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AN INTERDISCIPLINARY TEACHING APPLICATION: THE TOPIC OF PROTEINS

Dilek Sultan Acarli

Abstract. *The aim of present research was to examine the effects of interdisciplinary teaching approach on teaching the topic of proteins. In the research, unequal control group model- one of the quasi-experimental research designs was used. The experimental group included 16 students (8 female and 8 male) whereas the control group included 14 students (6 female and 8 male) in this research- which was conducted with the participation of the 12th grade students. A lesson plan in which the topic of proteins was taught in interdisciplinary approach was prepared as the tool of application. A concept map prepared by the researcher and a 5-point Likert type of question were used in collected the data. The data collection tool was given to both the experimental group and the control group as a pre-test and post-test. Wilcoxon Signed Rank Test, a non-parametric method- was used in comparing the participants' scores in the pre-test and post-test of concept map and Likert type question. As a result, it was found that the application of interdisciplinary teaching conducted in the experimental group had caused differences in students' associating the concepts in biology and chemistry available in the topic of proteins and in their perceptions of their skills in this respect.*

Keywords: *biology teaching, concept map, interdisciplinary teaching, quasi-experimental research, proteins.*

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Introduction

Critical thinking is one of the skills perhaps the most difficult to inculcate in the new generation individuals- who are expected to have those skills. Thinking critically in a domain means comprehending the logic of the domain. Comprehending the logic of a subject does not necessitate memorization, and it enables individuals to recall the forgotten knowledge through inferences. The more memorized knowledge you need in remembering the details of a subject, it means the less you have learnt the logic of their coming together. According to the adaptation of critical thinking into biology, "critical thinking in biology is logical and reflective biological thinking and it focuses on deciding on what to do or what to believe, and it also focuses on the large relationships between biology and the world" (Nosich, 2018). It is necessary to bring together the knowledge suggested by different disciplines and to have an interdisciplinary perspective in order to be able to set up the associations between biology and the world. It is useful here to focus on the word discipline. Disciplines emerged with the clustering of pieces of knowledge in groups according to their proximity. Berger (1972) described a discipline as "an area of research which has its own infrastructure of education, methods and content and which has proven that it can generate new knowledge in an area and that it can develop advanced knowledge in the area". Each discipline has a different perspective of events (Becher, 1989; Parker, 2002). Looking at an event from the perspective of a discipline involves being able to see the event from the zone of influence of the discipline, being able to evaluate it in terms of the concepts and categories of the discipline and being able to understand the connections between them. However, it is not adequate to approach from the perspective of only one discipline in solving problems and in perceiving the whole. Continuing from the same example, individuals also need to put their knowledge of areas such as geography, chemistry, physics, etc. into practice to make accurate interpretations about the living space of plants or to generate solutions to problems.

Jacobs (1989) defined the term interdisciplinary as an approach which uses the methods and knowledge of more than one discipline together so as to examine a subject or a concept. Defila and Guilio (2002), on the other hand, defined it as cooperative work of individuals coming from more than one discipline to reach a general view within the framework of a shared goal.

Perspectives of differing disciplines are needed in several areas, but they are more important in areas such as biology in particular which are naturally

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related to many disciplines. The knowledge and methods of other areas should be used together so that biology teaching is meaningful. Many topics in biology classes are interdisciplinary. There are many topics and concepts which coincide especially with the content of physics and chemistry and which need to be considered as a whole along with the knowledge in those courses. Those topics and concepts may not be meaningful or effective when they are considered within only one discipline or course. Here, the importance of an interdisciplinary teaching in which the knowledge and methods of all those disciplines are used together emerges.

Interdisciplinary approach should not be considered as teaching the topics of different disciplines independently of each other in a single class hour. It would be an artificial combination and it would not serve to the purpose. Instead, knowledge and skills belonging to different disciplines should be combined around a joint topic effectively and meaningfully (Yıldırım, 1996). Such teaching can be done through cooperation between two or more teachers and also by one teacher who integrates the content from other areas into his area (Jacobs, 1989).

It is possible through interdisciplinary teaching to learn knowledge and skills of certain disciplines together and to integrate them meaningfully instead of transferring knowledge of a single discipline (Aydın & Balım, 2005; Edeer, 2005; Gürdal et al., 1999). In this way, students are given the opportunity to analyse a subject from the perspective of different disciplines and thus they are made to gain versatile thinking (Yıldırım, 1996). The results of the research suggested that interdisciplinary teaching approach has positive effects on students' academic achievement, motivation, attitudes towards a course problem solving skills and on their critical thinking tendencies and the need to teach the course by setting up associations between disciplines (Akpınar & Ergin, 2004; Alp, 2010; Aslan Yolcu, 2013; Budak Coşkun, 2009; Chan, 2005; Cordogon & Stanciak, 2000; Dervişoğlu & Soran; 2003; Duman & Aybek, 2003; Gardner & Boix-Mansilla, 1994; Gürdal et al., 1999; Kander, 2003; Konukaldı, 2012; Leahey, 1999; Putica & Trivić, 2017; Suraco, 2006; White & Carpenter, 2008; Yarımca, 2011). What is important here is to set up the right associations between appropriate disciplines and to lead students so that they can see/ establish the associations. Here, teachers have the greatest share to play roles. They need to have the necessary motivation, knowledge and skills to be able to teach the course in interdisciplinary approach.

Biology course contains several abstract concepts and incidents. Therefore, it is among the courses which are difficult to teach and learn. Students learn through memorization because most of them cannot deal with the subject holistically and learn it in this way. As a result, there is no retention in learning, and misconceptions also arise (Jones & Rua, 2006; Kindfield, 1994; Lukin, 2013, Mak et al., 1999, Soyibo, 1993). The topics of molecular biology are among the most difficult topics of biology to teach and to learn (Fisher, 1985; Rotbain et al., 2005; Saygın, 2009; Sinan et al., 2006). This research, setting out from this fact, analyses the topic of proteins. Proteins are the fundamental components available in the structure of living organisms and the topic is an issue that students frequently face in the topic of protein synthesis in biology classes and in daily life. In addition to that, a great deal of knowledge used in describing the structure of proteins and the construction-destruction mechanisms is taught in chemistry course in such topics as interactions between chemical types, acids, bases, the chemistry of carbons and organic compounds. Thus, it is thought that using the knowledge in the two disciplines together in explaining the topic of proteins will enable students to approach the topic in a broader perspective, to see the connections better and to learn meaningfully.

Concept Maps in Interdisciplinary Teaching

Interdisciplinary teaching enables one to learn knowledge and skills in different disciplines in combination and to integrate them meaningfully (Edeer, 2005; Jacobs, 1989; Sherman, 2000). Therefore, meaningful learning should also be mentioned on mentioning interdisciplinary teaching. According to the theory of meaningful learning suggested by Ausubel (1968), cognitive structure is formed in stages and new concepts develop in the presence of existing concepts. Novak and Gowin (1984) suggested the use of "concept maps"- which put Ausubel's theory into practice and which can help organize learning materials. They defined concept maps as schemata which build a bridge between previous knowledge and the newly learnt knowledge and which show how individuals relate concepts in their mind. They pointed out that the general concepts should beat the top of concept maps and more specific concepts should be under them and thus the hierarchy and other relations between concepts could be demonstrated (Novak & Gowin, 1984). Consequently, it is known that associations should be established between concepts in meaningful learning, and the importance of concept maps in setting up the association is also known.

Concept maps are quite effective and functional instruments that can be used at any stage for different purposes in learning and teaching environments. They enable learners to express the logical ties between concepts

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visually. They also function as a summary of what is learnt at the end of an instance of learning (Novak & Gowin, 1984). Therefore, they are also used effectively in determining and evaluating students' levels of understanding and learning (Wallace & Mintzes, 1990). Gaines and Shaw (2002) classified the purposes in using concept maps as instrument of creativity, instrument of designing big texts, instrument of communication, instrument of learning, instrument of problem-solving and instrument of evaluation. Concept maps are also influential in analysing the cognitive structure, the concepts one has and the way the concepts are organized. The development of a concept throughout the process of learning can be observed by means of concept maps. An important advantage of concept maps in comparison with other measurement instruments is that they enable to measure meaningful learning more easily (Şahin, 2002). In those respects, they are the useful vehicles that can be employed by teachers in interdisciplinary teaching to show the relationships between concepts and to determine whether or not students can set up the relations.

In the scope of the research, a lesson plan presenting the knowledge about proteins available in both disciplines as a whole was prepared and the following questions were tried to be answered:

1. Does the interdisciplinary teaching approach make a significant difference on students' learning about proteins compared to the disciplinary approach?
2. Does the interdisciplinary teaching approach make a significant difference in students' perceptions of their skills to associating the concepts in biology and chemistry compared to the disciplinary approach?

Research Methodology

General Background

In this research, it was aimed to examine the effects of interdisciplinary teaching approach on teaching the topic of proteins. In accordance with this purpose, unequal control group model- one of the quasi-experimental research designs (Cresswell, 2014) was used. This research design was chosen due to the fact that equalizing the experimental and control groups in terms of variables in schools was difficult. In other words, the study groups were not composed of randomly chosen subjects; instead, comparisons were made through existing groups (i.e. classes). The research was carried out during the first semester of the 2019/2020 academic year in a secondary school in Ankara, Turkey.

Sample

Two classes of 12th grade students which were taught by the same biology and chemistry teachers and which had almost the same achievement average were chosen (by consulting teachers' opinions) to ensure that experiment and control groups are similar as far as possible. The reason for preferring the 12th grade students in the research was the desire to work with students who had studied the topic of proteins and the chemistry topics in relation to proteins before and thus who were not unfamiliar with the topic. It was thought that it would be easier to set up the associations between topics in the experimental group in this way, consistently with the approach of teaching. The decision on which class was to be made the experimental group and which group was to be made the control group was made in impartial choice. Thus, there were 16 students (8 girls and 8 boys) in the class, which was made the experimental group, whereas there were 14 students (6 girls and 8 boys) in the class, which was made the control group.

Instrument and Procedures

A lesson plan in which the topic of proteins was taught in interdisciplinary approach has been prepared for applying in the experimental group. Multi-disciplinary approach was used in preparing the lesson plan. The disciplines related to each other are combined in such an approach (Jacobs, 1989). This research presents the topic of proteins by putting together the knowledge in the disciplines of chemistry and biology at appropriate points. The approach of "lesson exceeding the limits of a domain"- which Huber (1999) described as one of the ways of arranging interdisciplinary lessons was used in teaching the lesson. Here, the teacher occasionally goes out of his domain, includes the content of other domains or the subjects connected with his domain in his lesson while teaching the lesson.

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A concept map created by the researcher and a 5-point Likert type question were used in collecting the research data:

A concept map aiming to show the relationships between the disciplines and mostly containing the hierarchical and classification elements was created. The appropriateness of the concept map was checked by 2 experts in chemistry education and 2 experts in biology education, and the concept map was given the final shape in accordance with the recommendations (see in Appendix 1). 16 items containing the concepts and events which were determined jointly by the researcher and by other experts were left blank, and the students were asked to fill in the blanks as the pre-test and post-test. Each correct answer was coded as 1 point and each incorrect answer was coded as 0 point in the blanks, and thus the total scores were found by adding up the scores for the correct answers. In this way, the students were assessed over 16 points.

Students' perceptions of their skills in associating the disciplines were also tried to be determined by using a 5-point Likert type question. Therefore, the experimental and control group students who completed the concept map were asked to what extent they associated the concepts they had learnt in chemistry and biology courses in this question. Their answers were marked as Strongly disagree=1, Disagree=2, Neither agree or disagree=3, Agree=4, Strongly agree=5; and the data were analysed on the SPSS.v23 programme.

The data collection tool consisting of a concept map and a 5-point Likert type question was initially applied to both the experimental and control groups as a pre-test. After two weeks, the topic of proteins was taught to the control group within the framework of biology curriculum in 2 class hours without setting up associations. The experimental group, on the other hand, was taught in 2 class hours such subjects and concepts as chemical bonds, acid-base, amphoteric, electric charge, chemical reactions briefly when necessary in addition to the content available in biology curriculum; they were made to remember their chemical knowledge and to set up associations and thus it was secured that they set up ties between subjects (for instance, they were made to remember that peptide bond was indeed a covalent bond when it was said that peptide bond was formed between amino acids, thus the subject of chemical bonds was mentioned and the types of chemical bonds were explained briefly). After lesson presentations, the same data collecting tool was applied to both the experimental and control groups as a post-test.

Data Analysis

The total scores that the students received from the 16 questions and the quantitative data coming from their answers to the Likert type question were analysed on the SPSS.v23 programme. Non-parametric methods were used in analyses because the sample size was below 30 and because there was no normal distribution in al data sets. First, Mann-Whitney *U*-Test, a method of non-parametric analysis was done to find whether there were any differences between the scores that the students in the control group and in the experimental group- which were thought to be equivalent- received from the concept map and from the pre-test of perceptions of skills in associating the disciplines; that is to say to see whether groups were really equivalent.

Wilcoxon Signed Rank Test, another non-parametric method- was used in comparing the participants' scores in the pre-test and post-test of concept map and associating the disciplines.

Ethical Procedures

In the research, the principle of voluntary participation was taken into consideration and the identities of the participants were kept confidential. All participants were informed about the purpose of the research and the right to leave the research at any time.

Research Results

The Mean Scores and Standard Deviations for the Concept Map and for the Perceptions of Skills in Associating the Disciplines

The total mean scores for the experimental group students' (N=16) and the control group students' (N=14) answers to the 16 questions in the pre-test and post-test in the concept map and the mean for the perceptions of skills in associating the disciplines and the standard deviations are shown in Table 1.

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Table 1
The mean scores and standard deviations for the concept map and for perceptions of skills in associating the disciplines

	Study Group	Pre-test		Post-test	
		X	*SD*	*X*	*SD*
Concept Map Score (max. 16 points)	Control Group	8.21	3.04	9.14	1.70
	Experimental Group	7	2.16	12	2.03
Score of Perceptions of Skills in Associating the Disciplines (max. 5 points)	Control Group	3.14	0.77	3.29	0.73
	Experimental Group	3.50	0.63	4.06	0.68

The Findings for the Equivalent Structure of the Control Group and the Experimental Group

Although a quasi-experimental design- in which the participants were not chosen randomly- was used in this research, Mann-Whitney *U*-Tests were given to find whether there were any significant differences between the control group students' and the experimental group students' concept map scores and scores of associating the disciplines.

The results for the Mann-Whitney *U*-Test, which was calculated for the significance of the differences between the control group students' and the experimental group students' concept map pre-test scores, are shown in Table 2. Accordingly, no significant differences were found between the control group students' and the experimental group students' concept map scores prior to the application (U=87; p>.05). in other words, the students' knowledge about the concepts in biology and chemistry about proteins and their knowledge about the relationships between those concepts were similar at the beginning

Table 2
Mann-Whitney U-Test results for the concept map pre-test scores

	N	Mean Rank	Sum of Ranks	*U*	*p*
Experimental Group	16	13.94	223	87	.313
Control Group	14	17.29	242		

The Man-Whitney *U*-Test result for the control group students' and the experimental group students' scores for perceptions of skills in associating the disciplines are shown in Table 3. The results demonstrated that there were no significant differences between the control group and the experimental group students' scores for perceptions of skills in associating the disciplines prior to the application (U=87; p>.05). In other words, their perceptions of their skills of associating the concepts in biology and chemistry were similar at the beginning.

Table 3
Mann-Whitney U-Test results for the perceptions of skills in associating the disciplines

	N	Mean Rank	Sum of Ranks	*U*	*p*
Experimental Group	16	17.06	273	87	.313
Control Group	14	13.71	192		

In consequence, it was found that there were no significant differences between the control group students' and the experimental group students' concept map scores and their perceptions of their skills of associating the disciplines. That is to say, the groups were found to be similar in terms of those variables prior to the research.

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A comparison of Concept Map Scores and Perceptions of Skills in Associating the Disciplines Prior to and After the Application

The results of Wilcoxon Signed Rank Test- which was done to analyse the differences between the pre-test and post-test scores that the control group and the experimental group students received from the concept map are shown in Table 4.

Table 4
The Results of Wilcoxon Signed Rank Test done for the differences between concept map pre-test and post-test scores

	Post-test-Pre-test	N	Mean Rank	Sum of Ranks	Z	p
Control Group	Negative Ranks	2	4.75	9.50	-1.559	.119
	Positive Ranks	7	5.07	35.50		
	Ties	5				
	Total	14				
Experimental Group	Negative Ranks	1	1.50	1.50	-3.446	.001
	Positive Ranks	15	8.97	134.50		
	Ties	0				
	Total	16				

According to Table 4, there are no significant differences between control group students' pre-test and post-test scores for the concept map ($Z_{control}$=-1.559, p>.05). On the other hand, there are significant differences between experimental group students' pre-test and post-test scores for the concept map ($Z_{experimental}$=-3.446, p<.05). Considering the mean rank and the totals, it can be stated that the differences are in favour of positive ranks- that is to say, in favour of post-test scores. Accordingly, it can be said that the interdisciplinary teaching application is influential in students' associating the concepts in biology and chemistry related to proteins.

The results of Wilcoxon Signed Rank Test which was done to analyse the differences between the pre-test and post-test scores that the control group and the experimental group students received from perceptions of skills in associating the disciplines are shown in Table 5.

Table 5
The Results of Wilcoxon Signed Rank Test done for the differences between the pre-post and post-test scores received from the perceptions of skills in associating the disciplines

	Post-test-Pre-test	N	Mean Rank	Sum of Ranks	Z	p
Control Group	Negative Ranks	0	0	0	-1.414	.157
	Positive Ranks	2	1.50	3		
	Ties	12				
	Total	14				
Experimental Group	Negative Ranks	0	0	0	-3.000	.003
	Positive Ranks	9	5	45		
	Ties	7				
	Total	16				

It is clear from Table 5 that there are no significant differences between control group students' pre-test and post-test scores they received from the perceptions of skills in associating the disciplines ($Z_{control}$=-1.414, p>.05). However, there are significant differences between experimental group students' pre-test and post-test scores they received from the perceptions of skills in associating the disciplines ($Z_{experimental}$=-3.000, p<.05). Considering the mean rank and the totals, it can be stated that the differences were in favour of positive ranks- that is to say, in favour of

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post-test scores. Accordingly, it can be said that the application of interdisciplinary teaching caused differences in students' perceptions of their perceptions of skills in associating the concepts in biology and chemistry and that it is influential in their having more self-confidence in this respect.

The control group and the experimental group students' responses to the questions in the concept map in the pre-test and in the post-test and the changes in correct answers following the application are shown in Table 6 as another finding obtained in data analysis.

Table 6
Responses to the questions in the concept map prior to and after the application

Numbers and Answers of Questions in the Concept Map	Control Group (*N=14*)					Experimental Group (*N=16*)				
	True *f*(%)	False *f*(%)	True *f*(%)	False *f*(%)	Change* *f*(%)	True *f*(%)	False *f*(%)	True *f*(%)	False *f*(%)	Change* *f*(%)
1. …have C, H, O atoms in their structures.	1(7)	13(93)	-	14(100)	-1(7)	2(12.5)	14(87.5)	11(69)	5(31)	+9(56.5)
2. Proteins	13(93)	1(7)	14(100)	-	+1(7)	16(100)	-	16(100)	-	-
3. Renaturation	8(57)	6(43)	13(93)	1(7)	+5(36)	10(62.5)	6(37.5)	16(100)	-	+6(37.5)
4. Biuret reagent	-	14(100)	-	14(100)	-	-	16(100)	3(19)	13(81)	+3(19)
5. H bonds, van der Waals bonds, ionic bonds	-	14(100)	5(36)	9(64)	+5(36)	-	16(100)	7(44)	9(56)	+7(44)
6. Amino acids	14(100)	-	12(86)	2(14)	-2(14)	16(100)	-	15(94)	1(6)	-1(6)
7. The part, containing C atom	9(64)	5(36)	9(64)	5(36)	-	8(50)	8(50)	1169	5(31)	+3(19)
8. The part that adds specificity.	3(21)	11(79)	4(29)	10(71)	+1(7)	3(19)	13(81)	11(69)	5(31)	+8(50)
9. Amino group	11(79)	3(21)	13(93)	1(7)	+2(14)	6(37.5)	10(62.5)	16(100)	-	+10(62.5)
10. Radical group	8(57)	6(43)	13(93)	1(7)	+5(36)	12(75)	4(25)	16(100)	-	+4(25)
11. Polar amino acid	11(79)	3(21)	12(86)	2(14)	+1(7)	10(62.5)	6(37.5)	16(100)	-	+6(37.5)
12. … lowers the pH of the medium	5(36)	9(64)	2(14)	12(86)	-3(21)	2(12.5)	14(87.5)	7(44)	9(56)	+5(31)
13. … increases the pH of the medium	5(36)	9(64)	2(14)	12(86)	-3(21)	2(12.5)	14(87.5)	7(44)	9(56)	+5(31)
14. Peptide bond	3(21)	11(79)	6(43)	8(57)	+3(21)	1(6)	15(94)	8(50)	8(50)	+7(44)
15. Covalent bond	11(79)	3(21)	14(100)	-	+3(21)	11(69)	5(31)	16(100)	-	+5(31)
16. Ionic bond	13(93)	1(7)	13(93)	1(7)	-	13(81)	3(19)	16(100)	-	+3(19)

Note: * The changes in the number of students who responded correctly to the question after the application (=the number of correct answers in the post-test – the number of correct answers in the pre-test)

On examining Table 6 it was found that the students in the control group and in the experimental group both possessed knowledge such as the fact that proteins were an organic compound and that amino acids were the building blocks of proteins -which could be learnt through memorization- but that they had difficulty in points where they needed to set up associations with their knowledge in chemistry. After the application, it was observed that the number of correct answers that experimental group students who were taught in interdisciplinary approach gave to the questions about *atoms available in the structure of organic compounds, the reagent of proteins, the chemical bonds in the structure of proteins, the constructs constituting amino acids, the types of amino acids emerging as a result of different radical groups and their properties, the types of chemical bonds and about giving peptide bonds as examples for covalent bonds* increased considerably.

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Discussion

It is considered very important for students to have critical and creative thinking skills and to have skills of integrating pieces of knowledge from different areas in those processes today. Students are expected not to feel restricted to the ways of thinking of a certain discipline and on the contrary to put knowledge of different disciplines into practice in combination. In this way, important steps will be taken towards raising individuals who keep updating themselves, who use the knowledge they have learnt and who can make decisions (Yıldırım, 1996). It would be beneficial here to analyse the effects of interdisciplinary teaching through experimental methods and to obtain concrete data. In present research, the effectiveness of interdisciplinary teaching in students' learning the topic of proteins and in their perceptions of their skills in associating the concepts in biology and chemistry was examined. The students were expected to associate their knowledge in biology with their knowledge in chemistry and to consider the topic from the perspective of the two disciplines as a whole in the concept map which was prepared by the researcher and in which the students were asked to fill in the blanks. The findings demonstrated that considerable changes were observed in the post-test answers of the students in the experimental group and that the number of students who gave correct answers to the questions requiring the implementation of knowledge of chemistry increased. The students in the experimental group were able to see the relationships between chemical bonds and the structure of proteins more clearly. They were able to evaluate organic compounds more accurately in terms of the atoms they had in their structure. They were also able to evaluate the amino, carboxyl and radical groups in terms of their atoms and properties from the perspective of chemistry. In a similar way, increases were observed in the students' correct answers in the parts where the different types of amino acids and the concepts of acidic and basic were associated in the concept map. As a result, the students were offered a concept map through which they could associate their knowledge about the disciplines of biology and chemistry and they could look at the topic of proteins from the shared window of the two disciplines; and following the application the students in the experimental group were found to see the whole better. It was also observed that reminding the experimental group students- who were taught in interdisciplinary approach- of their knowledge in chemistry and setting up associations promoted their interest in classes and made them excited. They said that what they had previously learnt in chemistry became more meaningful and that they were able to see the relationships between knowledge they had learnt in chemistry and in biology classes. Thus, students' answers to the 5-point Likert type question showed that the perceptions of the experimental group's skills to establish interdisciplinary relations increased after the application). In that case, both the observations in lessons and the students' statements and their answers after the application indicated the benefits of teaching the topic of proteins through interdisciplinary teaching. Considering the improvement in their answers to the concept map, the interpretation that students could see the relationships between concepts and that they learnt meaningfully could be made. Studies also found that interdisciplinary approach improved students' skills such as interpreting the knowledge, setting up conceptual associations, making inferences and thinking analytically, problem-solving and that it contributed to permanent and meaningful learning (Demirel & Diker Coşkun, 2010; Drake & Burns, 2004; Jacobs, 1989; Mathison & Freeman, 1997; Slavinec et al., 2019; Suraco, 2006). The results of present research also support these findings.

Interdisciplinary teaching is beneficial to students and teachers for an effective process of teaching, but it requires more time and efforts in planning a lesson and in implementing it than the disciplinary approach. In this research also the researcher needed to spend a certain amount of time and energy to prepare the content for the experimental group, to choose the examples for the concepts and to integrate the subjects of chemistry in the lesson content apart from the framework drawn by the course curriculum. Therefore, teachers should have willingness and knowledge in this respect. Some of the difficulties encountered in interdisciplinary teaching stem from teachers' lack of knowledge in other areas. Dervişoğlu and Soran (2003) found that considerable number of biology teachers' knowledge in other areas was inadequate for interdisciplinary teaching. Teachers need to know how to integrate and present their knowledge in other areas in addition to having knowledge in other areas. Students cannot be expected to see the relationships between disciplines if they teach without setting up associations between disciplines and by presenting clusters of knowledge separate from each other. Yet, some of the studies demonstrated that teachers and prospective teachers did not have adequate knowledge about interdisciplinary teaching (Dervişoğlu & Soran, 2003; Gürdal et al., 1999; Mikser et al., 2008). At this point, it is seen that also teacher training institutions should include interdisciplinary education in their programme. Biology teaching programmes in Turkey used to offer courses in chemistry and biology in addition to courses in biology until the year 2018. General chemistry, biochemistry, organic chemistry courses were included in the programmes but courses such as physics, biogeography and biostatistics were excluded from the programmes with regulations made in 2018. However, an elective course called Interdis-

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ciplinary Biology Teaching was added to the programmes (CoHE, 2018). The course is believed to be beneficial to prospective teachers in recognising the approach of interdisciplinary teaching. Yet, a close look at the programme shows that courses which enable the formation of interdisciplinary mentality are insufficient and that most of them are elective. It will be useful to make them obligatory and to increase the number and class hours of such courses.

The basic principles of opening double major undergraduate programmes and minor programmes were set with a regulation issued by the Council of Higher Education in 2010. Today, double major programmes and minor programmes can be conducted in educational faculties in accordance with those principles and with the rules set by the senate decisions of universities. Double major and minor programme is a good opportunity for prospective teachers since it helps them to develop an interdisciplinary perspective. Yet, the consequences in terms of employment and competence of the teachers raised are not known yet because it is a new application. Offering in-service training and seminars in interdisciplinary teaching to in-service teachers in schools could be useful.

It is important that teachers who are experts in different areas work together and they share their knowledge and views so that interdisciplinary teaching can be conducted effectively and accurately. The results of studies concerning interdisciplinary teaching show that teachers did not feel ready to work together (Dervişoğlu & Soran, 2003; Labudde, 2003). The biology and chemistry teachers who taught in classrooms where the application was done in this research also stated that they did not have any communication with each other for interdisciplinary teaching and that they did not have any collaborative work. However, interdisciplinary teaching necessitates cooperation between teachers of different areas and school administration (Rauch, 2002; Schoch & Seitz, 1997). The cooperation can be in many issues such as exchange of views, preparing lesson plans and using course materials and resources. Thus, interdisciplinary teaching will increase professional solidarity and cooperation beside students' meaningful learning. Teachers can also have the opportunity to know about other teachers' areas better and to plan how to work together in this way.

Insufficient class hours and overloaded curriculums are the other factors that make interdisciplinary teaching difficult (Aslan Yolcu, 2013; Çelik, 2014; Dervişoğlu & Soran, 2003; Reinhold & Bünder, 2001). Teachers and students said in this research that they did not have enough time for interdisciplinary teaching approach. In addition to that, the fact that examinations were based on the domain might have also caused students not to show enough interest in interdisciplinary teaching. However, the results of this research and of similar studies show that it would deserve the time and efforts spent and the cooperation. Making interdisciplinary teaching widespread in biology classes will enrich the teaching process and it will facilitate students to transfer what they have learnt into other lessons and into daily life.

Conclusions and Implications

The results of this research demonstrated the importance of and the necessity for preparing curricula in interdisciplinary approach once again. It is not enough to give only general guidance in relation to interdisciplinary teaching at this point. Instead, curriculum content should be made connected and it should be assured that the curricula for different disciplines should be complementary to each other. It can be beneficial to state in the curricula the topics which will be taught through interdisciplinary teaching and to offer guidance in setting up the associations between concepts for the process of effective interdisciplinary teaching. In this way, time is saved in interdisciplinary teaching process, since teachers are guided to facilitate the process and the subjects and concepts are integrated in the curricula. In addition to that, the participation of experts of different areas in the process of interdisciplinary curriculum development could also be useful. It can be possible in this way to prepare the curricula with an interdisciplinary perspective without being restricted to the framework of a single discipline. A curriculum for interdisciplinary teaching is more effective especially in a course such as biology- which is nested in life. Learning biological knowledge as integrated into other disciplines helps students to develop the right perspective for the environmental, medical, social and economic problems and to find solutions to them. Besides, the teachers and students also emphasised that the topic of proteins was suitable for teaching in a common framework of knowledge in biology and chemistry. Naturally, topics should have interdisciplinary qualities for interdisciplinary teaching. Several topics in biology are suitable for interdisciplinary teaching. Therefore, it is thought that it would be useful to repeat the research in question for different topics of biology and to share the prepared course materials with the teachers.

Teachers have a great role in interdisciplinary teaching process. Interdisciplinary teaching can be done as long as teachers believe in the benefits of interdisciplinary teaching and they have the knowledge about and desire for it. At this point, it is important to get the opinions of teachers and support them in interdisciplinary education.

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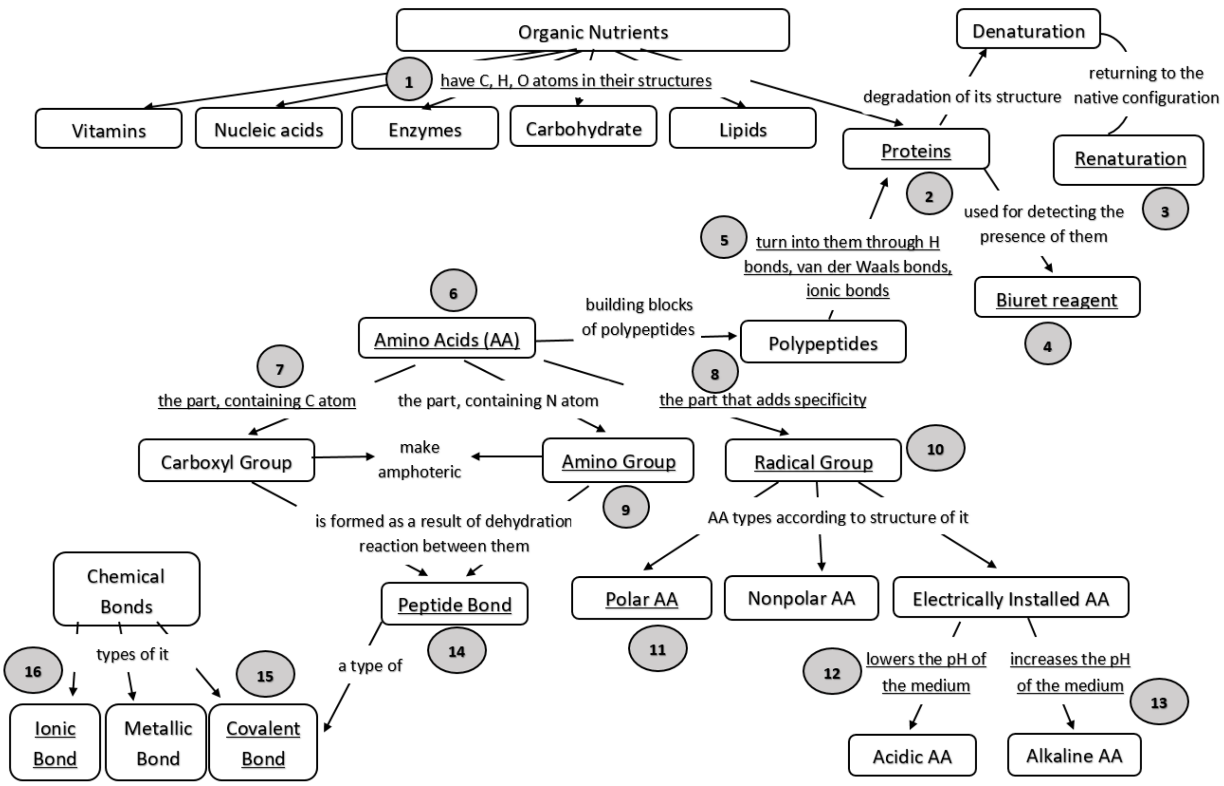
Appendix 1

The concept map used in the research



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