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ORIGINAL ARTICLE

The Effectiveness of Concept Teaching Using Concept Maps on Academic Achievement and Elimination of Misconceptions: Protein Synthesis Case

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ABSTRACT

This study aimed to analyze the effectiveness of concept maps on the academic achievements of Biology teacher candidates and the elimination of misconceptions comparing the method with the traditional rote learning method. The quasi-experimental design, specifically, the pre- and post-test control group type was used in this research to address the research questions. The research was carried out with 60 Biology teacher candidates. Achievement test and diagnostic test were used as data collection tools throughout the research. SPSS version 20 software was used to analyze the obtained quantitative data. Independent samples t-test was used to determine, whether there was a significant difference between the control and experimental group students' level of prior knowledge regarding the subject of protein synthesis. The findings revealed no statistically significant difference between the groups in pre-test ($\rho > 0.05$). However, the findings revealed a statistically significant difference between the groups, in the post-test, in favor of the concept map method used for the experiment group ($\rho < 0.05$). The increase in the post-test scores of the experiment group students indicated that the teaching method based on concept maps positively affected the students' academic achievement and elimination of misconceptions. Research indicated that students could not establish a correct relationship between the concepts of DNA, RNA, mRNA, tRNA, rRNA, nucleus, chromosome, gene, genetic code, codon, anticodon, translation, transcription, ribosome, protein, and amino acid terms taught in protein synthesis subject. It was concluded that the areas of use for concept maps should not be limited as a teaching tool, but should be further extended to for determining misconceptions, eliminating misconceptions, and evaluating the instruction.

KEY WORDS: Concept map; concept teaching; misconception; protein synthesis

INTRODUCTION

Discovering the structure and properties of DNA was one of the significant developments in the science of genetics (Watson and Crick, 1953). Following this discovery, concepts such as protein synthesis, DNA, RNA, and genes have begun to take place in teaching curricula (Yıldırım, 2008). Concept teaching is the task of ensuring that the concept to be taught is constructed in the mind of the child (Çaycı, 2006). The method to be chosen and used in concept teaching is important (Köksal, 2006). Providing the meanings of the concepts directly while teaching the concepts is not an effective method of conceptual teaching. In traditional conceptual teaching (rote learning) method, concepts are presented to students by introducing the concept, defining the concept, providing the descriptive and distinctive features of the concept, giving examples that are included and not included in the concept respectively (Kaptan, 1999). With this method, the student learns the concepts to a certain level. In modern conceptual teaching, which is another method used to ensure the effectiveness of concept teaching, the teacher asks the student to examine the examples that are included in the concept and to determine the descriptive and distinctive features accordingly. Effective and permanent conceptual teaching can be achieved by ensuring that concepts are learned together with their meanings, rather than encouraging students to memorize.

According to Ausubel (1968), meaningful learning takes place when former knowledge and new information are associated with each other and integrated in a cognitive structure. In meaningful learning, new concepts can be learned by bringing more detailed concepts together. More detailed concepts are referred to as advance organizers. Advance organizers may be an audio material, a picture, or a graphic. In any case, advance organizers should be designed to build a repertoire in the student's mind to learn new knowledge. According to Ausubel, learning takes place in three phases. These are Presentation of Advance Organizer, Presentation of the learning Task or Material, and Strengthening Cognitive organization. Ausubel's phases of learning are presented in Table 1.

Student-centered concept teaching methods help to improve the process of acquiring concepts correctly (Köksal, 2006). One of these methods is concept maps. Novak and Gowin (1984) suggested the term of utilizing concept maps in their work on "learning to learn." Concept maps, related to

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Table 1: Phases of meaningful learning (Ausubel, 1968)

Phase one	Advance organizer	Explicitly clarify aims of the lesson
		Presentation of the advance organizer
		Relate the organizer to students' prior knowledge
Phase two	Presentation of the learning task or material	Clearly specifying the organization of the new material
		Logically sequencing the learning material
		Engaging the students in meaningful learning activities
Phase three	Strengthening cognitive organization	Relate new information to advance organizer
		Promote active reception learning

meaningful learning, emerged as a result of the studies carried out by Joseph Novak and his students in the 1970s within the scope of a research project examining the issue of facilitating concept teaching in science education (Novak and Gowin, 1984). Concept maps are a method of establishing meaningful relationships between concepts and propositions. Novak suggests concept maps to be presented in a hierarchical order. New knowledge is learned based on the cognitive order and hierarchy of the concept maps. Cognitive order in concept maps has two significant contributions. The first is that knowledge is organized in line with a discipline and methodology. Ranking down in order of importance presents us the differences and relationships between successive concepts. Secondly, the visuality of the concept maps enables the students to perceive the connections more comfortably and thus facilitates the concept learning.

At the beginning of science courses, students are usually equipped with a number of concepts that are meaningful according to their own thinking structures but that conflict with scientific knowledge (Driver, 1991; Osborne and Wittrock, 1983; Treagust, 1988). Studies on explaining students' understanding of scientific concepts and the nature of science in a different way than those revealed by scientists are presented under different headings in the literature (Andersson, 1986; Griffiths and Preston, 1992). Students' acquisition of concept structures that conflict with the facts revealed by the scientific community are defined as misconception, pre-conception, alternative structures (Doran, 1972; Driver, 1981; Driver and Easley, 1978; Gabel and Bunce, 1994; Mike and Treagust, 1998; Nakhleh, 1994), children's science (Gunstone, 1990; Osborne and Freyberg, 1996; Treagust, 1988), and spontaneous knowledge (Champagne et al., 1983). As students learn new information, they combine it with the knowledge they have already acquired. The knowledge that students have previously acquired sometimes results in learning new concepts incorrectly. According to Piaget, misconceptions are such as a structure and continue by adding one on another. To eliminate misconceptions, incorrect information that students have acquired should be determined and replaced with the correct information to comply with the correct information to be further taught. The process of acquiring correct information, based on the constructivist learning theory, begins with determining the knowledge that students have acquired and teaching activities are prepared accordingly in line with this information (Stofflett, 1994). The process followed on this path, addressing correct information is referred to as the conceptual change (Smith and Blakeslee, 1993). The conceptual change approach developed by Posner and Gertzog (1982) based on the work of Piaget and Zeitgeist, emerges as a strategy based on Piaget's assimilation, accommodation, and equilibration principles (Chambers and Andre, 1997; Wang and Andre, 1991) and is an alternative approach that enables students to switch from non-scientific knowledge to scientifically revealed knowledge. During the assimilation phase students incorporate their existing knowledge and understanding in acquiring new concepts. Accommodation, on the other hand, is referred to as the step where the student reviews, modifies, organizes, and restructures their prior knowledge to be able to structure new concepts in their customized understanding (Canpolat and Pınarbaşı, 2002).

Studies examining misconceptions in the field of science education focus on determining misconceptions. However, trying to eliminate misconceptions is as important as detecting them. Elimination of misconceptions ensures that new information is not structured on the wrong ones; instead, it becomes important to teach the concept to be learned by associating it with other related concepts. Literature revealed that protein synthesis is a subject that students have had difficulty in learning (Lazarowitz and Penso, 1992; Marbach-Ad and Stavy, 2000; Membiela and Latorre, 1993; Pittman, 1999). It was further determined that students have had misconceptions about concepts such as DNA, RNA, transcription, translation, and gene taught under protein synthesis (Fisher, 1985; Kargbo et al., 1980; Saka et al., 2006). Diagnostic test is a method that is frequently used in the literature to determine misconceptions (Ayas, 2001). Diagnostic tests can be performed in the form of open-end tests or multiple-choice tests. While preparing the diagnostic test used in the research, the misconceptions found in the literature regarding the concepts taught on 'protein synthesis' subject were used (Demir, 2008; Fisher, 1985; Kargbo et al., 1980; Şahin & Hacıoğlu, 2010; Saka and Akdeniz, 2004).

Although there are studies aiming to determine the misconceptions about protein synthesis subject in the literature, there are limited number of studies aimed at eliminating associated misconceptions. In addition, the number of studies in the literature examining eliminating misconceptions using concept maps is limited. Thus, it is important to find out the effects of conceptual teaching using concept maps to facilitate learning of protein synthesis concepts, which learners often have difficulty. This study aimed to analyze the effectiveness of concept maps on the academic achievements of Biology teacher candidates and elimination of misconceptions comparing the method with the traditional rote learning method.

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METHOD

This research was conducted using an experimental design with pre- and post-test control groups, also referred to as "quasi-experimental design" (McMillan and Schumacher, 2006). In quasi-experimental designs, a pre- and post-test are applied to the research groups. The data obtained as a result of the pre-test give us clues about whether the experiment and control groups were equal before the main experiment and allow us to interpret post-test results in the light of these findings. The experimental design used in the research is displayed in Table 2.

Data Collection

The research was carried out on 60 students from two different classes studying Biology Education at Atatürk University's Kazım Karabekir Faculty of Education in the spring semester of 2014–2015. All participants were volunteers and provided informed consent as part of the first authors PhD study. The participants of the experiment and control groups from within the classes selected with the convenience sampling. Analytic phase of the study lasted for a total of 6 weeks; 1-week pre-test, 4-weeks trial, 1-week post-test. Teaching practices for the experiment and control groups were performed by the researcher in the classrooms of the faculty during Biology class hours. Teaching with the traditional method (rote learning) in the control group and the concept maps were prepared by the researcher on protein synthesis in the experiment group. At the end of the trials, academic achievement test and diagnostic test were re-applied to the experiment and control group students as a post-test to determine the extent to which the concept maps method has been beneficial for students. Some examples of concept maps (A, B, and C) prepared by the researcher on protein synthesis and used while lecturing are presented in Figures 1-3.

Data Collection Tools

"Academic Achievement Test" and "Diagnostic Test" were used as data collection tools throughout the research.

Academic achievement test

The academic achievement test addressed measuring the success level of Biology teacher candidates on the subject of "protein synthesis." This academic achievement test was developed as part of the first author's PhD study. The academic achievement test consists of 20 multiple-choice questions aimed at measuring the overall comprehension of bachelor's degree students about the "protein synthesis" unit. Validity of the questions in the test was checked by expert faculty members. Item analysis was performed for a total of 20 multiple-choice items in the test. For item analysis, firstly, the test scores of the students were calculated. While calculating, "1" point was given for each correct answer given in the test and "0" for each wrong answer. Then, scores of the students were ranked from the highest to the lowest. According to the results of this ranking, 8 (30*27/100) students were determined from within each of the highest and lowest score groups. Then, item difficulty was calculated using the formula p = (UC + LC)/2N, and item discrimination was calculated using the formula d = (UC-LC)/N (N: 27% of the whole group, UC: The upper group of those giving correct answers, LC: The lower group of those giving correct answers). Discrimination criterion, at the end of item analysis, was evaluated taking into account the criteria specified in the study conducted by Çalık and Ayas (2003). Item difficulty and item discrimination values of each test item, derived at the end of item analysis, are displayed in Table 3.

Average item difficulty of 0.60 in the achievement test applied to the experiment group as per Table 3 indicates that the test is a medium difficulty test. In addition, an item discrimination score of 0.51 indicates that item discrimination of the test is "good." All these scores indicate that the item discriminations of the test are rather good and the items can be used without modification. Following the item analysis, reliability was checked. Kuder-Richardson Formula 20 (KR-20) reliability coefficient was calculated as 0.78.

Diagnostic test

A 20-question multiple-choice diagnostic test was also prepared by the first author as part of her PhD. This diagnostic test was prepared by making use of the misconceptions identified in the literature on this subject. Each question in the diagnostic test has five optional answers; each question has four distracter options and one correct answer. Available options include

Table 2: Experimental design used in the research

Major	Group	Pre-test	Application	Post-test
Biology education	Control group	Achievement test Diagnostic test	Traditional rote learning	Achievement test Diagnostic test
Biology education	Experiment group	Achievement test Diagnostic test	Concept maps	Achievement test Diagnostic test

Table 3: Item analysis according to the number of correct answers given by the students in the lower and upper groups

Question	UC	LC	p	d	Question	UC	LC	p	d
1	7	4	0.69	0.38	11	8	2	0.63	0.75
2	8	6	0.88	0.25	12	8	0	0.50	1.00
3	8	3	0.69	0.63	13	8	1	0.56	0.88
4	7	3	0.63	0.50	14	8	3	0.69	0.63
5	2	0	0.13	0.25	15	8	4	0.75	0.50
6	8	3	0.69	0.63	16	7	1	0.50	0.75
7	6	2	0.50	0.50	17	7	4	0.69	0.38
8	5	0	0.31	0.63	18	7	4	0.69	0.38
9	8	3	0.69	0.63	19	8	6	0.88	0.25
10	6	1	0.44	0.63	20	5	3	0.50	0.25

UC: The upper group of those giving correct answers (27%=8 students); LC: The lower group of those giving correct answers (27%=8 students); p: item difficulty; d: item discrimination

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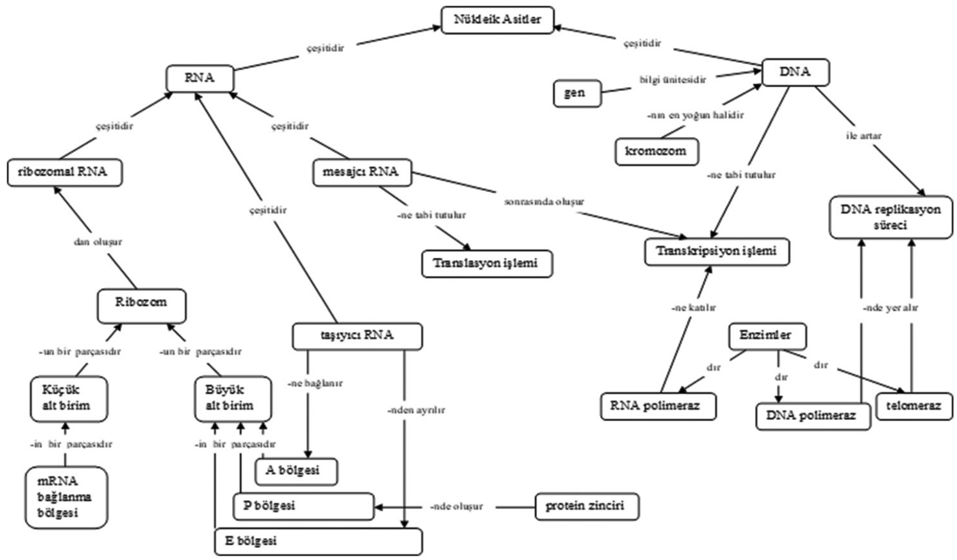

Figure 1: Protein synthesis concept map A

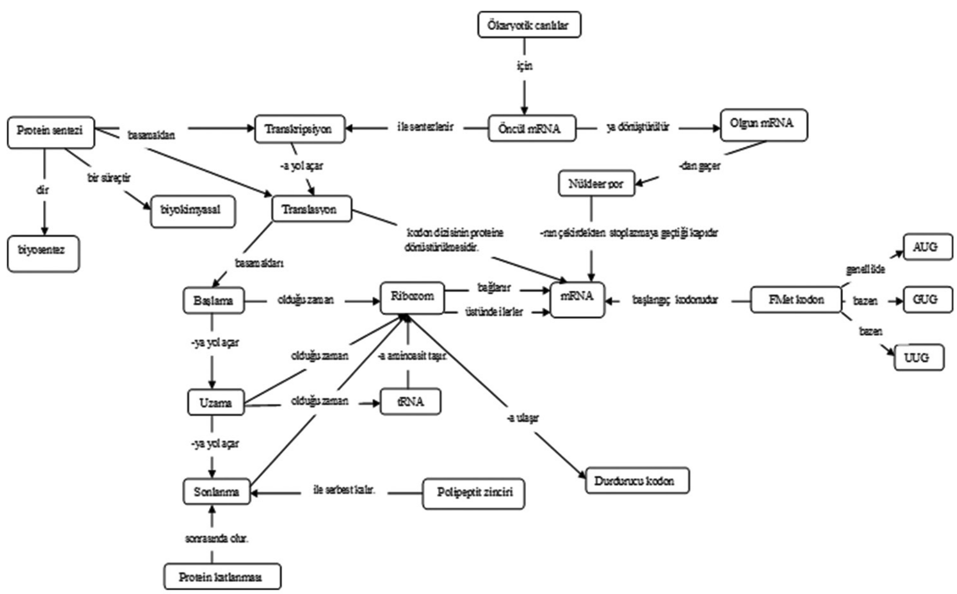

Figure 2: Protein synthesis concept map B

distracters that contain misconceptions. The relationships between concepts such as nucleus, DNA, gene, genetic code, chromosome, RNA, rRNA, mRNA, tRNA, codon, anti-codon, amino acid, protein, ribosome, transcription, translation, and protein synthesis were questioned in the diagnostic test.

Validity of the questions in the test was checked by expert faculty members. Item analysis was performed for the test prepared after taking the expert opinion. Item difficulty and item discrimination values of each test item are displayed in Table 4.

Average item difficulty of 0.43 in the diagnostic test applied to the experiment group as per Table 4 indicates that the test is a medium difficulty test. In addition, an item discrimination score of 0.55 indicates that item discrimination of the test is 'good'. These scores indicate that item discrimination of the test is quite good in accordance with the criteria stipulated in the study by Çalık and Ayas (2003), and the items can be used without any modification. Following the item analysis, reliability of the test was checked. Kuder-Richardson Formula 20 (KR-20) reliability coefficient was calculated as 0.93.

Data Analysis

T-test for independent groups was used in analyzing the quantitative data obtained in the experimental study.

FINDINGS AND COMMENTS

This section covers the findings and comments about the scores in academic achievement test and diagnostic test.

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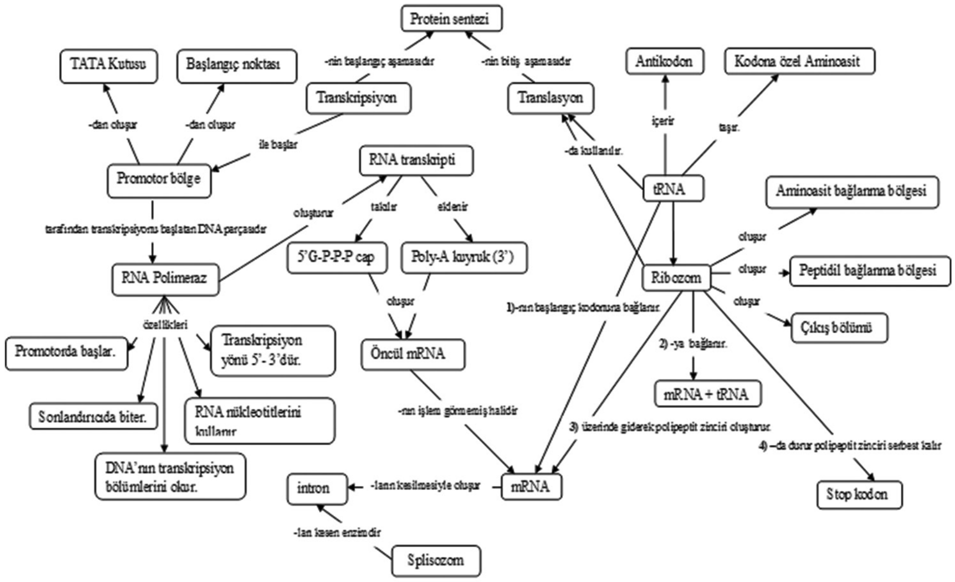

Figure 3: Protein synthesis concept map C

Table 4: Item analysis according to the number of correct answers given by the students in the lower and upper groups

Question	UC	LC	p	d	Question	UC	LC	p	d
1	8	6	0.88	0.25	11	7	0	0.44	0.88
2	8	2	0.63	0.75	12	8	0	0.50	1.00
3	7	3	0.63	0.50	13	8	1	0.56	0.88
4	7	3	0.63	0.50	14	8	1	0.56	0.88
5	4	1	0.31	0.38	15	8	1	0.56	0.88
6	8	1	0.56	0.88	16	4	0	0.25	0.50
7	8	0	0.50	1.00	17	3	0	0.19	0.38
8	8	1	0.56	0.88	18	4	1	0.31	0.38
9	6	2	0.50	0.50	19	8	2	0.63	0.75
10	4	1	0.31	0.38	20	4	0	0.25	0.50

UC: The upper group of those giving correct answers (27%=8 students); LC: The lower group of those giving correct answers (27%=8 students); p: item difficulty; d: item discrimination

Evaluation of the Academic Achievement Pre-test Findings of the Experiment and Control Groups

Independent samples t-test was applied to determine whether there was a significant difference between the experiment and control groups in terms of academic achievement test scores before the instruction (lecture). The findings obtained are presented in Table 5.

The results of the independent samples t-test performed to determine whether the difference between the arithmetic mean of pre-instruction academic achievement pre-test scores of experiment and control groups, which were 7.23 and 7.68, respectively, was significant or not is presented in Table 5 which reveals that the difference was found to be insignificant, $t(53) = -0.875$, $\rho > 0.01$.

Table 5: Academic achievement pre-test results of experiment and control groups

Groups	n	X	Ss	t	ρ
Academic achievement test					
Experiment group	30	7.23	2.02	−0.875	0.386
Control group	30	7.68	2.77		

Table 6: Academic achievement post-test results of experiment and control groups

Groups	n	X	Ss	t	ρ
Academic achievement test					
Experiment group	30	11.66	4.42	3.742	0.000
Control group	30	7.80	3.17		

Table 7: Diagnostic pre-test results of experiment and control groups

Groups	n	X	Ss	t	ρ
Diagnostic test					
Experiment group	30	6.40	2.42	0.445	0.658
Control group	30	5.20	2.21		

Evaluation of the Academic Achievement Post-test Findings of the Experiment and Control Groups

Independent samples t-test was applied to determine whether there was a significant difference between the experiment and control groups in terms of academic achievement test scores after the instruction (lecture). The findings obtained are presented in Table 6.

Table 8: Diagnostic post-test results of experiment and control groups

Groups	n	X	Ss	t	ρ
Diagnostic test					
Experiment group	30	9.67	5.53	3.996	0.000
Control group	30	6.12	2.40		

The results of the independent samples t-test performed to determine whether the difference between the arithmetic mean of post-instruction academic achievement post-test scores of experiment and control groups, which were 11.66 and 7.80, respectively, was significant or not is presented in Table 6 which reveals that the difference was found to be significant, $t(54) = 3.742$, $\rho < 0.01$. All these findings indicate that there

Table 9: Misconceptions and their numbers observed in the experiment and control groups

Misconceptions	CG pre test %	CG post test %	EG pre test %	EG post test %
Genes are bigger than DNA	16	10	12	4
Gene and DNA are the same concepts	10	8	10	5
Genes rule the DNA	12	8	8	4
Gene and DNA are separate components	18	12	8	4
DNA should be paired first to synthesize mRNA from genes	34	32	33	7
mRNA transfers the code it receives from genes to tRNA	10	8	6	2
Only mRNA is synthesized by gene transcription	42	40	37	8
Chromosomes make up DNA	20	26	25	12
Chromosomes and DNA are the same concepts	12	10	9	8
Chromosomes and DNA are separate components	10	12	11	6
DNA structure consists of chromosomes	22	24	23	14
Chromosomes are carried over genes	13	12	13	10
Genes are made up of chromosomes that come together	12	8	9	8
Chromosomes and genes are separate components	15	14	12	7
Chromosomes are made up of genes only	13	12	10	9
The structure of the gene consists of DNA, and the structure of DNA consists of chromosomes	22	20	24	10
There is DNA on the chromosome, DNAs are components of genes	25	24	23	8
Chromosomes make up DNAs, genes make up chromosomes	22	18	26	11
In prokaryotic organisms, DNA is found in the nucleus	19	17	15	12
In eukaryotic organisms, DNA is not found in the nucleus	17	16	13	12
Since prokaryotic organisms do not have a nucleus, they do not have DNA either	21	20	21	12
There is protein in the structure of DNA	35	31	28	12
The total number of nucleotides and the total number of sugars in a DNA molecule may be different	25	24	17	12
DNA is not involved in protein synthesis	18	11	12	10
mRNA is synthesized after the subcomponents of the ribosome are joined	16	14	11	8
tRNA is read in the ribosome, not the mRNA	24	20	13	10
The mRNA should be recognized to be read in the ribosome	18	12	10	9
Amino acid is synthesized after reading the mRNA	20	18	12	10
The codon available in the DNA structure corresponds to anti-codon	42	40	38	25
The codon available on the tRNA pairs with the anti-codon available on the mRNA	12	15	18	16
Anticodon is located opposite the codon during the pairing of the DNA	22	20	19	16
Protein, amino acid and tRNA are synthesized according to the genetic code	20	18	19	17
The building blocks of protein, amino acids, and tRNA are the same	22	21	23	20
The tRNA transmits code to the ribosome, subunits are formed, and protein is synthesized	27	25	20	18
tRNA forms amino acids together with the ribosome	23	20	21	20

CG: Control group, EG: Experiment group

was a significant difference between the experiment and control groups in terms of post-instruction academic achievement test.

Evaluation of the Diagnostic Pre-test Findings of the Experiment and Control Groups

The mean and standard deviations of pre-test scores obtained from the diagnostic test of the experiment and control groups were calculated. Independent samples t-test was applied to determine whether there was a significant difference between the experiment and control groups in terms of diagnostic test scores before the instruction (lecture). The findings obtained are presented in Table 7.

The results of the independent samples t-test performed to determine whether the difference between the arithmetic mean of pre-instruction diagnostic pre-test scores regarding the misconception of experiment and control groups, which were 6.40 and 5.20, respectively, was significant or not is presented in Table 7 which reveals that the difference was found to be insignificant, $t(55) = 0.445$, $\rho > 0.01$.

Evaluation of the Diagnostic Post-test Findings of the Experiment and Control Groups

The mean and standard deviations of post-test scores obtained from the diagnostic test of the experiment and control groups were calculated. Independent samples t-test was applied to determine whether there was a significant difference between the experiment and control groups in terms of post-instruction diagnostic test scores. The findings obtained are presented in Table 8.

The results of the independent samples t-test performed to determine whether the difference between the arithmetic mean of post-instruction diagnostic post-test scores of experiment and control groups, which were 9.67 and 6.12 respectively, was significant or not is presented in Table 8 which reveals that the difference was found to be significant, $t\ (55) = 3.996$, $\rho < 0.01$. All these findings indicate that there was a significant difference between the experiment and control groups in terms of post-instruction diagnostic test.

Pre- and post-instruction misconceptions and their numbers observed in the experiment and control groups are descriptively presented in Table 9.

Table 9 reveals that the misconceptions most frequently encountered in the experiment and control groups were: "mRNA transfers the code it receives from genes to tRNA," "The codon available in the DNA structure corresponds to anti-codon," "There is protein in the structure of DNA," "DNA should be paired first to synthesize mRNA from genes," "There is DNA on the chromosome, DNAs are components of genes", "DNAs are also gene components" "tRNA is read in the ribosome, not the mRNA," and "DNA structure consists of chromosomes."

A descriptive analysis of Table 9 reveals that number of post-instruction misconceptions observed in both the experiment and control groups were reduced. However, the decrease in the number of misconceptions observed in the experimental group was greater.

DISCUSSION AND CONCLUSION

Pre-instruction academic achievement pre-test scores of both groups applied throughout the research have revealed no statistically significant difference between the groups ($\rho > 0.05$), and pre-test academic achievement test scores of both groups were relatively low. Equivalent success levels of both research groups are considered to be significant in terms of evaluating the objectivity of the research. However, the findings obtained from the post-test achievement tests applied following the instruction, revealed a statistically significant difference between the groups in favor of the experiment group ($\rho < 0.05$). This increase observed in the post-test scores of the experiment group students can be interpreted as an indicator revealing that the teaching method based on concept maps had a positive effect on these students' achievement.

This result seems to be supported by the studies available in the literature. A study conducted by Franklin (1991) to examine the effect of using concept maps on the scientific achievement of the 8^{th} grade students revealed that students who study science with concept maps were more successful than students who studied with the traditional method. A study conducted by Horton et al. (1993) aiming to examine experimental studies on concept maps revealed that the success rate was higher in classes where teaching was performed with concept maps. Another study conducted by Lord (1999) revealed that academic achievement of students who were taught with concept maps were higher. Öner and Arslan (2005), in their research findings, revealed that the learning and remembering levels of the experiment group who were taught the unit of "Electricity" with concept maps were higher compared to the control group who were taught using the traditional rote learning. The study conducted by Kasapoğlu (2011) revealed that teaching with concept maps had a positive effect on students' academic achievements and attitudes.

Kazancı et al. (2003), in their study, compared the role of concept maps with traditional teaching methods on students' learning the genetics. While traditional teaching methods (rote learning) was applied in the control group, concept maps were used in addition to traditional teaching method in the experiment group. The level of success of the students in two research groups was compared with the t-test, and it was concluded that the group that were taught with the help of concept maps was more successful compared to the group that was taught with the traditional teaching method. A study conducted by Çağlayan (2006) aiming to examine the effect of using concept maps while teaching the unit on genetics on students' academic achievements and the ability to gain concepts revealed that making use of concept maps while teaching the unit on genetics positively affects academic achievement. Güneş et al. (2006), with the aim to examine the effects of using concept maps on academic achievement,

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identified 8 biology units within the scope of Biology II course and then formed an experiment and a control group from within second grade students who were studying science teaching. The students in the control group were taught with the traditional teaching method, whereas the students in the experiment group were first taught with the traditional teaching method but further asked to prepare a concept map related to the subjects. The experiment group who were asked to prepare concept maps was found to be more successful compared to the control group who were lectured using the traditional teaching method.

A study conducted by Güçlüer (2006) aiming to examine the effect of cognitive support provided by using concept maps in primary school science education on academic achievement, ability to remember concepts and students' attitudes toward science course revealed that the teaching method, supported by concept maps, is more effective than the traditional teaching method. Şan (2008) examined the effect of teaching 10th grade high school students the transport system in plants in the biology class using concept maps on students' academic success and revealed that the approach of using concept maps significantly improved academic achievement compared to traditional teaching. In a study conducted by Akay (2010), a 45-question biology achievement test was applied as a pre-test to both the experiment group instructed using concept maps and the control group instructed with traditional rote learning, and it was concluded that there was no statistically significant difference between the groups in terms of academic achievement. Considering the post-test scores applied after the instruction, the experiment group instructed using concept maps had higher average score compared to that of the control group instructed with traditional rote learning and that the difference between the groups was statistically significant. A study conducted by Aksoy (2010) revealed that instructing the subject with concept maps in secondary school chemistry class is more effective in increasing scientific achievement and improving students' attitude to chemistry compared to teaching with the traditional method. The study conducted by Aktaş (2012) indicated significantly higher academic achievement post-test mean scores than their pre-test mean scores. This finding supported the inference in the experimental group that science and technology education supported by concept maps contributed positively to students' academic achievement.

The findings obtained from the diagnostic test applied to the experiment and control groups as a pre-test revealed no statistically significant difference between the groups ($\rho > 0.05$) and indicated that both groups were at the same level. However, the findings obtained from the post-test diagnostic tests applied following the instruction, revealed a statistically significant difference between the groups in favor of the experiment group ($\rho < 0.05$). This increase observed in the post-test scores of the experiment group students can be interpreted as an indicator revealing that the teaching method based on concept maps has a positive effect on students' academic achievement. Studies encountered in the literature review examining the role of concept maps on overcoming misconceptions are found out to be supporting the findings of this study (Aykanat et al., 2005; Çalık and Ayas, 2003; Gürlek, 2002; Kaptan, 1998; Markham and Mintzes, 1993).

The study conducted by Çardak (2002) defined the misconceptions that the students had about the unit on diversity and classification of living organisms and to eliminate the misconceptions on this subject determined that the conceptual change texts provided with concept maps have a positive effect on the elimination of misconceptions. Atasoy (2002), in the study on concept maps, stated that concept maps can be used to discuss the meanings of concepts with students, identify and resolve misunderstandings and alternative concepts.

Research indicated that students had wrong and incomplete information about and could not establish a correct relationship between the concepts of DNA, RNA, mRNA, tRNA, rRNA, nucleus, chromosome, gene, genetic code, codon, anti-codon, translation, transcription, ribosome, protein, and amino acid terms taught in protein synthesis subject. This result seems to be supported by the studies available in the literature. The study conducted by Kargbo et al. (1980) concluded that chromosome and gene relationship are difficult concepts to learn. The study conducted by Fisher (1985) stipulated that students did have misconceptions about the concepts of translation and amino acids in the translation phase of protein synthesis. Similarly, Banet and Ayuso (2000) revealed that students understand basic concepts such as gene and chromosome incorrectly or incompletely. In the study conducted by Lewis et al. (2000), 18% of the students who tried to explain the relationship between the concepts of gene, chromosome and nucleus stated that chromosomes are larger than the nucleus. The study conducted by Wood-Robinson et al. (2000) stated that students were frequently confused about the relationships between the concepts of gene, DNA and chromosomes. Saka and Akdeniz (2004), on the other hand, identified in their study that some pre-service science teachers had misconceptions about concepts like chromosome, gene, and DNA. Findings derived from the conceptual understanding test and interviews conducted with students included in the study by Bedir (2007) revealed that students establish wrong relationships between difficult to learn concepts such as gene, DNA and chromosomes and they have misconceptions about these concepts. Academic achievement tests were used in the study conducted by Demir (2008) with the aim to compare the changes between experiment and control group students in terms of their academic achievements. There was a significant decrease in terms of success regarding the experiment and control groups in terms of the answers given to the informative questions about protein synthesis. Majority of the questions where more than 50% of the students could not answer in both the control and experiment groups are reported to be related to DNA, RNA, protein synthesis and nucleotides. The study by Altınay (2009) revealed that students frequently had misconceptions about concepts like gene, DNA, and chromosomes. The most common misconceptions observed in students on this issue were found to be that DNA is a smaller structure than a gene and that chromosomes are carried over genes. Can and Vural (2011) identified in their study that some candidate science teachers had difficulty in associating the concepts of DNA, chromosome, and genes with each other.

Concept maps method can be used for students to make sense of micro-dimension concepts such as protein synthesis and to facilitate them to make connections between these concepts. As students are used to the traditional method of instruction (rote learning), they may feel unfamiliar with lectures instructed with concept maps. Therefore, the concept map approach should be explained to the students in detail before instructing with concept maps. Concept map is an alternative method in education. Therefore, the use of concept map with other methods may further reinforce learning.

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