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EFFECTIVENESS OF INTERDISCIPLINARY TEACHING APPROACH ON COGNITIVE STRUCTURE ABOUT PROTEINS

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Abstract

In this study, the effect of teaching the subject of proteins with an interdisciplinary approach on students' cognitive structures was investigated. For this purpose, it was examined whether a course taught with an interdisciplinary approach effectively develops different perspectives and establishes relationships between concepts belonging to different disciplines. The study group in this research, which used a quasi-experimental design, was composed of 28 high school students (14 of whom were assigned to the experimental group and 14 to the control group). The subject of proteins was taught to the control group in a disciplinary approach while to the experimental group in an interdisciplinary approach. The effects of the approaches on students' cognitive structures were determined using a word association test. The answers obtained from the word association test were analyzed by qualitative content analysis. As a result of the analysis, models were created that show the change in the student's cognitive structures. As a result of the research, it was observed that the interdisciplinary approach increased the students' ability to think in the framework of different disciplines.

Keywords: *Biology Teaching; Interdisciplinary Teaching; Proteins; Word Association Test.*

A. Introduction

Humans perceive the events in the external world as a "whole." Forming the "whole" is possible by meaningfully bringing pieces of knowledge belonging to more than one domain. Indeed, the problems of humanity today are not limited to specific disciplines, but their analysis and solution often require cooperation between separate disciplines. Thus, the need for individuals who can meet the requirements and associate pieces of knowledge in separate disciplines and use them together also increases. In this context, the significance and influence of the interdisciplinary approach in education is increasing daily.

The concept of "interdisciplinary" means bringing at least two areas together and including one into another (Cluck, 1980; Kline, 1995). An interdisciplinary approach is an approach that makes use of methods and knowledge belonging to at least two disciplines in analyzing a concept, theme, or problem (Jacobs, 1989). Erickson (1995) defines an interdisciplinary approach as integrating concepts of separate disciplines. However, it should not be considered only as bringing similar information and skills from various disciplines together. It does not mean something like teaching a small quantity of history, a small quantity of geography, or mathematics in a class hour. Such teaching is an artificial combination. Instead, information and skills from separate disciplines should be combined effectively and meaningfully around a theme common to the disciplines in interdisciplinary teaching. However, integration is only possible in some subjects. Integration can be made only if the disciplines share meaningful and appropriate knowledge. Ties between disciplines should be solid and easy to understand in this context (Chrysostomou, 2004). For example, to examine the complex issue of water pollution, a chemistry teacher could have students analyze water quality, while a biology teacher could have students examine the effect of pollution on organisms in the water (MacKenzie, 2020).

The areas that can make the most appropriate combinations in terms of application and scientific approaches used in problem-solving were found as physical sciences, mathematics, and technology (National Research Council

[NRC], 1996). Subjects and concepts related particularly to physics, chemistry, and biology are closely correlated, one facilitates understanding another, and they complement each other. For this reason, integration should be made to set up associations between concepts and describe events as a whole. An interdisciplinary approach should be integrated into curricula at this point, and plans to enable to transfer of knowledge about different disciplines to students in integrity should be made. Cooperation between teachers of separate disciplines and the content of lesson plans is of great importance in such planning.

It is known that an interdisciplinary approach is effective in keeping students active by increasing their interest in the course and their power to think. Thus, it inculcates in students a holistic perspective and enables meaningful and permanent learning (Edeer, 2005; MacKenzie, 2020). There is much research in the literature reporting that interdisciplinary teaching affects students. Cordogan and Stanciak (2000) determined that their interdisciplinary curriculum effectively affected high school student's interest in the courses and their academic success. White & Carpenter (2008) developed and implemented a biology science laboratory course for university students in which they integrated mathematics. They reported that their applications increased students' awareness of the relationships between biology concepts and concepts in mathematics and increased student participation. Putica & Trivić (2017) stated that the interdisciplinary teaching approach was significantly more effective in promoting high-school students' conceptual understanding and functionalization of knowledge concerning the process of digestion in comparison to the disciplinary teaching approach. Guven and Sulun (2018), as a result of their research, determined that interdisciplinary teaching practices developed and enriched students' cognitive structures regarding the concept of energy. Acarlı (2020) investigated the effect of an interdisciplinary teaching approach on high school students learning about protein. The experimental group students, who were taught with an interdisciplinary approach, completed the spaces (concepts and relations) in the given concept maps more accurately. Thus, it was concluded that interdisciplinary teaching positively affected students' learning. Based on this information in the literature, the effect of interdisciplinary teaching on students' cognitive structures was examined in this study.

Biology course has several subjects and concepts that overlap with the content of physics and chemistry courses and need to be considered in integrity. One of them is the subject of "proteins." It is a subject that high school students learn in the biology course and in the chemistry course and which they encounter in daily life. Besides, it is also one of the subjects which students find difficult to learn since it contains abstract concepts (Fisher, 1985; Francis & Sellers, 1994; Sinan et al., 2006). However, learning the subject of proteins accurately and permanently is essential because it forms the basis of such subjects as enzymes and protein synthesis.

While the general structure of proteins, their importance of them, and their synthesis are taught in the biology course, subjects such as the features of atoms and molecules forming proteins and the chemical bonds they contain are taught in detail in the chemistry course. Therefore, combining the knowledge from the two disciplines in explaining the subject of proteins will enable students to approach the subject from a broader perspective and establish relations between different concepts. Based on this idea, a lesson plan in which information on proteins from both disciplines is presented as a whole was prepared, and the effect of interdisciplinary teaching on students' cognitive structures was investigated.

B. Method

This research is quantitative research with a quasi-experimental method, a nonequivalent control group design with a pre-test and a post-test, was used in the research (Cresswell, 2014). This approach can assist researchers in evaluating the effectiveness of interventions or treatments in specific groups and helps understand the relationships between different variables (Walidin et al., 2025).

In this study, two classes of 12th graders in the same school were selected to be the control and experimental groups for a protein-related interdisciplinary teaching intervention. The same biology and chemistry teachers were used for both groups to minimize the effect of teaching methods and classroom management. The classes were chosen based on their similarity in achievement and other features. The 12th graders were chosen because they had previously studied the subject of proteins and related chemistry topics, making them suitable for the study. The experimental and control groups were randomly assigned from the two classes, with one class consisting of 7 girls and seven boys as the experimental group and the other consisting of 6 girls and eight boys as the control group.

The study used a word association test as the data collection tool (Hovardas & Korfiatis, 2006), where individuals were given a stimulating word related to the research subject and asked to make a list of words associated with the given word. The study used "proteins" as the stimulating word, and the students were asked to write words associated with biology and chemistry courses (Sato & James, 1999). The students were also asked to write a sentence in 40 seconds in the context of biology and chemistry courses. The test was given as a pre-test to both the control and experimental groups, and the subject of proteins was taught to both groups in different teaching approaches. The control group was taught using a traditional disciplinary approach, while the experimental group was taught using an interdisciplinary approach that combined knowledge from the disciplines of chemistry and biology (Jacobson, 1989). After the lesson presentation, the word association test was given again as a post-test to both groups.

The study used MAXqda, a qualitative data analysis program, to analyze the responses given to the word association test using summative content analysis (Mayring, 2002). The words used in the answers were divided into categories based on semantic relations. Two experts independently analyzed the words used in the answers for data analysis reliability, and then they agreed on a categorization system. Frequency tables were prepared for the answers included under certain headings, and models describing the cognitive structures of the subject of proteins were created based on the categories and answers. Incorrect knowledge was identified in the sentences written about the concept of proteins. The data for the section in which students' views and recommendations were asked were analyzed to reveal the control and experimental group students' approaches towards and awareness of the practice.

Finally, the data obtained from the section in which students' views and recommendations were asked was also analyzed to reveal the approaches and awareness of the practice by both the control and experimental groups. By utilizing research design and rigorous data analysis methods, the study obtained precise and reliable results regarding the effectiveness of an interdisciplinary teaching approach in enhancing students' cognitive structures about proteins.

C. Result and Discussion

1. Result

The results coming from the word association test- which the control group and the experimental group students answered prior to and after the practice- were divided into seven headings specified as “The Structure of Amino Acids, The Structure and Synthesis of Proteins, The Importance of Proteins, Constructs Containing Protein, Proteins as Food, Chemical Bonds, and Molecules and Their Interactions” (see Table 1).

Table 1. The results of the word association test

Control Group		Experimental Group	
Pre-test	**Post-test**	**Pre-test**	**Post-test**
The Structure of Amino Acids			
Carbon (12)	Carbon (8)	Carbon (12)	Carbon (14)
Hydrogen (10)	Hydrogen (10)	Hydrogen (11)	Hydrogen (14)
Nitrogen (9)	Nitrogen (11)	Nitrogen (10)	Nitrogen (12)
Carboxyl group (7)	Carboxyl group (9)	Oxygen (8)	Oxygen (10)
Amino group (6)	Amino group (6)	Amino group (2)	Amino group (11)
Oxygen (6)	Oxygen (8)	Carboxyl group (2)	Carboxyl group (11)
Radical group (4)	Radical group (7)	Acidic (2)	Acidic (4)
Acidic (4)	Acidic (4)	Essential (1)	Essential (3)
Basic (4)	Basic (4)	Radical group (1)	Radical group (10)
Essential (2)	Essential (2)	pH (1)	pH (9)
pH (2)	pH (2)		Amphoter (9)

Control Group		Experimental Group	
Pre-test	**Post-test**	**Pre-test**	**Post-test**
	Amphoter (3)		Polar amino acid (5) Apolar amino acid (4) Basic (4)
Total:66	*Total:74*	*Total:50*	*Total:120*
Percentage of frequency change: %12 ↑		*Percentage of frequency change:* %140 ↑	
The Structure and Synthesis of Proteins			
Peptide bond (13) Amino acid (10) Protein synthesis (7) Ribosome (6) RNA (2) DNA (2) Polypeptide (1) Codon (4)	Peptide bond (11) Amino acid (10) Protein synthesis (3) Ribosome (6) RNA (3) DNA (3) Polypeptide (3)	Amino acid (11) Peptide bond (9) Ribosome (7) RNA (5) DNA (5) Polypeptide (4) Dipeptide (2) Transcription (1) Translation (1) Protein synthesis (4) Polymer (3) Codon (2)	Amino acid (12) Peptide bond (10) Ribosome (7) RNA (5) DNA (5) Polypeptide (8) Dipeptide (2) Transcription (2) Translation (2) Quaternary (5) Secondary (4) Tertiary (4)
Total:45	*Total:39*	*Total:54*	*Total:66*
Percentage of frequency change: %13 ↓		*Percentage of frequency change:* %22 ↑	
The Importance of Proteins			
Energy (8) Building material (6) Regulatory (4)	Energy (4) Building material (6) Regulatory (2)	Building material (7) Regulatory (3) Energy (2)	Building material (8) Regulatory (3) Energy (3)
Total:18	*Total:12*	*Total:12*	*Total:14*
Percentage of frequency change: %33 ↓		*Percentage of frequency change:* %17 ↑	
Constructs Containing Protein			
Enzyme (7) Muscle (4) Hormone (4)	Enzyme (3) Muscle (3) Hemoglobin (3) Antibody (3) Keratin (2) Glycoprotein (2) Cell membrane (2)	Enzyme (7) Muscle (5) Cell membrane (2) Hormone (2)	Enzyme (5) Muscle (8) Cell membrane (4) Hormone (4) Hemoglobin (5) Keratin (3) Antibody (2) Fibrinogen (2) Glycoprotein (2)
Total:15	*Total:18*	*Total:16*	*Total:35*
Percentage of frequency change: %20 ↑		*Percentage of frequency change:* %119 ↑	
Proteins as Food			
Egg (4) Milk (4) Protein powder (2)	Egg (1) Milk (1)	Meat (8) Egg (2) Legumes (2)	Meat (2) Egg (2)
Total:10	*Total:2*	*Total:12*	*Total:4*
Percentage of frequency change: %80 ↓		*Percentage of frequency change:* %67 ↓	

Control Group		Experimental Group	
Pre-test	**Post-test**	**Pre-test**	**Post-test**
Chemical Bonds			
Chemical bond (3)	Chemical bond (2)	Hydrogen bond (5)	Hydrogen bond (10)
Hydrogen bond (2)	Hydrogen bond (4)	Covalent bond (2)	Covalent bond (11)
Covalent bond (1)	Covalent bond (3)	Chemical bond (2)	Chemical bond (3)
	Van der Waals interactions (5)		Van der Waals interactions (6)
			Ionic bond (6)
			Apolar bond (5)
			Polar bond (5)
			Disulfide bridges (4)
			Weak interaction (3)
			Strong interaction(3)
			Metallic bond (3)
Total:6	*Total:14*	*Total:9*	*Total:59*
Percentage of frequency change: %133 ↑		*Percentage of frequency change:* %556 ↑	
Molecules and Their Interactions			
Organic molecule (6)	Organic molecule (7)	Organic molecule (9)	Organic molecule (12)
Dehydration (6)	Dehydration (7)	Reaction (4)	Reaction (2)
Water (1)	Water (2)	Water (3)	Water (3)
Compound (3)	Renaturation (2)	Compound (3)	Compound (1)
		Denaturation (2)	Denaturation (5)
			Dehydration (5)
Total:16	*Total:18*	*Total:21*	*Total:28*
Percentage of frequency change: %12.5 ↑		*Percentage of frequency change:* %33 ↑	

The words used in answers given only to the pre-test or the post-test were emphasized.

It is apparent from Table 1 that there is an increase in the total frequencies of both the control group students' and the experimental group students' answers in the categories of "The Structure of Amino Acids," "Constructs Containing Protein," "Chemical Bonds" and "Molecules and Their Interactions" after the practice. While the total frequencies of control group students' answers in "The Importance of Proteins" and "The Structure and Synthesis of Proteins" fell after the practice, the frequencies in the experimental group increased.

The post-test total frequencies in the category of "Proteins as Food" fell in both groups in the post-test when compared to the pre-test results. In addition, an examination of the change in percentages of frequencies made it clear that there were more positive changes in the experimental group than in the control group in all categories. Even though the total frequencies for the categories offer clues about the research groups' cognitive structures about proteins, the issue of what words frequencies increased and what words were added as new answers after the practice is essential. Therefore, the groups' pre-test and post-test answers were shown in diagrams with the models created.

Figure 1 shows the model created for the status of control group students' cognitive structures about proteins in the pre-test and the post-test.

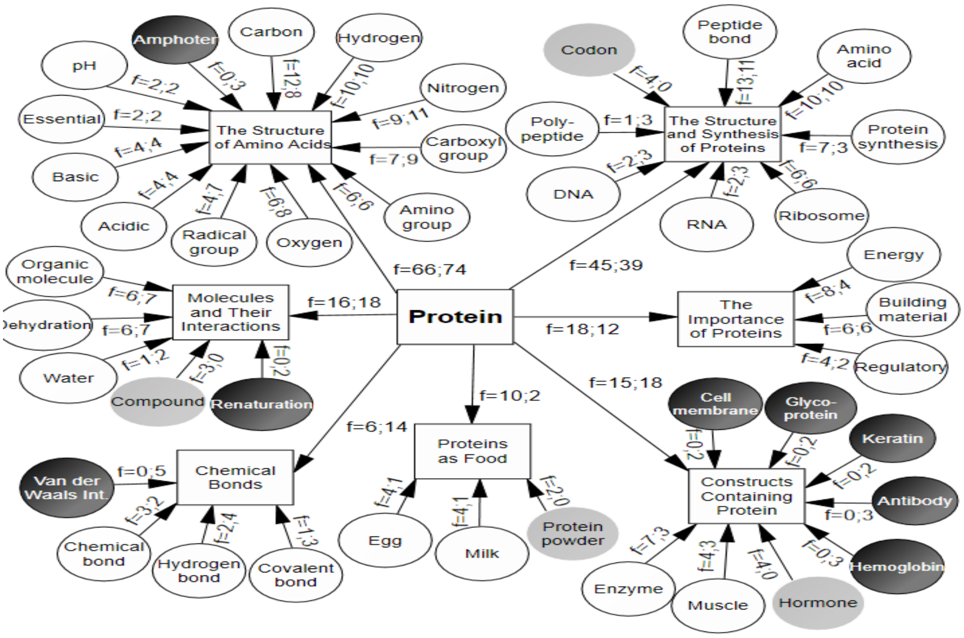

Figure 1. The Model of Control Group Students' Cognitive Structures about Proteins (F=Frequency of Pre-Test; Frequency of Post-Test; XXX: Answers Given Only in The Pre-Test; XXX: Answers Given Only in The Post-Test)..

It is clear on examining Figure 1 that there are three increases in the frequency of the control group students' answers "radical group" in the category of "the Structure of Amino Acids," there are two increases in the frequency of the answers "nitrogen, carboxyl group, and oxygen" and decrease from 12 to 8 in the frequency of the answer "carbon" after the practice. The only concept added to the answers in this category after the practice was "amphoteric (f=3)".

The control group students' answers in "The Structure and Synthesis of Proteins remained the same. There was an increase only in the frequencies of the answers "RNA", "DNA", and "polypeptide" in the category. However, there was a fall in the frequencies of the answers "proteins synthesis" and "peptide bond." Apart from that, the answer "codon" given by 4 students in the pre-test was not given by any students in the post-test.

It became apparent that the frequency of the control group students' answers "energy and regulatory" in the "The Importance of Proteins" category fell by half in the post-test. In contrast, the answer "building material" frequency remained the same. Another remarkable finding was that the words used as answers in this category did not change and remained the same in the pre-test and the post-test.

The frequency of control group students' answers "enzyme" and "muscle" in the category of "Constructs Containing Protein" fell. However, the answer "hormone" given by four students in the pre-test was not given by any students in the post-test. Besides, it was also found that the answers "hemoglobin, antibody, fibrinogen" -which were not given in the pre-test-were given by three students in the post-test and that the answers "keratin, glycoprotein, and cell membrane" -which were not given in the pre-test were given by two students in the post-test.

The frequency of the control group students' answers "egg" and "milk" in the category of "Proteins as Food" fell from 4 to 1, and the frequency of the answer "protein powder"- which was given by 2 students in the pre-test- was not given by any students in the post-test.

The frequency of the control group students' answers "hydrogen bond" and covalent bond" in the category of "Chemical Bonds" increased by 2. However, the frequency of the answer "chemical bond" fell from 3 to 2. The only phrase which was given as an answer in the post-test but which was not given in the pre-test was "van der Waals interactions" (f=5).

While the frequencies of the control group students' answers "organic molecule" and "dehydration" in the category of "Molecules and

Their Interactions" increased by 1, the frequency of the answer "water" fell by 1. The answer "compound"- given by two students in the pre-test- was not given by any students in the post-test, and the answer "renaturation"- which was not available in the pre-test- was given by two students in the post-test.

Figure 2 shows the model created for the status of experimental group students' cognitive structures about proteins in the pre-test and post-test.

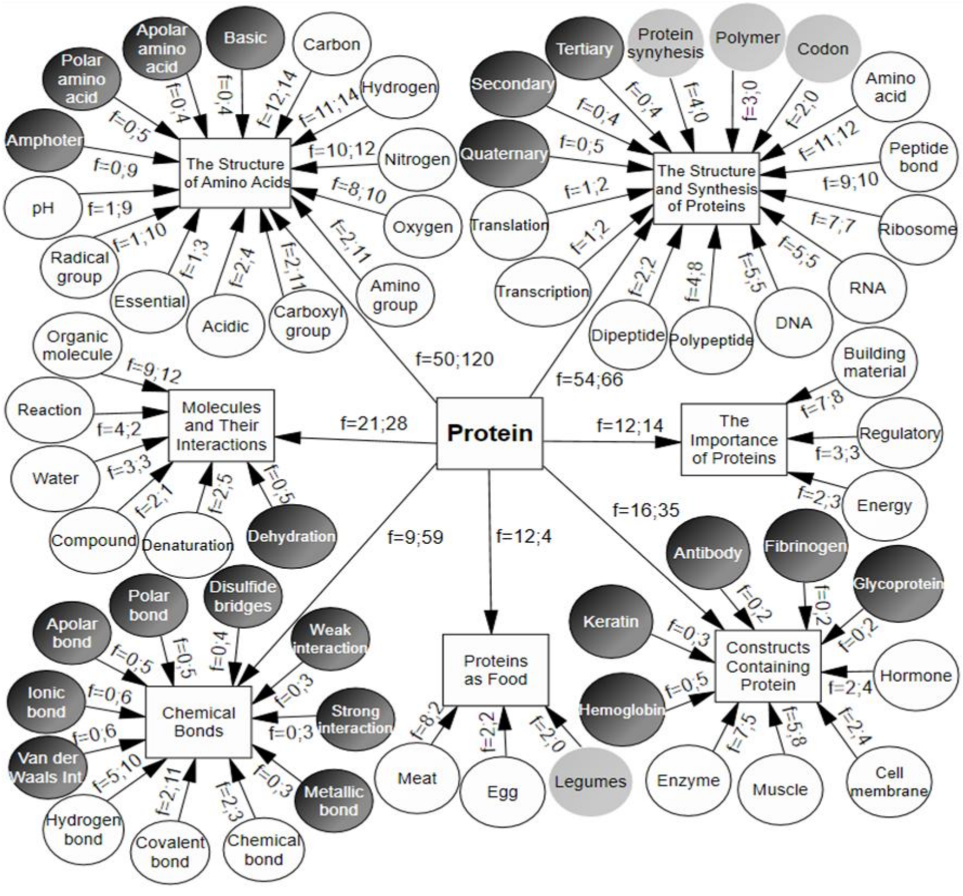

Figure 2. The Model of Experimental Group Students' Cognitive Structures about Proteins (F= Frequency of Pre-Test; Frequency of Post-Test; XXX: Answers Given Only in The Pre-Test; XXX: Answers Given Only in The Post-Test).

Considerable increases occurred in the frequencies of some of the experimental group students' answers in the "The Structure of Amino

Acids" category after the practice. It is apparent from Figure 2 that the frequencies of the answer "radical group" increased by 9, the frequencies of the answer "hydrogen" increased by 3, and the frequencies of the answers "carbon", "nitrogen", "acidic", and "essential" increased by 2. Besides, the concepts "amphoteric, polar amino acid, apolar amino acid, basic" - not available in the pre-test- were used as answers in frequencies ranging between 4 and 9.

The frequency of the answer "polypeptide" in the category of "The Structure and Synthesis of Proteins" - which was 4 in the pre-test- rose to 8 in the post-test, and the frequencies of the answers "amino acid, peptide bond, transcription, and translation" increased by 1. The answers "protein synthesis, polymer, codon" in the pre-test were unavailable in the post-test. In addition, the answers "quaternary, secondary, tertiary" - not available in the pre-test- were available in the post-test.

The experimental group students used the exact words as the control students in their answers in "The Importance of Proteins". The frequencies of the answers "building material" and "energy" increased by 1 in the post-test, but the frequency of the answer "regulatory" did not change (f=3).

The change in the post-test in the "Constructs Containing Protein" category in the experimental group was similar to the one in the control group. The frequencies of the answers "cell membrane" and "hormone" rose from 2 to 4, while the frequency of the answer "muscle" rose from 5 to 8. However, the answer "enzyme" frequency fell from 7 to 5. Additionally, the answer "hemoglobin" was given by five students, "keratin" was given by three students, and the answers "antibody, fibrinogen, glycoprotein" were given by two students in the post-test only.

The frequency of experimental group students' answer "meat" in the category of "Proteins as Food" fell from 8 to 2, and the frequency of the answer "legumes" - which was given by two students in the pre-test- was not given by any students in the post-test. The answer "egg" frequency did not change (f=2).

In the category of "Chemical Bonds"- in which the percentage of increase was the highest in the experimental group- the answer "covalent bond" increased by 9, "hydrogen bond" increased by five, and "chemical bond" increased by 1. Apart from that, the post-test also contained answers "ionic bond" (f=6), "van der Waals interactions" (f=6), "apolar bond" (f=5), polar bond (f=5), disulfide bridges (f=4), weak interaction (f=3), strong interaction (f=3) and metallic bond (f=3)- which were not available in the pre-test.

The frequencies of the answers "organic molecules" and "denaturation" given by the experimental group students in the category of "Molecules and Their Interactions" increased by 3 in the post-test. The frequencies of the answers "reaction" and "compound," on the other hand, fell by 2. The answer "dehydration" - not available in the pre-test- was given by five students in the post-test.

Examining the students' sentences made it clear that both the control group and the experimental group students had written sentences mainly about the importance of proteins (constructive, remedial, regulatory) in the biology course. In contrast, they had written sentences about the elements available in the structure of proteins in the chemistry course in the pre-test. Sample sentences written by both groups are as in the following (C: Control group students; E: Experimental group students):

> *"The amino group, carboxyl group and radical group as a variable are regulatory compounds -which are contained in the structure- in our body". (C11)*
>
> *"Proteins, whose building blocks are amino acids, are the organic compounds which are used in the body as structural, catalytic, and regulatory". (C14)*
>
> *"Proteins, which are perhaps the most important organic compounds of vitality are regulatory, they join the structure and they also give energy". (E5)*
>
> *"Proteins are the polymers which are very important in that they are included in the structure of enzymes and hormones in our body and in that they give energy". (E8)*
>
> *"The elements C, H, O, N are available in the structure of proteins". (C12)*
>
> *"An organic compound which contains the C, H, O and N atoms". (E14)*

It was found that the sentences written by the control group and the experimental group students in the pre-test needed to be corrected. The control group students were found to write incorrect sentences, especially about the concept of "amphoteric". Thus, they were found to assign meanings apart from being acidic and essential to the concept by saying that amino acids can be acidic, essential, and amphoteric. The incorrect statements made by the experimental group students were related to the claim that proteins were the building blocks of living creatures and about the formation of amino acids. Samples for the incorrect statements made by the control group and the experimental group students are as in the following:

> *"Not all of the amino acids are acidic. Some of them are amphoteric"*. (C3)
>
> *"Some of the 20 types of amino acids in nature are acidic, some of them are basic, and some are amphoteric"*. (C14)
>
> *"The amino acids which are formed by hydrogen and covalent bonds constitute the basic component called protein by setting up peptide bonds"*, (C7)
>
> *"Proteins can contain atom N as different from other organic compounds"*. (C4)
>
> *"Amino acids are formed as a result of break in bonds between protein chains"*. (E7)

None of the incorrect sentences written by the control group and the experimental group students in the pre-test was repeated after the practice. There were no significant changes in other statements the control group students made. The statements thought and written by them in the context of the chemistry course were again mostly related to the elements available in the structure of proteins. The sentences written by the experimental group students in the context of the chemistry course, on the other hand, were concerned with the chemical bonds in the structure of proteins, with the idea that they were amphoteric and that they were organic compounds as different from the ones written in the pre-test. Some of the samples for sentences written by the experimental group students in the post-test were as in the following:

> *"Amino acids are amphoteric, are used as buffers and they form covalent bonds between them". (E2)*
>
> *"Amino acids, which are the building blocks of proteins, are amphoteric". (E6)*
>
> *"while two amino acids form dipeptides, the carboxyl group of one is tied to the amino group of the other with covalent bond". (E8)*
>
> *"They are the amphoteric compounds which have C, H, O and N in their structure and which are amphoteric". (E9)*
>
> *"Proteins are the organic food which is formed by amino acids' forming polypeptides with peptide bonds and by polypeptides' having quaternary structure after tertiary structure with bonds and disulfide bridges". (E11)*

The students in the control group expressed their thankfulness about the practice in the section about views after the practice, and they said that the practice helped them to remember and revise the subject. The students in the experimental group - who were taught an interdisciplinary approach- however, stated that the practice had associated their knowledge about biology with their chemistry knowledge and thus helped them to understand the subject better. Some of the statements they had made in this respect were as in the following:

> *"I was able to associate chemistry with biology better". (E3)*
>
> *"It was useful to teach the subject along with chemistry. I was able to associate the two". (E4)*
>
> *Teaching biology through chemistry makes it easier to understand biology. Chemistry answers our questions, especially about the structure of some molecules. In this way, we can better understand the bonds between molecules and how they are formed. Biology helps chemistry, and chemistry helps biology". (E8)*
>
> *"Setting up ties between chemistry and biology has enabled me to grasp the rationale of what we learn". (E11)*
>
> *"The subject of proteins is vital in biology, and we used chemistry to learn the subject better. I saw that the properties of proteins could be understood better using bonds available in chemistry. I understood that everything had a logic". (E12)*

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2. Discussion

This study aims to determine whether the interdisciplinary teaching practice makes a difference in the student's cognitive structures when compared to the disciplinary teaching practice in the processing of the subject of proteins. It was found in this study that there was a significant increase in the variety and frequency of experimental group students' answers, especially in subjects that were common to chemistry and biology, such as chemical bonds and the structure of amino acids.

Even though there was an increase in the control group students' answers, the variety and frequency of concepts were remarkably higher in the experimental group. Thus, it can be stated that interdisciplinary teaching inculcates students with a holistic perspective (Edeer, 2005; Stember, 1998). In this way, the students in the experimental group had the opportunity to evaluate the content in chemistry and the content in biology concerning proteins in combination and to see them as a whole by bringing the two together. The students were made to set up associations between the two disciplines and to approach the subjects from different perspectives, thanks to interdisciplinary teaching practice. The students' power of thinking was increased in this way. It can be said based on the percentage of changes in the frequency of students' answers and their statements reflecting their views on the practice.

The experimental group students' interest in and excitement about the course during the practice were also remarkable, even though they were not presented as factual data. The effects of such subjects as chemical bonds and the structure and interactions of molecules- which had been taught in chemistry independently of biology- on understanding and learning the subject of proteins meaningfully were noticed and stated by the students. The finding reflected the claim that interdisciplinary teaching promoted interest in classes and enabled meaningful learning (MacKenzie, 2020)- which is pointed out in the literature by several researchers.

It is thought that the decrease in the post-test total frequency of the "Proteins as Food" category compared to the pre-test in both groups may be because more emphasis was placed on protein structure and function in the lectures. However, the incorrect sentences written by the control group and the experimental group students in the pre-test were not available in the post-test in either group. Whether the incorrect sentences were misconceptions or wrongly stated, knowledge stemming from failure to remember can be made clear through future research.

In addition, the misconception that "amino acids are produced through protein synthesis" detected by Fisher (1985) can be considered a misconception that students have had for a long time. In the same way, the experimental group students also stated in the pre-test that amino acids were formed due to the destruction of proteins. Therefore, it is thought that more practice and more time are needed to remedy the misconceptions about the formation of amino acids. Besides, the knowledge the experimental group students learned in a holistic approach is expected to be more permanent. Repeating the measurement with a knowledge or word association test for this purpose will be beneficial.

D. Conclusion

According to the research findings, the experimental group students could evaluate the chemistry and biology course content knowledge on protein. The interdisciplinary teaching provided students with a holistic perspective. Therefore, treating subjects with interdisciplinary features in biology would be beneficial in this way. Teachers' knowledge, wishes, and competencies are necessary at this point. The lesson plan they will follow is essential in performing interdisciplinary practice.

It is known that resources apart from course books are used, lesson plans are considered necessary, and programs need to be flexible in classes that are taught with an interdisciplinary approach. Teachers should prepare their lesson plans accordingly and include references to and explanations about other disciplines in their lesson plans for teaching classes in an interdisciplinary teaching approach. With this approach, they should have the desire and knowledge to prepare a lesson plan. In this context, inculcating content knowledge and professional knowledge about relevant disciplines in the pre-service teachers during their training in teacher training institutions is essential for the pre-service teacher to use an interdisciplinary teaching approach.

Undoubtedly, preparing and putting such a lesson plan into action causes an additional workload for teachers, even though they are duly equipped. Having teachers be able to plan and execute an interdisciplinary unit takes coordination, expected planning time, and dedication to the importance of this kind of learning experience. Also, the curriculum should offer guidance to teachers in this respect. Thus, it would be beneficial if the curriculum included directions and information for what points and how associations could be set up with other disciplines and examples of interdisciplinary activities.

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