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Prospective Science Teachers Conceptual Understanding About Proteins and Protein Synthesis

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Abstract: In present study, it was aimed to determine the effects of traditional teaching on levels of conceptual understanding of prospective science teachers on protein and protein synthesis before, after and six months after of instruction. Firstly, according to the views of the expert in the area, concept analysis was carried out about protein and protein synthesis. Considering the concept analysis, a six-item conceptual understanding test was prepared and administered as the pre-test, post-test and delayed post-test. As a result of the study, it was determined that the prospective science teachers had some difficulties in understanding concepts about protein and protein synthesis and traditional instruction was insufficient to overcome these problems. Especially, it was revealed that the candidates had severe misconceptions about process of protein synthesis and structure of protein. Finally, some suggestions were presented with the support of the findings obtained from this study.

Key words: Conceptual understanding, misconceptions, protein synthesis, teacher training

INTRODUCTION

In this study it has been analyzed how students conceptual understanding levels on proteins and protein synthesis have changed throughout education in order to provide a better education for science teacher candidates and it has been emphasized what should be done to correct the flaws occurred during the process.

Although conceptual understanding is the most important target of science courses it has been observed that students from all age groups have difficulties in understanding of science concepts (Noh and Scharmann, 1997). It is an important task in science education to monitor the points where students have difficulties. It is very important for the educators to know students capacity since educators need a good starting point (Pittman, 1999). Therefore, conceptual understanding levels of the students should be determined and education activities should be accordingly reconstructed.

Various researchers define conceptual understanding in different ways in their works. Darmofal *et al.* (2002) describes conceptual understanding as an ability of transferring the information into different status that has never been come across before. Alao and Guthrie (1999) on the other hand categorizes it accordingly depth and width. While width represents a very large part of a specific part of information depth includes information of scientific principles that define relationships between concepts. In their work Alao and Guthrie (1999) defines conceptual understanding as knowledge of basic ecological concepts and the ability of being able to use the ecological principles to explain interactions in food chain.

Cavalcante *et al.* (1997) saying that one of the most important aims of science education is to increase conceptual understanding of children he states that conceptual understanding can not be transferred from teacher to student and thus students should construct this understanding themselves.

According to Ozden (2003) conceptual understanding is to learn the essence of the subject. He claims that instead of learning a lot of subject superficially and isolated from each other, learning of basic concepts, principles, rules and generalities will be more effective activity for providing conceptual understanding.

Although, so many works have been done so far in various subjects there is only one study done by Pittman (1999) that can be shown as an example for conceptual

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understanding on protein synthesis in literature. Claiming that students generally have difficulties in visualizing protein synthesis Pittman (1999) demonstrated the necessity of their work. He also emphasizes that protein synthesis is also important as they provide a significant background for genetic subjects.

Reminding the importance of establishing a relationship between previous knowledge and new one according to the constructive learning theory Pittman (1999) claims that analogy is a valuable teaching instrument to establish this link.

Misconceptions: Within last 25-30 years although a lot of researches has been conducted on misconceptions (Pfundt and Duit, 2005) there is quite few research on defining and eliminating misconceptions about proteins, enzymes and protein synthesis.

Mak *et al.* (1999) emphasizes that teachers find out that students have inadequate understanding on basic biological concepts and warns that poor teaching in these areas will lead to developing inaccurate ideas and will have a negative affect on learning next concepts. With similar views Kinchin (2000) also stresses that if critical concepts are not understood well the time cannot be used effectively to teach secondary concepts.

Mak *et al.* (1999) reports that studies on misconceptions caused by teachers have been done in relatively small numbers. He thinks that behind this lies the assumption that teachers have an adequate knowledge in subject area and can sufficiently transfer this knowledge to the students. Yet Mak *et al.* (1999) states that this view cannot be defended and this was a serious problem in Hong Kong.

He claims that since they are the most significant informal source of inspiration teachers who are insufficient in subject area will have a badly effect on students in understanding science concepts. Mak *et al.* (1999) claims that the objective of the teachers is not to persuade the students to accept a scientific statement submissively but to guide them to express their informal ideas, to discuss their own understandings and to construct a conceptual framework with the knowledge they have. And to accomplish this task the teachers must meaningfully possess the necessary subject area knowledge in depth.

Fisher (1985) found out that students of biology and genetics had a lot of misconceptions on protein synthesis. He states that many of these misconceptions are persistent and they resist the change. He informs that for some reasons misconceptions occur between translation, which is one of the steps of protein synthesis and amino acids, which are essential components of proteins. Moreover, Fisher (1985) states that since most of the biological events cannot be seen they remain abstract and this makes them more difficult to be understood.

The reasons why this work has been done can be explained mainly in three titles. These are:

- Because there are quite few works have been done so far on conceptual understanding of science teachers and candidates who are and will be responsible for students education.
- Because in biology classes proteins, enzymes and protein synthesis include important basic concepts for constructing conceptual understanding
- Because there are few work done for determining students conceptual understanding level on proteins, enzymes and protein synthesis.

METHOD OF THE RESEARCH

Participants: The research is designed as a single group pre-test and post-test model. The changes on level of conceptual understandings of the students had been followed by applying the same test before instruction, right after instruction and six month later. Instructor had followed traditional methods of education during the process.

The sampling of this study consist of 88 undergraduate students (38 female, 50 male) who were studying in the department of science education at Necatibey Education Faculty, Balikesir University, Turkey and all of them took Biology 1 course in 2003-2004 fall term.

Data collection: All the questions in the conceptual understanding test have been developed by the authors. Conceptual understanding test used as a main instrument to collect data in this study consists of 6 main questions. 1st, 3rd, 4th and 5th questions of the test have sub questions. All the questions in the test need explanation (Appendix 1).

First of all, having obtained expert view a concept analyses had been done in order to define the limits of conceptual understanding test. Subsequently, a conceptual analyze table had been constructed in order to be able to show the concepts corresponds with each question (Table 1).

Interviews had been conducted in order to confirm the answers given by the students to the test questions and obtain more detailed information. Semi-constructed interview form, which was finalized by a pilot study, was used during 30-40 min interviews in which 19 students had participated and interviews were recorded by a voice-recording device.

Table 1: Concept analysis table for proteins and protein synthesis

Subject	Concepts		Questions 1	2	3	4	5	6
Amino acid								
	Monomer				♦			♦
	Amphoter	Amine group			♦			♦
		Carboxyl group			♦			
	R group				♦			
Proteins								
	Peptite bond, dehydration				♦			
	Dipeptide, polypeptide							♦
	Primary, secondary, tertiary, Quaternary protein							♦
	Essential amino acid				♦			
	Gene-protein relation			♦			♦	
	Structural protein		♦	♦			♦	
	Receptor protein		♦	♦				
	Antijen, anticor			♦				
Protein synthesis								
	Ribosome, polisome					♦		
	Transcription					♦		
	Translation					♦		
	Codon, anticodon					♦		
	Sense strand, complementary strand					♦		

Data analysis: After checking the answers given by the students to each question and sub-questions categories were formed. These categories obtained from the pre, the post and the delayed post-tests transformed into a table, which is given with student % frequencies. In these tables 3 main categories formed as A, B and C. In category A the answers, which can scientifically be acceptable or include correct version of given proposition are given. Category B includes the answers, which cannot scientifically be acceptable or offers wrong version of given proposition. Scientifically the most correct and the most inaccurate statements are respectively given at the top and bottom lines of A and B categories. Category C includes the answers such as do not know, do not remember and so on.

Conceptual changes in students answers to the pre, post and the delayed post-tests are put in five main categories. These categories are explained below:

- **Positive Change:** Those which were changed into A from B and C and stayed in A
- **Partial positive change:** This category includes very small positive changes between already close levels and short-term positive changes in only the post and the delayed post-tests.
- **No change:** Those that were at the same level in all three tests.
- **Negative change:** Transitions from category A namely from scientifically acceptable answers to category B i.e., to scientifically unacceptable answers or within category B scientifically unacceptable changes.
- **Others:** The Changes that cannot be categorized meaningfully.

Table 2: The changes on scientifically acceptable and unacceptable answers in the conceptual understanding test

Questions	Category	The ratio of scientifically acceptable answers			The ratio of scientifically unacceptable answers		
No. of the questions	Proposition/ matching/ choice	Pre test	Post test	Delayed post test	Pre test	Post test	Delayed post test
1st question	1. Proposition	80.7	92.0	94.3	12.5	8.0	5.7
	2. Proposition	68.2	65.9	67.0	13.6	20.5	22.7
	3. Proposition	84.1	96.6	100.0	2.3	1.1	-
2nd question	-	100.0	96.6	95.5	-	2.3	2.3
3rd question	1. Matching	21.6	70.5	78.4	34.1	15.9	1.1
	2. Matching	39.8	85.2	88.6	35.2	6.8	4.5
	3. Matching	51.1	84.1	77.3	31.8	9.1	14.8
	4. Matching	48.9	71.6	80.7	27.3	17.0	6.8
4th question	1. Proposition	27.3	61.4	64.8	46.6	36.4	33.0
	2. Proposition	55.7	87.5	84.1	9.1	3.4	6.8
	3. Proposition	58.0	85.2	78.4	4.5	6.8	13.6
	4. Proposition	46.6	85.2	68.2	15.9	1.1	19.3
5th question	Choice a	93.2	97.7	97.7	3.4	2.3	-
	Choice b	81.8	96.6	90.9	11.4	2.3	4.5
	Choice c	62.5	75.0	60.2	20.5	20.5	27.3
6th question	-	38.6	68.2	60.2	46.6	26.1	35.2

RESULTS AND DISCUSSION

The changes in answers given by the students to the conceptual understanding test are given in Table 2 in general. It can be seen that scientifically acceptable answers of the students increased and the lasting has been obtained. Since scientifically acceptable answers in the delayed post test are higher than pre-test for all the questions and are higher than post test for some question the end result can be interpreted as a positive outcome and this shows teaching was affective. These results show that teaching was affective to the some extent. Educators high level experience and his being involved in a research on a high school level unit analyses can be considered important factors for the success of traditional teaching methods. However, students had some difficulties in understanding some concepts and it has been found out that they gained some misconceptions during the course as well.

When general status of the table is analyzed apart from 2nd proposition of the 1st question and 2nd question there has been a positive change for all the other questions after the instruction. Moreover, it catches the eye that the level of the determined scientifically acceptable answers given to all propositions of 1st question, 1st, 2nd and 4th matchings of 3rd question, 1st proposition of 4th question and choice a of the 5th question in delayed post test are not lower than those in post test.

On the other hand, the situation in which scientifically unacceptable answers has increased after the instruction can be observed in 2nd proposition of 1st question, in 2nd question, 3rd and 4th proposition

of 4th question and in choice c of 5th question. For other questions there was a decrease in scientifically unacceptable answers in various proportions.

Each of the Students' answers to the conceptual understanding test has been analyzed and tables have been formed in order to show their conceptual understanding levels in, post and delayed post-tests. 4 of the 16 category tables, which are considered as the most important ones are given and interpreted with the data, obtained trough interviews in this research. By interviews with the students their answers to the test were confirmed on the one hand and their understanding levels were explained in more detail on the other.

The answers of the students in pre, post and delayed post-tests to the 1st matching of 3rd question on amphoter characteristic of amino acids are given in the Table 3.

It can be shown from the Table 3 that scientifically acceptable answers have increased about 3.5-4 times after the instruction. The data shows that the highest ratio for scientifically acceptable answers was given to the delayed post-test (61.4%) and next to the post test (54.5%). The lowest ratio belongs to the pre-test with 3.4%.

While scientifically unacceptable answers were 34.1% for pre-test they were dropped to 15.9% fro the post-test and 1.1% for the delayed post-test. In category B among the scientifically unacceptable answers 5.7% in pre test and 2.3% in post-test students gave the explanation: Amfoter provides a differentiation for amino acids. Amfoter means variable. It has R group. For this matching 44.3% in the pre test, 13.6% in the post-test and 20.5% in the delayed post-test of the students offered no answer or had no idea.

The conceptual change for this matching of the test (Fig. 1).

According to the graph about 77% of the students showed a positive improvement. On the other hand there is only 9% negative change. As a result it can be argued that teaching activities had an important affect on acquiring basic knowledge.

Moreover, in Table 3 it is seen that scientifically acceptable answers increased for the delayed post-test and this can be interpreted, as the instruction was very affective and concepts learned during the instruction constructed new references afterwards. However, since this matching of the test was to evaluate basic knowledge of the students it is hard to tell that conceptual understanding had been realized. It can only be drawn as result that students had been learned most of the basic knowledge about amphoter.

After analyzing scientifically unacceptable answers it can be concluded that there is hardly any explanation,

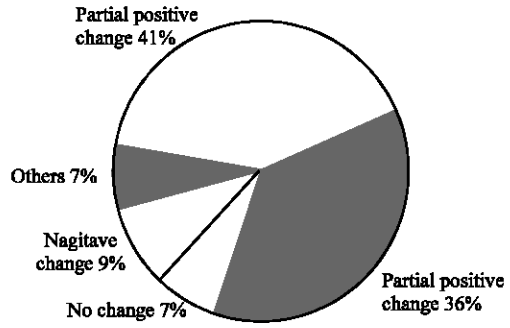

Fig. 1: The conceptual change graphic of 1st matching of 3rd question

which can be described as misconception. There is some confusion and these are considered as minor mistakes.

During the interviews when the students had been asked what function the amphoter characteristics does, which is a general knowledge about proteins they offered the explanations given below:

I (Interviewer): What function does this amphoter characteristic do.
S (Student): I am sure it does (thinks-pause). It helps proteins to adopt themselves into the environment more easily. When proteins enter into an acidic environment they behave like base and when they enter into basic environment they behave like acid. Reactions become easier. For example when food arrives to the stomach if it is acid, acid stomach might get hurt. Food shows here basic characteristic (46).
S: Digestion becomes easier. For example proteins are digested in small intestine as well as in stomach. (53)
S: (pause-thinks). Protein is being digested in stomach, stomach is acidic and they need to be acidic. It protects itself. As base in acidic environment, as acid in basic environment it protects itself (40).
I: For example, when an amino acid arrives small intestine, which is basic, does it give a basic reaction?
S: Possible (40).

In the dialogs above it can be said that students establish a link between digestion and amphoterness. It is seen that there are probably some misconceptions between acid-base concepts, digestion organs having different pH values and amphoterness. Student 46 claims that because proteins become amphoter stomach is not harmed. Student 53 argues that due to the amphoter characteristic proteins are more easily digested. Student 40 on the other hand supposing that proteins should protect themselves she thinks that they should behave like base in acidic environment and like acid in basic environment.

Table 3: Category table of 1st matching of 3rd question

Category type	Answers of the students	Pre test (%)	Post test (%)	D. Post test (%)
A. Scientifically acceptable answers				
	Correct matching			
A1	Amino acids are amphoteric since they include amine, which is basic and carboxyl group, which is acidic.	3.4	54.5	61.4
A2	Amphoter is about amine and carboxyl group. These show flexible structures with the elements they bond.			2.3
A3	Amino acids bond each other trough amin and carboxyl groups. One end of this strand has no limit therefore shows amphoter characteristic.			4.5
	Alternative matching			
A4	Amphoter is an element, which reacts both with acids and bases. This characteristic provides differentiation for amino acids.	1.1		
A5	Amino acids are the essential structures of nutrition.	1.1		
A6	There is a link between amphoter and nutrition.		1.1	5.7
	No matching			
A7	Amphoter is an element, which reacts both with metals and ametals.	2.3		
A8	Amphoter is an element, which shows both acidic and basic characteristics.		3.4	
A9	No explanation	13.6	11.4	4.5
Total		21.6	70.5	78.4
B. Scientifically unacceptable answers				
B1	Amin group is acidic and carboxyl group is basic. Amphoter elements can react both with acids and bases. They show basic characteristics to acids and acidic characteristics to bases.	3.4	5.7	
B2	Amphoter provides differentiation for amino acids. Amphoter means variable. R group is stable.	5.7	2.3	
B3	Amphoter means nobel metals. These are heavy metals such as gold and silver, which do not react. Amin and carboxyl groups do not react.	1.1		
B4	There is peptide bond between amphoters.		1.1	
B5	Amphoter means an element, which reacts with every element.		1.1	
B6	No explanation	23.9	5.7	1.1
Total		34.1	15.9	1.1
C. Other answers				
C1	No answer	20.5	9.1	8.0
C2	I do not know/I have no idea/I do not remember	23.9	4.5	12.5
Total		44.3	13.6	20.5

It is possible that some of these misconceptions might disappear after studying digestion system. Because after having a course about digestion system and developing new references students might correct some inaccurate learnings automatically. This thinking proves how important establishing intra and interdisciplinary links is. Particularly most of the pre-learnings for concepts related to proteins and protein synthesis are being thought in chemistry courses. Therefore it is necessary to create a background for these subjects.

In the 1st proposition of 4th question of conceptual understanding test it was asked if DNA is replicated or not. Students answers for the three tests are shown Table 4.

It can be observed from the Table 4 that in pre-test 27.3% of the students stated that in protein synthesis there is no need for DNA's replication. This ratio became 61.4 for post-test and reached 64.8% for the delayed post-test so that showed almost 100% improvements. However, only one third of the students managed to give explanations, which prove that conceptual understanding had been realized in the post and delayed post-tests. While scientifically acceptable answers ratio was 8% for pre-test, the ratio increased to 33% for the post-test and it dropped back to 30.7% for the delayed post-test. Strangely, while before the instruction it was 4.5% for the wrong explanation of DNA replicates itself even there is no protein synthesis the ratio increased to 8% right after instruction and to 11.4% six months later.

In the pre-test the ratio was 6.8% for those who said that replication of DNA is about protein synthesis and continued DNA replicates itself in both protein synthesis and cell division. If DNA reveals the code from the middle that means it is going to make protein synthesis. 5.7% of the students offered similar explanation for the same question in the post-test and there was no similar answer in the delayed post-test. The ratio was %10.2 in pre-test, 8% in post-test and 4.5% in the delayed post-test for those who said that replication of DNA is the first and an important step in protein synthesis. In the pre-test 2.3% and in the delayed post-test 11.4% of the students explained that by replication of DNA the basis of new protein is founded and protein starts to be formed while there was not any similar view in the post-test.

The changes in the answers of the students to the 1st proposition of 4th question of conceptual understanding test have shown as a graphic in Fig. 2.

It can be seen that there are considerable positive and negative changes in the students answers to the three tests. The fact that one forth of the students faced

Table 4: Category table of 1st proposition of 4th question

Category type	Answers of the students	Pre test (%)	Post test (%)	D. Post test (%)
A. DNA's replication is not about the protein synthesis.				
A1	DNA's replication is not needed for the protein synthesis. Because DNA's replication is needed for cell division.	8.0	33.0	30.7
A2	Only related genes interviene. DNA syntheses RNA Wrong explanation	2.3	2.3	4.5
A3	DNA replicates itself even if there is no protein synthesis.	4.5	8.0	11.4
A4	Each person's protein is different. This difference is kept by inheritance i.e., by DNA's replication.	1.1		
A5	DNA's replication takes place only in reproduction and in meiosis division.	3.4	3.4	
A6	During the replication process they become semi-protected (separation in the middle) and can make protein synthesis.			1.1
A7	No explanation	8.0	14.8	17.0
Total		27.3	61.4	64.8
B. DNA's replication is about the protein synthesis.				
B1	Both in replication and cell division processes DNA replicates itself. If DNA gives the code from the middle it means that it is going to make protein synthesis.	6.8	5.7	
B2	Whenever DNA is replicated protein synthesis takes place. Because the cell is either divided or producing endospore.		1.1	
B3	Replication of DNA is the first and important step.	10.2	8.0	4.5
B4	First of all DNA needs to be replicated and when it is replicated mRNA synthesis should be made with ATP produced.	4.5		
B5	By the replication of DNA the basis of the new protein, which is going to be formed, is founded and by this new protein begins to be formed.	2.3		11.4
B6	Because DNA should be protected by protein case.		1.1	1.1
B7	DNA is replicated in protein synthesis and inheritance information increased two fold in order to be transferred into the other cell.		1.1	2.3
B8	Sense strand of DNA replicates complementary strand.		2.3	
B9	After DNA has replicated itself codes, which belong to it, are going to be formed.			5.7
B10	Because it is a replication which is central dogma shape.			1.1
B11	No explanation	22.7	17.0	6.8
Total		46.6	36.4	33.0
C. Other answers				
C1	No answer	18.2	2.3	2.3
C2	I do not know/ I have no idea/ I do not remember	8.0	-	-
Total		26.1	2.3	2.3

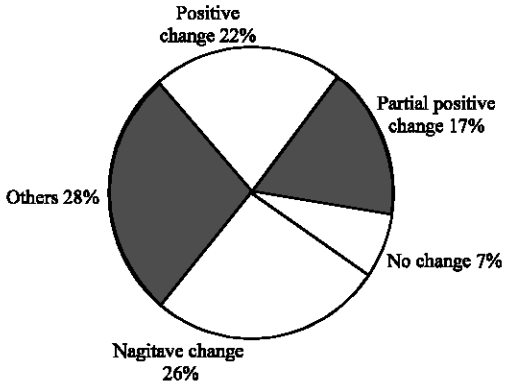

Fig. 2: Conceptual change graphics of 1st proposition of 4th question

a negative change and as it can be seen in the category table one third of the students said that replication of DNA is needed in protein synthesis points out that students had significant difficulties while learning these concepts.

Students explanations are displayed in more detail in the dialogs given below. Student 60 said these:

I : In protein synthesis is DNA replicated? Why?
S : In order to replicate DNA two strands must completely be separated. But in protein synthesis only some parts are separated. In cell division DNA replicates itself (60).

This student showed that she has completed the understanding by establishing necessary links about the related concept. While she understood DNAs structure, she also understood protein synthesis mechanism as well as cell division and established necessary links.

Student 61s explanation to the question if DNA is replicated or not during protein synthesis as follows:

S : DNA is replicated. One of them transforms into mRNA.
I : When there are 2 DNA does one of them stay? And does the other go to the cytoplasm?
S : Yes. That one will form mRNA.
I : Does this part go to the ribosome together with mRNA?
S : Yes let it go.

I : mRNA will pass trough ribosome. What will happen to DNA?
S : I do not know.
I : Is DNA replicated in full or just related part is replicated?
S : Related part is replicated.

This student thinks that new piece formed after replicating of DNA is transferred into mRNA and offers contradictory explanations about later steps of protein synthesis. Student 61 had alternative ideas on why DNA should be replicated. He said that DNA is replicated partially from a side and one of the newly formed pieces is transferred into mRNA in one way or other and mRNA carries out protein synthesis in ribosome. This student while stating that during the protein synthesis DNA should be replicated he offered no explanation about the replication of DNA during the cell division in all three tests.

Student 46's views on protein synthesis as follows:

I : How are the codes on DNA transferred to RNA?
S : The part needed for protein synthesis is cut off from DNA. Before that DNA is replicated. mRNA carries the broken part. Because DNA loses pieces every time DNA needs to be replicated.
I : Does mRNA all the time carry these messages?
S : No. If it has no function it disappears. If it has function it is synthesized again.
I : For the replacement of disappearing mRNA how and where are the new ones produced?
S : From RNA... (pause-doubtful)
I : From which RNA. There were 3.
S : (pause-thinks) it is synthesized from rRNA (doubtful)

According to the answers he gave during the interview student 46 thinks that piece of DNA is carried by mRNA that is why DNA needs to be replicated. It is thought that he has an inaccurate learning about how mRNA synthesis is done. He thinks that as if there is a code in DNA and this code is carried to a region where there had been an mRNA before. Moreover, because he does not or cannot know that RNA cannot synthesis itself he guesses that rRNA syntheses mRNA. In the light of these results it can be argued that the students have important deficiencies on nucleic acid knowledge and these create misconceptions that make difficult for him to understand protein syntheses.

It is found out that although during the instruction it is emphasized that in protein synthesis DNA is not replicated some students keep their previous knowledge. Here is the dialog with student 53:

I : How does protein synthesis happen? Can you explain?
S : By rRNAs.... (Pause-thinks-doubtful). rRNA is related to the structure of ribosome. Information comes to ribosome. Lets say this information comes to rRNA. May be that information comes from cell's DNA. Then carrier RNA carries messenger RNA. There is information in RNA. Synthesis takes place.
I : How does synthesis take place?
S : Replication occurs.
I : What is it get replicated?
S : For example protein is formed in accordance with the gene structure. Sense strand you see, there is complementary strand as well. One more like this sense strand is produced.
I : Does this mean DNA is replicated there?
S : Something like that but according to the notes we have taken DNA should not have been replicated.

Probably students previous knowledge did not change by the instruction. Because the student said that there was nothing like what he had just said in his notes. On the one hand he explained in his opinion why DNA should be replicated on the other he was puzzled since the notes taken during the instruction was telling him that DNA should not be replicated. Between two different views he opted to trust his previous knowledge. While this student did not offer a scientifically acceptable explanation before and right after instruction he offered a wrong explanation of without protein synthesis DNA replicates itself after six months. It is understood that he memorized the concept but could not fill it up. Although he seems to understand he offered inaccurate explanations when he was asked questions which designed to reveal conceptual understanding.

Students answers to choice c of the 5th question, which is about the genes, the proteins and appearance of conceptual understanding test is shown in Table 5.

According to the Table scientifically acceptable answers were 62.5% for the pre-test and they increased to 75% for post-test but dropped back to 60.2% for the delayed post-test. While 20.5% of the students gave scientifically unacceptable answers for the pre and post-tests the ratio has gone up to 27.3% for the delayed post-test. Among these answers the explanation of they do not be different since they are the same species. Same species are formed by re-production has 4.5% place for the pre-test and 6.8% for the post-test and 2.3% for the delayed General changes in the students answers for the choice c of the question 5 of the conceptual understanding test are given in Fig. 3.

Table 5: Category table of choice c of the 5th question

Category type	Answers of the students	Pre test (%)	Post test (%)	D. Post test (%)
A. Scientifically acceptable answers				
A1	Like human beings and animals the plants synthesize the proteins in accordance with the codes coming from the DNA	20.5	4.5	12.5
A2	Inherited characteristics and the environment effect. Nutrition too effects.	9.1	17.0	11.4
A3	It results from gene structures' being different.	22.7	18.2	26.1
A4	Yes. Natural selection and the environment is affecting.	5.7	5.7	4.5
A5	It is valid for all living beings.		2.3	3.4
A6	No explanation	4.5	27.3	2.3
Total		62.5	75.0	60.2
B. Scientifically unacceptable answers				
B1	Because they are in the same forest the environment conditions are not different and they have the same appearance.	6.8		5.7
B2	They cannot be different since they are the same species. Same life forms are formed by reproduction.	4.5	6.8	2.3
B3	Plants transfer the genetic codes as they are because they have both male and female reproduction systems on themselves. They can use the same pollens during the pollination.	2.3	2.3	5.7
B4	It does not happen since the oak trees are reproduced by seeds. If two seeds of the very same tree grow in the same environment they become the very same.	2.3	2.3	
B5	Since the plants are not sexually reproduced and they grow by mitotic division living beings with same characteristics are produced.	3.4	2.2	9.1
B6	Their DNAs are different but their proteins might be the same.		1.1	
B7	It is not valid. The genetic codes of the same species are the same.			1.1
B8	It does not happen since the genetic codes are not transferred in oak trees. Because the oak trees do not have mRNA and DNAç		4.5	2.3
B9	Açıklama Yok	1.1	1.1	1.1
Total		20.5	20.5	27.3
C. Other answers				
C1	No answer	8.0	1.1	5.7
C2	I do not know/I have no idea/I do not remember	9.1	3.4	6.8
Total		17.0	4.5	12.5

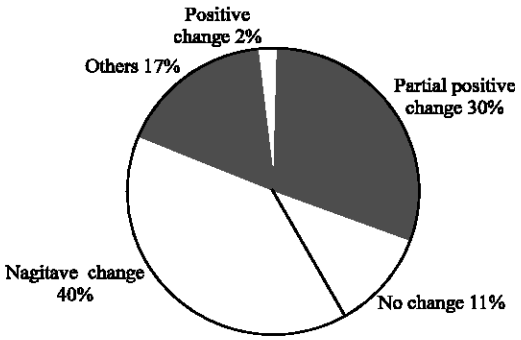

Fig. 3: Conceptual change graphic of choice c of the 5th question

From Fig. 5 it can be shown that there are 40% negative change. It is worth to pay attention that there had been negative change in the conceptual understandings of the students even after the instruction. Total positive change on the other hand remained as 32%. When the category table and the above graph are examined it will not be hard to tell that traditional teaching methods were very inadequate. In order to analyze the reasons of the problem defined above interviews with the students had been conducted and the dialogs worth to tell are given as.

It can be argued that the explanation of Do not happen. Because genetic codes are not transferred in oak trees as they do not have mRNA and DNA which was offered for the post and delayed post-tests and had no place among the answers for the pre-test was a misconception caused by the instruction. The ratio of this explanation was higher after the instruction compare to the six months later's ratio and this can be interpreted that there are some problems of the instruction. Student 51 explanation of his ideas about this answer he gave in the test as follows:

I : In the test you are saying that appearance of living beings are related to gene protein structure and this is relevant for human and animals but not for plants. How do you explain this? You are saying that differentiation is not relevant for Oak trees since they do not have DNA. Do not the plants have DNA?

S : They do not have (doubtful).

I : How are they reproduced?

S : ... (Silence)

I : Are the plants cell structured?

S : They have cell structure. Then they have DNA as well.

I : Well what brought you to this conclusion?

Table 6: Category table of the 6th question

Category type	Answers of the students	Pre test (%)	Post test (%)	D. Post test (%)
A. Scientifically acceptable order				
A1	Amin group (NH_2) exists in amino acid. Two amino acids join with peptide bond and form dipeptide, many amino acids join and form polypeptide. Primary proteins are the first long polypeptide chains in ribosome. Primary proteins after various processes are transformed into secondary, tertiary and quarternary proteins.	-	12.5	19.3
A2	N is the smallest one. N exists in amin group. Amin group exists in amino acids. Dipeptide is formed by 2 and polypeptide is formed by many amino acids' bonding. Protein is the biggest. I do not know the tertiary protein.	18.2	34.1	26.1
A3	Peptide+Peptide = Dipeptide n(peptide) polypeptide. Wrong Explanation		6.8	
A4	N should be small. Since essential structure of nucleic acids is amino acid it is in 2nd place. Amin group is formed by joining of a couple of amino acids. It should be dipeptide bond. Poly is bigger. I have never heard of tritary protein.	6.8	4.5	
A5	No correct order/explanation	13.6	10.2	14.8
Total		38.6	68.2	60.2
B. Scientifically unacceptable order				
B1	AA,N,…,…,…,TP. While amino acids bond together and form protein water is produced. There is a dipeptide bond between 2 amino acids. Among more there is polypeptide bond.	2.3		
B2	N,AG,AA,TP,DP,PP. Amin group forms amino acid. 2 amino acids form dipeptide and many amino acids form polypeptide.	8.0		3.4
B3	N,AG,DP,PP,AA,TP. Nitrogen atom and amin group form amino acid. Amino acids and peptide bonds join and form protein. Polypeptides form dipeptides too.	2.3	1.1	
B4	N,DP,PP,AG,AA,TP. Peptide bonds are formed by N atoms. Polypeptide is bigger than dipeptide. By joining of amin groups together amino acids are formed, by joining of amino acids together proteins are formed.	4.5	2.3	1.1
B5	N,AG,AA,TP,DP,PP. There is N atom in the structure of amino acids. Amino acids are formed by joining of amin and carboxyl groups. Formed amino acids joins with peptide bonds to form proteins. It is called dipeptide bond which links two proteins and polypeptide bond which links many proteins.	13.6	8.0	18.2
B6	N,AA,DP,PP,AG,TP. Nitrogen is the smallest. Then amino acid comes. 2 amino acids bond together by dipeptide bond. By polypeptide bond many amoni acids joins together too. These amino acids form amin group. And these form tertiary protein.		3.4	
B7	Wrong order/no explanation	15.9	11.4	12.5
Total		46.6	26.1	35.2
C. Other answers				
C1	No answer	6.8	1.1	2.3
C2	I do not know/I have no idea/ I do not remember	8.0	4.5	2.3
Total		14.8	5.7	4.5

S : Namely appearance. I am confusing there. Their appearances are same but in humans it is different. When we consider sparrow they are same too. When it is like this... Whether they have DNA or do not I am confused. But when I think they have cell structure I figured out that they have DNA. However, since their disappearance are the very same I am saying they do not have it.

This student stated that the plants do not have DNA predicating his account on appearances of human, animals and plants. It is possible to think that he does not consider the plants in the category of living beings. But we do not have his views apart from those, which are given above. It can be said that the student have significantly inadequate and wrong learnings particularly about cell biology, reproduction and the relation between proteins and genes. Such a problem can be a result of the instruction or might be a result of his attention and interest to the course as well. Moreover, it can be considered that the textbooks, the language used for the instruction and some cultural backgrounds might result in said problem. The answers of the science teacher candidates to the question 6 of the conceptual understanding test which were designed to examine their ideas on what sub-divisions form the structure of the proteins are shown in Table 6.

When the table given above is examined it is seen that scientifically acceptable answers of the students has increased after the instruction and there is accordingly a decrease in scientifically unacceptable answers. While scientifically acceptable answers were 38.6% before the instruction it went up to 68.2% after the instruction but dropped back to 60.2% after six months of the instruction. There was not any scientifically the most acceptable answer among the answers given to the pre-test but it was 12.5 and 19.3% for the post and the delayed post-test, respectively. Among the answers to the pre- test there was 46.6% scientifically unacceptable ones and this ratio dropped to 26.1% for the post-test but went up to 35.2% for the delayed post-test.

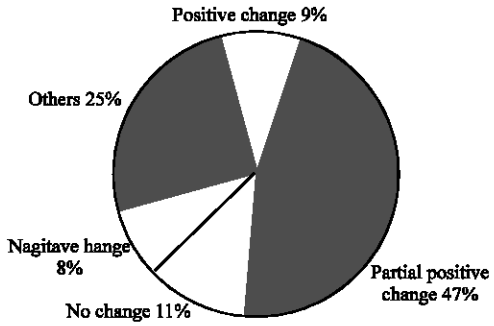

Fig. 4: Conceptual change graphic of the 6th question

The change in answers of the students to the question 6 of the conceptual understanding test is displayed in the graph given below (Fig. 4).

When the conceptual change graphic given above is examined it is seen that while there is a positive change among the 56% of the students there is a negative change among the 8% of them. On the other hand 11% of them showed no change at all and 25% of them could not be put in any category. According to these results it can be argued that there had been a positive change in general in conceptual understanding of the students but they had some difficulties on some certain points.

When both the category table and the conceptual change graphic are generally examined it can be claimed that the instruction was successful to some extent. The increase in the scientifically acceptable answers of the students and its continuity after six month shows the positive aspects of the traditional teaching methods used for the instruction. It has been observed that there had been a quantitative as well as qualitative increase in scientifically acceptable answers of the students. Because while no scientifically acceptable answer could be found among the answers given to the pre-test there were 12.5 and 19.3% these kind of answers among the answers given to the post and the delayed post-tests, respectively. Moreover, for the pre-test 6.8% and for the post-test 4.5% of the students who managed to put in correct order but offered some wrong explanations did not give the same answers for the delayed post test. This can be explained by the affects of the subjects learned after protein synthesis since it can be argued that students might have developed new references by the subjects learned afterwards. For this reason there might be corrections in some wrong learning.

Although a decrease was observed in the results of the post-test the increase in the results of the delayed post-test for scientifically unacceptable answers of the students might indicate that the instruction was not effective enough for the continued existence of the learning. To find the explanations coded as B4 and B5 and shown in Table 6 in all tree tests indicates that students have some misconceptions. To find out that for the delayed post-test the ratio of the explanation coded as B5 was higher than it was for the pre-test can be considered as an evidence that shows the shortcomings of the instruction.

Moreover, after the instruction students explanations coded as B6 make us think that the teaching methods need to be redesigned. Not detecting this explanation before and six months after instruction might show that activities during the instruction caused this mistake.

Most of the false learnings indicate that there are important problems in the basic knowledge of the students. Particularly in the concepts of atom, molecule and bond the students have some inadequate and false learning.

Interesting findings surfaced during the interviews, which were conducted in order to confirm students answers to the tests and obtain more detailed information. These are given below in order:

A dialog with student 53 developed as follows:

I : What are dipeptide and polypeptide?
S : It is a bond. Dipeptide means double bond. Polypeptide means multiple bond. It is an amino acid bond. Dipeptide between 2 amino acids... (pauses)...double bond. If it is Polypeptide there are many bonds.
I : For example, suppose 3 bonds take place between 2 amino acids is it polypeptide?
S : It can be called Tripeptit as well.
I : Suppose it becomes 10.
S : Polipeptit.
I : 2 amino acids join. Where and how does the third one join?
S : They join side by side. For dipeptit there is single bond, for others there is single bond as well then.
I : Suppose there are 10 amino acids. Are the bonds between polypeptide?
S : Yes.

This student did not give an explanation like this for the conceptual understanding test. Yet, according to the interview it can be said that the student has some misconceptions on dipeptit and polypeptide. This can set an example for the misconceptions caused by the language used for the instruction. Student supposing di means two or double and thinking peptit bond argues that dipeptit is double bond. Going further with the same

thinking he thinks that polypeptide is multiple bonds too. At first he described double bond between two amino acids as dipeptit, but later changes his mind and said that it was single bond. Finding out that students had still had the above-mentioned views although special attention was given to this subject during the instruction proves that some changes should be made in the teaching methods. For this matter it can be suggested that new teaching techniques should be used.

Student 51 said the followings about peptit bond:

S : Dipeptit, it is formed when 2 peptit bonds join.
I : You mean dipeptit is 2 bonds?
S : Yes. Polypeptide too is formed by joining many peptide bonds. ...was it by joining proteins I wonder.
I : You are saying that dipeptit is a bond, which is formed by joining 2 peptide bonds. What does peptide bond link?
S : It links proteins.
I : It links A and B proteins. You are calling both dipeptit together.
S : Yes. Polypeptide is formed by joining many proteins.

During the interviews with the students as continuation of dipeptit concept primary and secondary states of the proteins were asked and following answers were taken:

I : What is primary, secondary, tertiary and quaternary protein?
S : (Thinking) one of them is single level the other has three dimensions (41, 53).
S : I think proteins with single ring and double ring are implied but I do not know in detail (56).
S : Primary protein does not function the others does. I do not know the structure (69).
S : Primary protein. I had not written (in the test) I think. It had not been mentioned much in the course. It's sound familiar but I do not remember (42).
S : I do not remember hearing them neither here nor in high school. It does not sound that much unfamiliar but it does not mean anything. (52)
S : Primary. The one, which comes first but...(39).
S : Primary the protein that comes first. I wonder is it the one we need the most. I think so (46).
S : I do not know (43,44,60,61,66,40,55).

In the dialogs given above many of the students stated that they did not hear or did not know primary, secondary, tertiary and quaternary proteins. It was detected trough observations that these concepts were not touched upon during the instruction. As result of this insufficient learning of these concepts, it can be argued that functionalisation, denaturalization and renaturalisation of the proteins cannot be conceptualized. Moreover, it should not be forgotten that these concepts have a significant role in learning of protein synthesis and their transformation into a secretion or a functional structure in a cell.

The most seen misconceptions: Presented in Findings and Discussion chapters some of the misconceptions which students have the most and seen the most important are as follows:

- DNA needs to be copied for protein synthesis.
- There is protein and/or amino acid in the structures of DNA and RNA.
- Dipeptit is a double bond.
- There is gene-protein-ap pearance relation in human beings, but not in animals and in plants. To have the very same appearance proves that animals and plants do not have mayos divisions and coupling reproduction even they do not have DNA and/or RNA.

CONCLUSIONS

The change in the answers of the students to the conceptual understanding test is displayed in general in Table 2. It is understood from the table that scientifically acceptable answers of the students were increased and existence of learning continued after the instruction. The ratio of scientifically acceptable answers in the delayed post-test was higher than it was in the pre-test for all the questions and in the post-test for some questions. This can be considered as a positive result that shows the instruction was effective. These results show that the instruction was effective to some extent. Educator's high level experience and his being involved in a research on a high school level unit analyses can be considered important factors for the success of traditional teaching methods. Yet, students had some difficulties in understanding some concepts and it has been found out that they gained some misconceptions during the course as well. This result shows that none of instructions is the best and all need to be redesigned.

When overall picture is examined from the table, there is a positive change after instruction for all questions

apart from for the 2nd proposition of the 1st question and for the 2nd question. Moreover, it is seen that the level of scientifically acceptable answers in the delayed post-test for all the propositions of the 1st question, for the 1st, 2nd and 3rd matching of the 3rd question, for the 1st proposition of the 4th question and choice a of the 5th question was not lower than it was in the post-test.

IMPLICATIONS FOR SCIENCE EDUCATORS

- Program developers and teachers need to take into account the misconceptions that students have. Furthermore, pre-conceptions of the students should be disclosed by different tools such as tests, interviews and so on. Teachers can organise more conveniently their teaching programs if pre-conceptions and misconceptions of the students are known.
- Conceptual change techniques, which are designed to find out students' misconceptions and correct them, might be used. For example, conceptual change texts might be used (Cetin, 2003; Kose, 2004). Some events might be actualized by drama (Stencel and Bar-koff, 1993). Analogies in which students interacts might be designed and integrated into teaching environment. It is said that especially for protein synthesis analogies are effective (Pittman, 1999). In addition to these it can be useful to benefit from teaching technologies. In order to help the students to visualize abstract concepts and event about proteins and protein synthesis some visual instruments can be used (Duit, 2007).
- It is found out that to give signal hypothesis together with protein synthesis causes some confusion. Mention of signal hypothesis before students understand the steps in protein synthesis in full makes it difficult for the students to understand. For this reason, it might be more appropriate to give first the protein synthesis in its most simple way and then to explain signal hypothesis.
- It is observed that students have difficulties in establishing intra and interdisciplinary links. For example; to mention the structure, the function and protection of DNA, the relations between organelles, what enzymes do, what secretories are and how they are made observed during the instruction and might be considered examples of establishing positive links.
- Proteins primary, secondary, tertiary and quaternary structures should be more emphasized. Lacking at this point might cause for the students not to understand denaturasition completely. It can be argued that if they first understand that when proteins are synthesized they become primary, secondary, tertiary and quaternary states and when these states are broken off they become denaturalized the students might establish the links more easily.
- Before giving the subject of proteins the shortcomings of the students on subjects such as atom, molecules, bond, polymer, polymerization, dehydration etc. should be corrected. Before protein synthesis the students should understand the structures of the proteins and nucleic acids very well.

RECOMMENDATIONS FOR FURTHER RESEARCH

Based on a review of the relevant literature and data analysis, the following recommendations for additional research are offered.

Further studies, which aim to analyse curriculums designed to eliminate the most common misconceptions and to bring about conceptual change, should be conducted.

In order to compare the advantages and the disadvantages of the constructive and the traditional instructions a further study should be administered. For example, a control group might be given a traditional instruction while the test group might have a constructive instruction and at the end the outcomes of both instructions might be compared and analysed.

APPENDIX

Conceptual understanding test:

- Explain the correct and incorrect prepositions given below with reasons.
  - Proteins are primarily energy sources in living beings.
  - Proteins are the least found organic structure in living beings.
  - Proteins function as receptor molecules in cell walls.
- It is known that the success rate of organ transfers between close relatives is higher. Explain why this is with reasons.
- Some of the characteristics of amino acids are given below. Match the numbers given in 1st box with the most suitable ones in the 2nd box. Afterwards explain why you have done these matching for each matching. (If you wish to add a characteristic you might write it down in the empty lines).

1		2
1	Amphoter	Provides variety for amino acids
2	R group	Peptide bond
3	Dehydration	Nutrition
4	Essential amino acid	Amin and carboxyl groups
5	.....	.....

- Divide the steps given below into two groups as related to protein synthesis and not related to protein synthesis and explain why.
  - Replication of DNA
  - mRNA's being read in ribosome
  - mRNA's being synthesized.
  - Merging of sub-divisions of ribosome
- a) There are about 6 billion human on earth. Appearance of each is different from one other. What might be the reason of these differences? What do you think?

  b) Is this differentiation valid for sparrow population as well? Why?

  c) Might the situation stated above be the case for the oak trees from same species as well? Why?
- Some of the components of cells are given below.

Amino acid	N (Nitrogen) atom	Dipeptide	Tertiary protein	Poly-peptide	Amine group

Put these elements in ascending order in the table given below. Afterward explain why you made this ordering.

The smallest

-

-

-

The biggest

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