.0	17.0	3.0	17.0
standard deviation	2.43	2.25	2.73	3.21
skewness	.431	-.789	.485	-1.09
kurtosis	-.598	.954	-.228	.955

As Table 1 shows, both the experimental and control groups displayed an increase between the pre-test and post-test values. The difference between the pre-test and post-test mean values of the experimental group was 10.75, and the mean value increased from 5.06 to 15.81. For the control group, the pre-test mean value was 5.36, and the post-test mean value was 13.80. The mean value increase in the control group was 8.44. The increase in the experimental group was greater than the increase in the control group.

When we examined Table 1 from another perspective to provide evidence of whether the data obtained through the applications displayed a normal distribution, we saw that the pre-test mean value (5.06) and the pre-test median value (5.0) of the experimental group were the same, and the mode value (4.0) was close to these values. As for the post-test data of the experimental group, we saw that the mean (15.81), median (16.0), and mode (17.0) values were close to each other. Moreover, the skewness and kurtosis values for the pre-test were .431 and -.598, respectively, and for the post-test, -.789 and .954, respectively. Since the skewness and kurtosis values were between -1 and +1, which is considered evidence for normal distribution (Clements, 1989), we accepted that the data showed a normal distribution.

When we examined the mean, median, and mode values of the control group pre-test and post-test data, a similar situation to the one in the experimental group was observed. Although these values were not the same, they were close to each other. In Table 1, the normal distribution graph of the control group PRE-NSAT and POST-NSAT scores was given. The skewness and kurtosis values of the pre-test data, which were .485 and -.228, respectively, were between -1 and +1, which indicates normal distribution. In addition, the skewness value was -1.09 and the kurtosis value was .955 for the post-test data. The skewness value (-1.09) fell a bit outside the range of -1 to +1, but we thought that we could consider it acceptable evidence for a normal distribution.

To decide whether the data obtained from the experimental and control groups presented a normal distribution, for the control group, we considered the Kolmogorov-Smirnov test results (Pallant, 2016) since the sample size was 50 or more, and for the experimental group, we used the Shapiro-Wilk test of normality since the sample size was below 50.

Table 2. PRE-NSAT and POST-NSAT Test of Normality Analysis Results

Tests	Groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	p	Statistic	df	p
PRE-NSAT	Experimental	.148	48	.010	.953	48	.051
	Control	.960	51	.086	.960	51	.017
POST-NSAT	Experimental	.179	48	.001	.930	48	.007
	Control	.175	51	.000	.871	51	.000

As Table 2 indicates, based on the analysis results, the PRE-NSAT data of the experimental and control groups showed a normal distribution. At the same time, the POST-NSAT data of both the experimental and control groups did not present a normal distribution ($p<.05$). However, because Kolmogorov-Smirnov and Shapiro-Wilk test results are not the only criteria for deciding whether the data present a normal distribution, and because in the related literature, there are studies emphasizing that central tendency measures (George & Mallery, 2001) and skewness and kurtosis values (Çokluk et al., 2014) can also be considered in addition to the test of normality results, the values mentioned above and shown in Table 1 were considered. Given all this information, we decided that the NSAT pre-test and post-test data for both groups presented a normal distribution.

We applied another scale in the current study, the Conceptions of Learning Biology (COLB) scale, and Table 3 presents the descriptive statistical analysis results of the data gathered through this scale.

Table 3. Descriptive Statistics for COLB

	Experimental Group		Control Group	
COLB	Pre-test	Post-test	Pre-test	Post-test
n	48	48	51	51
mean	117.17	117.75	115.15	117.94
median	116.50	118.00	115.50	116.00
mode	112.00	109.00	115.00	111.00
standard deviation	10.20	8.65	13.69	12.32
skewness	.164	.043	-.229	-.017
kurtosis	.312	-1.104	-.173	.629

Table 3 reveals that the mean difference in terms of biology COLs between pre-test and post-test applications in both the experimental and control groups was not very large or observable. The increase in the mean values of PRE-COLB and POST-COLB in the experimental group was.58. However, the mean value of the control group PRE-COLB was 115.15, the POST-COLB mean value was 117.94, and the increase in the mean value was only 2.79.

In addition to the descriptive statistical analysis results summarized above, Table 3 also presents some central measure values as well as skewness and kurtosis values belonging to the experimental and control group PRE-COLB and POST-COLB. Specifically, we examined the mean, median, and mode values as well as the skewness and kurtosis values to examine whether the data presented a normal distribution. For the PRE-COLB in the experimental group, we considered it important that the mean, median, and mode values were close to each other, and the skewness (.164) and kurtosis (.312) values fell within the acceptable range; we decided that these values presented a normal distribution. As for the experimental group POST-COLB data, the mean (117.75) and the median (118.00) values were very close to each other, and the mode value was close, though not equal, to the other central measure values. Moreover, although the skewness value (.043) was again between -1 and +1 (Clements, 1989) but the kurtosis value (-1.104) did not fall within this range, since the kurtosis value did not deviate much from the acceptable range, we accepted that the POST-COLB data showed a normal distribution. In addition, according to the studies in the related literature about the normal distribution premise for skewness and kurtosis values, it is considered adequate for these values to fall within the range of -2 to +2 (Köklü et al., 2007).

For the control group, the PRE-COLB mean, median, and mode values were the same, as required by the normality scale. Moreover, the skewness (-.229) and kurtosis (-.173) values were within the desired range of -1 to +1. The mean (117.94), median (116.00), and mode (111.00) values of the POST-COLB scale were considered close to each other. The skewness (-.017) and kurtosis (-.629) values were both between -1 and +1. Therefore, within the scope of the present study, we regarded the POST-COLB data as presenting a normal distribution.

In addition to the evaluations explained above regarding the normal distribution of the PRE-COLB and POST-COLB data in the experimental and control groups, we also evaluated the Kolmogorov-Smirnov and Shapiro-Wilk test results (Table 4).

Table 4. PRE-COLB and POST-COLB Test of Normality Analysis Results

Tests	Groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	p	Statistic	Df	p
PRE-COLB	Experimental	.092	48	.200	.986	48	.831
	Control	.072	51	.200	.981	51	.583
POST-COLB	Experimental	.119	48	.086	.943	48	.022
	Control	.138	51	.016	.956	51	.056

According to Table 4, the PRE-COLB data for the experimental and control groups presented a normal distribution (p>.05), but the POST-COLB data did not (p<.05). However, as it is explained above, the Kolmogorov-Smirnov and Shapiro-Wilk tests are not the only criteria for deciding whether the data have a normal distribution, so we also considered other measures (central tendency measures, skewness and kurtosis values) when making the decision. Therefore, we decided that the POST-COLB data for the experimental and control groups had a normal distribution.

Inferential Statistics

This section presents the NSAT and COLB pre-test and post-test analysis results.

NSAT and COLB Pre-test Findings

To test whether the difference between the averages of the NSAT pre-test scores of the experimental and the control groups was significant, and because we thought that if there was a difference, this might affect the post-test scores, we used the independent sample t-test. Table 5 presents the analysis results.

Table 5. Independent Sample T-test Results of the Comparison between the PRE-NSAT Scores of the Experimental and Control Groups

Test		Levene's test			t-test
		F	Sig.	df	Sig. (2-tailed)
PRE-NSAT	Equal variance assumed	.309	.580	97	.529
	Equal variance not assumed			96.71	.528

According to the explanations made above, Levene's test pre-test achievement scores in Table 5 were not significant (p>.05). In other words, the variances of the group scores were homogeneous and were accepted as equal. When the variances were considered equal, no significant difference was found between the experimental and control group NSAT pre-test scores (t (97)= .632, p>0.05). As a result, in the interpretations regarding the differences between the post-test scores of the experimental and the control groups, we saw that the covariate effect of the pre-test scores did not exist. In addition, before the experimental application, we accepted that the experimental and control groups were equivalent in terms of their NSAT scores.

Since we thought that a STEM activity–enriched learning method might affect biology COLs, the COLB data was categorized as a dependent variable, and to decide whether there was a difference between the pre-test scores of the groups regarding this dependent variable and whether this would affect the post-test scores, we implemented an independent sample t-test before the application (Table 6). As a result of this analysis, group variance was found to be homogeneous, and no significant difference was found between the groups in terms of COLB data (t (97) = .824, p>0.05). Therefore, we observed that in terms of biology COLs, the students were not significantly different from each other before the application, and the PRE-COLB would not be taken as a common variable when interpreting the post-test data of the pre-test.

Table 6. Independent Sample T-test Results of the Comparison between the PRE-COLB Scores of the Experimental and Control Groups

Test		Levene's test			t-test
		F	Sig.	df	Sig. (2-tailed)
PRE-COLB	Equal variance assumed	2.819	.096	97	.412
	Equal variance not assumed			92.241	.408

MANOVA Findings

To determine whether the participants' total NSAT and COLB scores differed depending on the different teaching methods employed in the experimental and control groups, we used multivariate analysis of variance (MANOVA). NSAT and COLB were the dependent variables, and the teaching method was the independent variable. The assumptions that needed to be evaluated for MANOVA were analyzed, and we saw that the assumptions such as normal distribution, group variance equality, and data independence were met. Then, to determine the difference in the post-test scores of the experimental and control groups, we implemented MANOVA (Table 7).

Table 7. MANOVA Findings

Effect	Pillai's Trace	F	hyp. df	error df.	P (Sig.)
Group	.130	7.165	2.0	96.0	.001

In terms of dependent variables (combined dependent variable), there was a statistically significant difference between the groups (Pillai's Trace = .130, F (2, 96) = 7.165, p = .001). In other words, the independent variable had a significant effect on at least one of the two dependent variables between the groups. However, to determine in terms of which dependent variable this significant difference existed, we performed a test of between-subjects effects (Table 8).

Table 8. Test of Between-Subjects Effects

Source	Dependent variables	df	Mean square	F	Sig.
Group	POST-NSAT	1	99.76	12.81	.001
	POST-COLB	1	213.90	1.82	.181

Comparing the experimental and control groups with regard to dependent variables reveals that the statistically significant difference was in the NSAT dependent variable (F (1, 97) = 12.81, p = .001). When we examined the NSAT total score averages, we found the experimental group mean value to be 15.81, and for the control group, it was 13.80. As a result, we can say that the difference in the total score averages in terms of NSAT dependent variable was in favor of the experimental group. However, we observed that there was no significant difference between the groups in terms of the COLB dependent variable ($F(1, 97) = 1.82$, $p = .181$).

Discussion

The present study investigated the effect of STEM-enriched activities based on the 5E learning cycle model on Turkish high school students' academic achievement and biology COLs in the subject field of the nervous system. In what follows, we interpret the findings in light of the related literature and make suggestions accordingly.

After the implementation, we observed some differences in NSAT averages in the experimental group, in which STEM-enriched activities based on the 5E model were implemented, and in the control group, in which a teacher-centered teaching model was implemented. The difference in the averages was statistically significant in favor of the experimental group. Based on this finding, we can say that STEM-based activities and applications increase academic achievement. Studies in the related literature parallel to this finding emphasize that STEM-based applications have a positive effect on achievement (Han et al., 2015). For example, in their study with 146 Latino students, Cole and Espinoza (2008) aimed to determine the academic achievement of the students in STEM disciplines and the factors that might affect this achievement. They highlight that the students with higher academic achievement preferred STEM fields more. Moreover, when they reevaluated the results with gender as a variable, they found that female students' academic achievement in STEM disciplines was higher. Similarly, in her study with an ex post facto research design, Olivarez (2014) examined the effect of a STEM education program on student achievement, finding that a group of 73 students in a STEM education program that employed project-based learning (PBL) were more successful in fields such as mathematics, science, and reading compared with the group of 103 students who did not attend a STEM education program. In their study at the university level, Van Soom and Donche (2014) reached similar conclusions, stating that STEM applications affected student achievement positively. The findings of the international studies mentioned above overlap with the findings of the current study. In addition, Turkish studies have also indicated that STEM applications affect academic achievement positively when these applications are implemented at different grade levels and with different learning models. For instance, in her study with fifth graders, Karcı (2018) examined the effects of a STEM activity–enhanced scenario-based learning approach on academic achievement, interest in STEM fields, and motivation in learning science. According to the findings of the study, which used an experimental comparison design, there was a significant difference in the academic achievement test scores of the experimental and control groups. In her study using a mixed research method, Eroğlu (2018) aimed to determine the effect of STEM applications based on the 5E learning cycle model on ninth graders' academic achievement, scientific creativity, and opinions about the nature of science. The researcher identified a significant difference between the experimental and control groups in favor of the experimental group in terms of all three areas. In brief, in the related literature, there are several studies emphasizing that STEM applications have a positive effect on the achievement levels of students from different grade levels. These experimental studies, like the present study, also emphasize that there are some important issues that need to be focused on. Lesson plans that are designed and implemented in line with the purpose of the study are of great importance. The existence of the applications to be implemented in the lesson plans regarding STEM fields is also crucial. In the STEM activities in the current study, it was important for students to employ engineering design processes and to create a working model because through this process, the activity enabled the students to discover and learn the concepts regarding the subject of the lesson.

Within the scope of the present study, we analyzed the effect of STEM-enriched activities based on the 5E learning cycle model not only on academic achievement but also on the students' biology COLs as measured by the COLB scale. After the experimental application, the groups were statistically compared in terms of COLB, and we found no significant difference between the experimental and control groups in terms of their post-test scores. Although there are studies in the related literature that examine the effect of STEM education programs on several variables, such as problem solving, critical thinking, self-efficacy, attitudes toward and motivation in science, epistemic beliefs, scientific process skills, scientific creativity, interest in STEM fields, and opinions about the nature of science, in addition to academic achievement, there are no studies examining its effect on COL, which is defined as academic epistemic beliefs. Therefore, we have interpreted the findings of the current study by considering many factors. A limited number of studies have examined the effect of other learning methods implemented in classroom environment on COLs (Arı, 2017; Tsai et al., 2011). For example, in her study including a 10-week application, Arı (2017) examined the effect of the cooperative learning method on academic achievement, self-efficacy, and biology COLs and found that the learning method had a positive effect on COLs in the experimental group. She revealed that the averages of the sub-dimensions of memorizing, preparing for exams, increasing knowledge, understanding, applying, and seeing in a new way significantly differed in the experimental and control groups.

In addition to this, many studies highlight the relationship between COL, which is defined as what students think about the topics they have learned and about the learning process (Benson & Bor, 1999), and other variables, and were conducted in different learning environments and cultures (Li et al., 2013). In these studies, one important point emphasized is that conceptions of learning may vary depending on the field, the topic, or cultural features. These findings might be indicators that should be considered while evaluating the findings of the current study. That is, the reason why the independent variable identified in the current study did not make a difference in the COLs might be that based on the field or the topic, the implemented activity did not take place during a period that might have led to a difference. In their three-year-long study, Quinnell et al. (2012) examined the differences in biology COLs and biology learning approaches in students over time. By interpreting the data that they had gathered in the beginning and end of the semester, they identified four different student profiles. Although the study covered a long period of time, they found that some students developed a resistance to changing their COLs. To summarize, it is necessary to conduct new studies lasting for longer periods of time in order to determine whether COLs differ under the effect of other methods such as a STEM activity–based learning method. Thus, conducting new experimental studies employing new methods and techniques is also important. We interpreted the findings of the current study according to the data collected from a limited number of Turkish high school students within the scope of a specific topic in a certain unit. In further studies, considering COL as a dependent variable in different grade levels on different topics will contribute to the related literature.

Following are some suggestions to researchers who will conduct similar studies on the basis of the findings summarized above as well as to teachers, administrators, and educators who are interested in the issue. First, in light of the information gathered from the teachers and students during the study, while preparing STEM-based activities and their lesson plans, it is necessary to obtain expert advice. Furthermore, time management for the implementation of STEM-based activities in class is also important. Also, to increase the use of STEM-based activities in biology classes and to ease their implementation, it is important to conduct the necessary studies to provide the suitable conditions and necessary opportunities. In the present study, we arranged STEM activities for the learning outcome of the structure, function, and mechanism of the nervous system in biology lessons, and so we interpreted the findings of the study within the limits of this topic. STEM activities should be organized for different biology topics or for physics or chemistry topics. We conducted this study at the high school level and limited the dependent variables to the academic achievement and biology COLs. However, researchers could conduct similar studies at different grade levels and with different dependent variables. Depending on the characteristics of the topics that selected for similar future studies and the activities implemented in such studies, we suggest that a longer study calendar should be designed. Finally, we suggest that experimental studies with biology COL, which was the dependent variable of the present study, should be conducted for different disciplines and the findings compared.

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