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PROSPECTIVE TEACHERS' COGNITIVE STRUCTURES CONCERNING PROTEIN SYNTHESIS AND THEIR DEGREE OF UNDERSTANDING

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Abstract. *The purpose of education is to actualise meaningful learning. Therefore, researching the issues on how students process information and how they configure it is important for meaningful learning. The issue of protein synthesis contains a number of abstract topics and concepts. Hence, it is important in biology teaching to be informed of students' cognitive structures concerning protein synthesis. This research aims to analyse prospective teachers' cognitive structures about protein synthesis and their degree of understanding the subject. The research group was composed of 17 volunteering prospective teachers who had been chosen through purposeful sampling. The data were collected via semi-structured interviews. Flow maps and content analysis were used in analysing the data. The results demonstrated that prospective teachers had too many misconceptions about protein synthesis and that their knowledge extent and rich connection are inadequate. The prospective teachers' degree of understanding protein synthesis was divided into three categories. The results obtained in this research suggested that teachers should be careful in teaching the subject of protein synthesis. Students' prior knowledge and their misconceptions should be determined and content or contexts to facilitate them to learn an abstract subject such as protein synthesis should be presented.*

Keywords: *cognitive structure, degree of understanding, flow map, meaningful learning, protein synthesis*

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Introduction

Physics, chemistry and biology contain abstract concepts. Therefore, research into how students process information and how they configure it is considered important for meaningful learning (Abraham, Gryzybowski, Renner, & Marek, 1992; Brumby, 1984). Failure to fulfil meaningful learning can stem from a number of factors such as students, teachers, teaching materials, school conditions, inadequacy of curricula, wrong teaching strategies, and ignoring misconceptions (Pines & West, 1986; Sadler, Coyle, Cook Smith, Miller, Mintzes, Tanner, & Murray, 2013; Snow, 1989; Tsai, 2000). Besides, students' inability to associate conceptual structures in their mind, their inadequate levels of readiness, and their efforts to configure subjects with incorrect knowledge also influence their learning in negative ways (Ausubel, 1968; Daskolia, Dimos & Kampylis, 2012; Waheed & Lucas, 1992). According to Kinchin (2011) and Chi (2001), meaningful learning does not occur due to such reasons as students' failure to notice concepts and the associations between those concepts in science classes, their tendency to memorise, and the inefficacy of education in presenting the concepts and the associations between the concepts.

According to constructivist approach, learning means forming associations between previous knowledge and new knowledge rather than adding continuously new knowledge into the mind (Anderson, 1992; Olitsky & Milne, 2012). In other words, it means re-constructing the correct and incorrect schemata in students' mind with scientific knowledge, re-processing the knowledge and it is also the process of students' internalising the situation. Cognitive development- that is to say, individuals' ability to think and to understand- improves through constructivist approach. One of the problems encountered in researching cognitive structure is how to use qualitative concepts as definitions and how to shape cognitive structure in visual format. Anderson and Demetrius (1993) presented verbal statements in a visually- that is to say, in flow maps. In this research, flow maps are used as an analytic instrument effective in exhibiting individuals' cognitive structures (Tsai, 2001; Wu & Tsai, 2005). Flow maps are also used in determining misconceptions.

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The number of incorrect concepts shown in flow maps can also be used as indicators that conceptual frameworks are correct. Analysing students' cognitive structures in the format of flow maps is important for science educators in terms of presenting the cognitive structure quantitatively and in terms of content analysis of the important concepts recalled and information processing strategies (Temel & Özcan, 2016; Tsai, 2001). Bischoff and Anderson (2001) determined high school students' cognitive structures with flow maps and content analysis. The researchers interviewed the 9th and 10th graders and presented their results about the students' development in the issue. As a result, they indicated that information on students' cognitive structures could be obtained through three-week training. Tsai and Huang (2001) conducted a three-week research with the 5th graders about reproduction. They determined the development of students' cognitive structures in the subject of reproduction in three weeks. After two months, the researchers analysed the data which they collected in interviews with the students by using flow maps. They analysed students' cognitive structures on the basis of the formation, extension and regulation of knowledge.

Concept teaching is important in making sense of knowledge. If students can transfer knowledge into new situations they encounter, they are considered to have grasped or learnt it (Colley, 2006; Taber, 2000; Wilson, Anderson, Heidemann, Merrill, Merritt, Richmond, 2006). For this reason, it is very important to learn concepts correctly in biology. Students' failure to configure the knowledge presented to them results in having misconceptions (Bahar, 2003; Treagust, 1988). Because concept maps, word association, semantic network and flow maps are used in exhibiting cognitive structure (Acar & Tarhan, 2008; Aufschnaiter & Aufschnaiter 2003; Bischoff & Anderson, 1998; Cremer, Dingshoff, de Beer, & Schoonen, 2011; Hovardas & Korfiatis, 2006; Kinchin, 2001; Kostova & Radoynovska, 2010; Novak, 1990). According to Eylon and Linn (1988), there are 4 categories in exhibiting the cognitive structure in science teaching. Accordingly, the categories are conceptual learning, development, differentiation and problem solving. Tsai and Huang (2002) determined cognitive structure and exhibited students' previous knowledge and pre-conceptions. The researchers contend that exhibiting cognitive structure enables teachers to be informed of their students' previous knowledge and of how scientific the knowledge is.

It is apparent that protein synthesis and related subjects are included in science and biology curricula in secondary school and high school programmes (see Table 1). The fact that the topic also involves such comprehensive subjects as cells (structure and organelles), organic compounds, nucleic acids (DNA and RNA), proteins, chemical digestion, and enzymes and that it is connected with a discipline like chemistry shows its importance. As in all other subjects of biology, researching students' cognitive structures in protein synthesis- which is an interdisciplinary subject- is important. It was found in studies related with biology that students had learnt the subjects of cells (Deysfus & Jungwirth, 1988), enzymes (Francis & Sellers, 1994; Lazarowitz & Naim, 2013), genetics (Cavello & Schafer, 1994; Stewart, Hafner & Dala, 1990), amino acids (Fisher, 1985) and biotechnology (Dawson, 2007) incorrectly and insufficiently.

Table 1. Protein synthesis and related subjects in science and biology curricula in secondary school and high school programmes in Turkey.

School and grade level	Course	Subject
Secondary school 5th, 6th, 7th and 8th grades	Science	Food and its properties (general information on proteins)
		Cells, their structure and organelles (nucleus, ribosome)
		Digestive system (chemical digestion, digestion of proteins)
		DNA and genetic code (from chromosomes to nucleotides, DNA's matching itself)
High school 9th,11th, 12th grades	Biology	Basic components of living organisms (proteins, enzymes, nucleic acids)
		Digestive system (chemical digestion of food, digestion of proteins)
		From genes to proteins (discovery and importance of nucleic acids: genetic code, protein synthesis and associations between them)

The fact that there are almost no studies exhibiting prospective teachers' cognitive structures about protein synthesis by means of flow maps and that this research analyses the degree to which students understand the subject of protein synthesis as well as their misconceptions indicates the significance of this research. Besides, it is also believed that determining prospective teachers' cognitive structures about protein synthesis with flow maps, and analysing the statements on the maps one by one in terms of the degree of understanding them will contribute significantly to the literature. In addition to that, this research also contains important results to show the scope and richness of prospective teachers' cognitive structures.

Problem of the Research

Protein synthesis is difficult to learn meaningfully because it is connected with several subjects. It was found in evaluations that prospective teachers had problems in understanding protein synthesis. Thus, it is important to demonstrate prospective teachers' cognitive structure about protein synthesis-which is a complex subject- and the degree to which they understand it. This research aims to analyse prospective biology teachers' degree of understanding protein synthesis and their cognitive structures about protein synthesis. For this purpose, the following questions were formulated:

1. What is prospective biology teachers' degree of understanding the subject of protein synthesis according to Marek's (1986) classification?
2. What are prospective teachers' cognitive structure outcomes through flow maps in relation to protein synthesis?

Methodology of Research

This is a qualitative research aiming to analyse prospective teachers' cognitive structure about protein synthesis and the degree to which they understand the subject. In line with this purpose, case study was employed -one of the types of qualitative research. Case study is a specific research design in which a phenomenon or an event is studied in depth based on the reasons for the details (Yin, 1984). This research was conducted with the third-year students at Hacettepe University in the Fall Semester of 2016-2017 academic year. Flow maps and content analysis were used in the analysis of semi-structured interviews which were conducted so as to exhibit prospective teachers' cognitive structure about protein synthesis and the degree to which they understand the subject in accordance with the purpose of the research.

Sample of Research

The research group was composed of 17 prospective biology teachers who had taken General Biology and Genetics courses. Every year, 20 students from various high schools are accepted into the Biology Education programme according to the results of the transition to higher education examination. Four of the participants were male while 13 of them were female students- who were in the 20-22 age range. Purposeful sampling method was employed in forming the research group. Purposeful sampling method is a method which enables one to explain better the problems focussed in cases where there is a demand to research the problems in depth (Şimşek & Yıldırım, 2013).

All of the participants had taken General Biology and Genetics courses. Almost 22 students take these courses every semester. Because the aim is to demonstrate cognitive structures in detail, the research group was restricted to 17 prospective teachers. It may be said that this number is representative of the number of students in the classroom. The research group was formed on the basis of volunteering inclusion.

Description of Course Content

Students learn protein synthesis under such subjects as Proteins, Genetic Code, Cells and Nucleic Acids in Science and Biology courses at secondary school and high school. In addition to that, prospective biology teachers are offered knowledge about protein synthesis in more details through such courses as General Biology and Genetics. General Biology course is offered in two semesters in their first year and it is offered only in the fall semester in the third year. No lab applications are available in neither of these courses in relation to protein synthesis. Teacher-centred instruction, question and answer, and demonstration techniques are available in both courses.

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Data Collection Tools

1. Semi-structured interviews

Interview questions were prepared based on various course books of General Biology (Keeton, Gould & Gould, 1993; Reece, Urry, Cain, Wasserman, Minorsky & Jackson, 2011) and Genetics (Fletcher & Hickey, 2012; Klug, Cummings & Spencer, 2006) since the aim was to analyse prospective teachers' cognitive structures about protein synthesis. By considering the observations made, insufficient knowledge in protein synthesis and the learning difficulties; the ones suiting to the purpose of the research were chosen. Then, a time table was prepared for interviews with the research group and then semi-structured interviews were conducted with the participants. In order to avoid loss of data, the interviews were audio recorded. Interviewing is a method used both in assessing whether concepts are understood (Gilbert & Watts, 1983; Vance, Miller & Hand, 1995) and in identifying misconceptions (Osborne & Gilbert, 1980; Tsai & Huang, 2002).

2. Flow map

The prospective teachers participating in the research were asked the following questions in relation to protein synthesis:

1. What is protein synthesis? Why does a cell perform protein synthesis? What can you say about this?
2. How is protein synthesised in a eukaryotic cell? What can you say about the process of synthesis?

Interviews in which the above- mentioned questions were asked lasted for approximately 5 minutes. The data coming from the interviews were then transcribed, and a flow map was prepared for each prospective teacher. While the sequential flow of prospective biology teachers' views about the subject are represented in linear arrows, connections between the ideas are shown in recurred arrows. The recurred arrows were used for the views prospective teachers stated before. Misconceptions informing us of the accuracy of the cognitive structure are also shown in flow maps.

Ethics, Validity and Reliability Analyses

Because the concept of ethics is important in studies, prospective teachers were offered information on this issue prior to the research. The voluntary participants were assured that they could give up being a participant whenever they wished. It was also pointed out to them that the results to be obtained would be used for scientific purposes and that their names would be kept confidential.

Required validity and reliability analyses were also conducted and member checking was obtained for internal validity (Şimşek & Yıldırım, 2013). External validity was increased by explaining each stage of the research in details. Great care was taken to determine the participants and the environment in which the research was conducted, to collect the data required and to do the analyses in increasing external reliability.

A second independent researcher was used for the reliability of the flow maps. The second researcher changed prospective teachers' narrations into diagrams. Intercoder agreement for sequential statements was found to be .88, whereas it was found to be 0.85 for recurrent linkages in this research.

Data Analysis

Quantitative variables determined by Tsai (2001) were used for flow maps in representing each prospective biology teacher's cognitive structure. The qualitative variables used for data analysis are shown below.

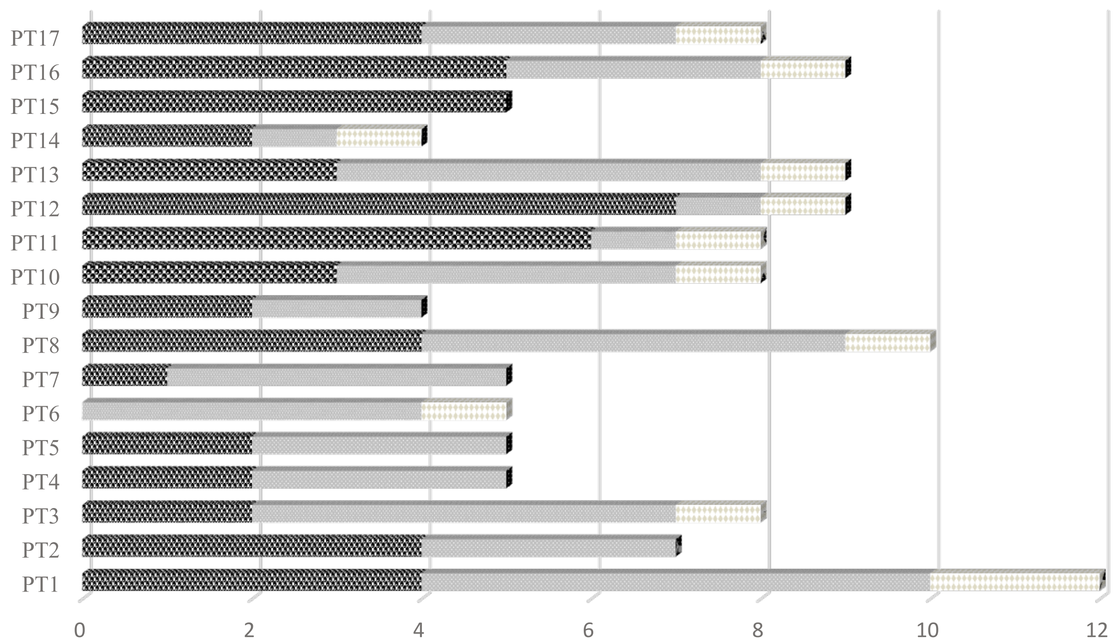
- Extent: Extent is the quantitative variable represented as the total number of ideas (the number of linear linkages) in the flow maps.
- Misconception: It is represented as the number of misconceptions in the flow maps.
- Richness (recurrent linkages): Richness is represented as the number of recurrent linkages in the flow maps.
- Integration: The number of recurrent linkages in the flow maps/ (total number of ideas + the number of recurrent linkages) were calculated as integration (Tsai, 2001).

Secondly, the linkages in the flow maps were analysed according to degree of understanding based on Marek's (1986) classification. The classification was made as in the following:

- No Response (NR): The subject is unknown to the students, explanation is not comprehensible.
- Specific Misunderstanding (SM): Explanation has illogical, irrelevant and incorrect information.
- Partial Understanding (PU): Explanation is correct but inadequate.
- Sound Understanding (SU): Correct and complete explanation (Marek, 1986).

Results of Research

Prospective teachers' degree of understanding the subject of protein synthesis was determined with the first research problem. Figure 1 shows the results.



	PT1	PT2	PT3	PT4	PT5	PT6	PT7	PT8	PT9	PT10	PT11	PT12	PT13	PT14	PT15	PT16	PT17
NR	4	4	2	2	2	0	1	4	2	3	6	7	3	2	5	5	4
SM	6	3	5	3	3	4	4	5	2	4	1	1	5	1	0	3	3
PU	2	0	1	0	0	1	0	1	0	1	1	1	1	1	0	1	1
SU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 1: Prospective teachers' degree of understanding protein synthesis.

It is clear from Figure 1, prospective teachers' degree of understanding the subject of protein synthesis is clustered in 3 (NR, SM and PU) out of 4 categories. Accordingly, 56 (46%) statements are in the category of NR, 53 (44%) are in the category of SM, and 12 (10%) are in the category of PU. Thus, there are no statements in the category of SU.

Prospective teachers were asked two questions during the semi-structured interviews in accordance with the first research problem so as to determine their degree of understanding. On analysing the prospective teachers' degree of understanding on the basis of the first research question having two parts formulated as "What is protein synthesis? Why does a cell perform protein synthesis?" the answers were found to cluster in the categories of NR, SM and PU. Accordingly, the participants gave the following answers in the category of NR:

- Protein synthesis is performed in order to transfer the information in DNA and to regulate the hormones. It is important for life.
- I can say that protein synthesis means amino acids coming together and forming a polymer structure.
- Protein synthesis is done to meet the needs of living things.

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- I think that living things have to perform protein synthesis because proteins are the building blocks. Living things need energy.
- The following responses were in the category of SM:
- Firstly, DNA replicates itself in the cytoplasm in a cell.
- Protein synthesis is composed of DNA.
- The necessary energy in a cell and it does that for ATP, and protein is synthesised.
- When someone says protein synthesis, recombinant DNA is formed in my mind.
- When someone says protein synthesis, ribosome comes into my mind and then protein comes into my mind. In other words, protein synthesis is performed in order to meet the protein needs of our body.
- The following responses were in the category of PU:
- Protein synthesis occurs when DNA replicates itself, and then RNA is formed (transcription), and translation and protein are formed. It performs protein synthesis to synthesise the proteins necessary for our body and to meet the structural and enzymatic needs of a cell.
- DNA synchronizes itself and thus protein synthesis occurs. First transcription occurs and then rRNA occurs for this. Then, translation occurs, and protein synthesis occurs. As a result, it is a vital process with multiple functions.
- For example, enzymes are also proteins and we need proteins to be able to regulate life functions. Our cells need proteins (for building blocks). Therefore, proteins are created.
- Protein synthesis is an important and necessary activity in order for living organisms to sustain vital activities.

It was also found that the participants' answers to the second research question "How is protein synthesised in a eukaryotic cell? What can you say about the process of synthesis?" clustered in the categories of NR, SM and PU. Accordingly, the following answers were in the category of NR:

- If I am not mistaken, it is synthesised from 5′ to 3′ or from 3′ to 5′.
- Translation occurs in the chloroplast. I confuse it. If I can remember correctly, it is in stomas, mitochondrion is in the matrix, in the ribosomes, in the chloroplast stoma.
- There is something called DNA sequencing. Primase enzyme has a duty there.
- Such as, ribosomes are created in ribosomal RNA.
- It happens at the top and bottom of ribosomes; I cannot remember it very well.
- I cannot remember it very well, was it transcription?
- Some of the proteins in the cytoplasm come into the nucleus. And was it rDNA? It combines with proteins there and the sub-units of ribosome are formed in the nucleus. Then they pass into cytoplasm.
- There is an enzyme. I cannot remember its name now. I know it, but I cannot say it now exactly.
- As far as I know, this reading action called translation occurs in ribosomes – if I do not confuse it with something else.
- I might have forgotten, or I may confuse it with something else.
- When I mix it up, I cannot remember what replication is.
- I do not know the process exactly.

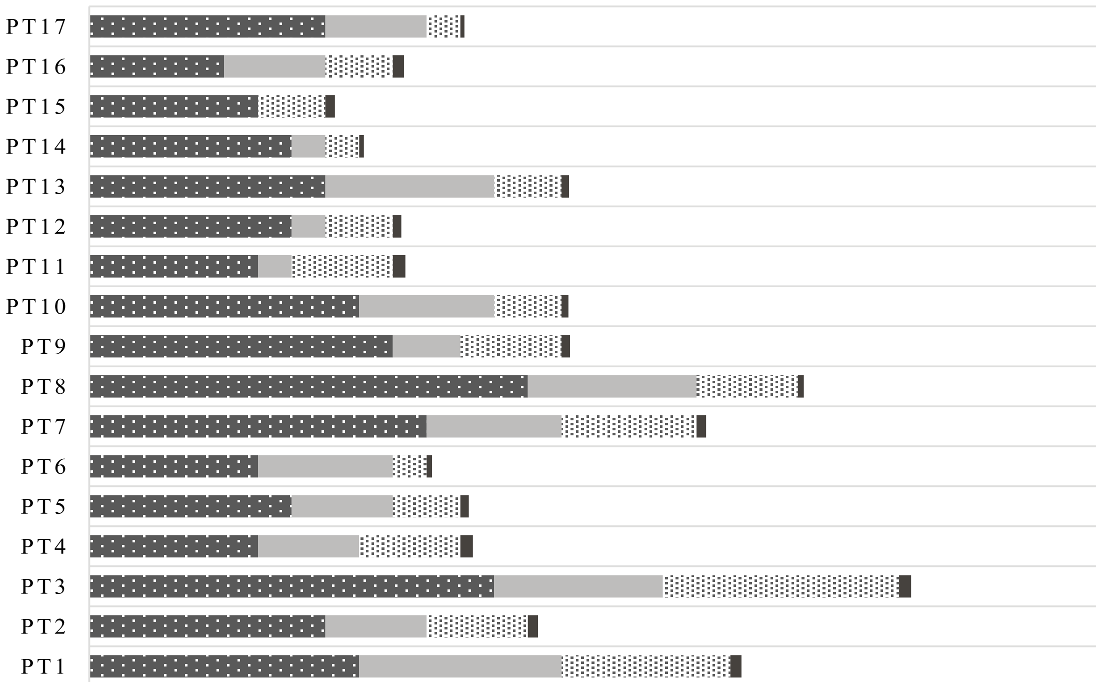
The following answers were in the category of SM:

- It starts in the DNA. It comes to RNA. RNA is called transcription, and performing protein synthesis from RNA is called translation.
- Helicase enzymes cause replication fork to loosen.
- Topoisomerase enzymes first straighten the spiral thing of DNA. Then, primase DNA works, and it enables DNA to read RNA.
- The reason for recombinant DNA is formed is that we have a genetic structure. It is shaped in a certain way thanks to codes and codons in the DNA chain.
- First proteins such as helicase work in the DNA.
- There are more curls in the other branch of the DNA spiral. Topoisomerase protein works to eliminate this. This enzyme breaks the spiral, rotates it and loosens it, and then it ties it again.
- Replicated DNA pieces go through transcription and turn into RNA.
- Translation is the transfer of information in mRNA into tRNA.
- Replication is the synchronisation of a cell.

- Transcription occurs with rRNA in the process of protein synthesis. Apart from that, other RNAs also work but rRNA is used most in protein synthesis.
- Replication occurs thanks to certain hormones.

The following answers to the second question were in the category of PU:

- It is the structure making it possible to carry amino acids here while mRNA is read on the tRNA ribosome.
- mRNA information is brought to ribosome and polypeptides are formed after replication occurs.



	PT1	PT2	PT3	PT4	PT5	PT6	PT7	PT8	PT9	PT10	PT11	PT12	PT13	PT14	PT15	PT16	PT17
Extent	8	7	12	5	6	5	10	13	9	8	5	6	7	6	5	4	7
Miscon-ception	6	3	5	3	3	4	4	5	2	4	1	1	5	1	0	3	3
Richness	5	3	7	3	2	1	4	3	3	2	3	2	2	1	2	2	1
Integration	0,33	0,3	0,36	0,37	0,25	0,16	0,28	0,18	0,25	0,2	0,37	0,25	0,22	0,14	0,28	0,33	0,12

Figure 2: Prospective teachers' cognitive structure outcomes.

Prospective teachers' cognitive structures and the outcomes for the structures were analysed in the flow maps technique in accordance with the second research question. Flow maps were prepared for each of the 17 prospective teachers included in the research. The most and least detailed ones of the flow maps are shown in the Appendix. (see the Appendix). Figure 2 shows the outcomes for prospective teachers' cognitive structures. Accordingly, the extent of prospective teachers' knowledge of protein synthesis (sequential linkages) is between 4 and 13. The number of misconceptions is 6 at the maximum, and richness variable is between 1 and 7. The integration variable is between 0.12 and 0.37.

Discussion

Prospective teachers' degree of understanding and the sample statements for the degree were obtained based on the first research problem. It was found according to the participants' answers to the two questions that their degree of understanding fell into the categories of NR, SM and PU from the most to the least. Thus, the fact that the prospective teachers explained protein synthesis in such responses as "transferring the information in

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the DNA", "meeting the needs", "generating energy", "I am confusing", "I cannot remember", "if I am not mistaken", "I cannot say exactly" (in the category of NR) indicated that they had not understood the subject. Francis (1994) points out that proteins have enzymatic, structural and very complex roles in cells and organisms and that it was difficult to learn them. Lazarowitz and Penso (1992) describe the subjects which are difficult for teachers to teach and for students to learn. The researchers – who include protein synthesis, the structure and functions of enzymes in the list of difficult subjects- state that there are basically two reasons for why those subjects are difficult. First, integrity cannot be attained at the level of biological organisation, and the second reason is that some of the subjects are abstract. A review of the biology curriculum makes it clear that some preliminary knowledge on cells, proteins and DNA is offered at secondary school and high school (MONE, 2013a; 2013b). The fact that the prospective teachers could not answer the questions with self-confidence may be attributed to the fact that they could not understand or that they inadequately understood the subject.

The prospective teachers gave such responses as "for proteins, energy and ATP", "protein synthesis occurring from RNA is called translation", "loosening of the fork (branches of DNA)", "topoisomerase enzyme straightens the branches of DNA", " firstly proteins such as helicase work in DNA (in replication)", "transfer of the information in mRNA into tRNA", "replication is the synchronisation of a cell", "replication happens thanks to certain hormones", " the reason for recombinant DNA formation", and "topoisomerase protein works" in the category of SM. Studies available also demonstrate that there are misconceptions about genetics (Cavello & Schafer, 1994; Fisher, 1985; Kargbo, Hobbs & Erickson, 1980). Dreyfus and Jungwirth (1988) state that misconceptions in the field of biology are mostly in such abstract subjects as cells.

The students stated that they could not eliminate their misconception even after they had taken a biology course, and that it was mainly because their misconceptions were too strong to change (Brumby, 1984; Marek, Cowan & Cavallo, 1994; Westbrook & Marek, 1991). Such misconceptions were found in all age groups at the levels of primary school, secondary school, high school and university (Flories, 2003; Gelbart & Yarden, 2006; Kellert 1985, Özcan, 2013; Trowbridge & Mintzes, 1988; Yip, 1998). Protein synthesis is connected with many concepts and topics. For instance, if the fact that replication is not necessary for protein synthesis is not emphasised; the subject is confused with segmentation and it may result in misconceptions. It may be said that misconceptions stem from languages. For example, prospective teachers were found to confuse such concepts as polymer, primary and polypeptide. Results demonstrate that prospective teachers confuse different topics (segmentation, hormones, protein synthesis, biotechnology) and that they had difficulty in setting up horizontal and vertical associations between them. Additionally, it was also found that prospective teachers tried to explain their answers to questions with knowledge fragments (such as generating energy, segmentation, hormones, recombinant, DNA) they remember from their past experiences. That is to say they made explanations by setting up connections between knowledge fragments that they thought to be related with protein synthesis.

The participants gave such responses as "protein synthesis is DNA's replication", "transcription and translation stages (formation of RNA)" and "protein synthesis is performed to meet the vital needs of a living organism and the structural needs and enzymatic needs of a cell" in the category of PU. Complex, abstract and disorganised knowledge causes students' failure to configure knowledge or to configure it inadequately (Bischoff & Anderson, 2001; Fisher, 1985). Results show that some of the prospective teachers have little knowledge about the issue but that their knowledge is inadequate and lacking. Especially the fact that the answers to the questions were superficial and that they contained only basic concepts (such as replication, transcription, RNA) is supportive of this view.

In connection with the second research problem, prospective teachers' degree of understanding protein synthesis and their cognitive structures were analysed in the technique of flow maps. For this purpose, flow maps were prepared for each participant and analyses were done. Four extent variables, misconceptions, richness and integration suggested by Tsai (2001) were taken into consideration in preparing the flow maps. It was found that prospective teachers had 6 misconceptions at the maximum in terms of protein synthesis, that the quantitative variable of knowledge extent was between 4 and 13, that the variable of richness was between 1 and 7, and that the variable of integration was between 0.12 and 0.37. These results show that prospective teachers have plenty of misconceptions about protein synthesis and that their knowledge extent and rich connection are inadequate. The fact that the subject of protein synthesis is at microscopic level and that there are too many concepts and related subjects might have caused the students to have difficulty in learning and to memorise. This in turn might have resulted in misconceptions. Chi (2001) lists the causes of misconceptions as lacking or incorrect prior knowledge and as unsuitable educational setting in the teaching of concepts. The flow maps showing the broadest and the narrowest cognitive structures in terms of extent are included in the Appendix (see Figure 1).

Conclusions

The results obtained in this research showed that prospective teachers included in the research had not understood the subject of protein synthesis and that they had misconceptions about the subject. Thus, teachers should be careful in teaching protein synthesis. Students' prior knowledge about protein synthesis and relevant topics at the level of high school and their misconceptions should be determined. Students should be offered content and contexts in relation to protein synthesis- which is an abstract subject- to facilitate meaningful learning. Students' attention should be called to relevant concepts and the connections between the concepts. Advance organisers such as concept maps in addition to such methods as semantic networks, semantic feature analysis and conceptual change texts should be used so that students can form contexts/connections between concepts. In this way, richer integrated conceptual frameworks can be developed. This will help students to understand the relevant scientific knowledge and to develop complex organised knowledge.

This research is restricted to interviews with prospective teachers and to flow map method. Further applied research should be done by using different methods and techniques with different age groups so as to obtain detailed information on the issue.

References

Abraham, M. R., Gryzybowski, E. B., Renner, J. W., & Marek, A. E. (1992). Understanding and misunderstanding of eighth graders of five chemistry concepts found in textbooks. *Journal of Research in Science Teaching*, *29* (2), 105-120.

Acar, B., & Tarhan, L. (2008). Effects of cooperative learning on students' understanding of metallic bonding. *Research in Science Education, 38*, 401–420.

Anderson, O. R. (1992). Some interrelationships between constructivist models of learning and current neurobiological theory, with implications for science education. *Journal of Research in Science Teaching, 29*, 1037- 1058.

Anderson, O. R., & Demetrius. O. J. (1993). A flow-map method of representing cognitive structure based on respondents' narrative using science content. *Journal of Research in Science Teaching*, *30* (8), 953-969.

Aufschnaiter, C., & Aufschnaiter, S. (2003). Theoretical framework and empirical evidence of students' cognitive processes in three dimensions of content, complexity, and time. *Journal of Research in Science Teaching*, *40* (7), 616-648.

Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York, NY: Holt, Rinehart, and Winston.

Bahar, M. (2003). Misconceptions in biology education and conceptual change strategies. *Educational Sciences: Theory & Practice, 3* (1), 55-64.

Bischoff, P. J., & Anderson, O. R. (1998). A case study analysis of the development of knowledge schema, ideational networks, and higher cognitive operations among high school students who studied ecology. *School Science and Mathematics, 54*, 228–237.

Bischoff, P. J., & Anderson, O. R. (2001). Development of knowledge frameworks and higher order cognitive operations among secondary school students who studied a unit on ecology. *Journal of Biological Education, 35* (2), 81-88.

Brumby, M., (1984). Misconceptions about the concept of natural selection. *Science Education*, *68* (4), 493-503. doi:10.1002/sce.3730680412.

Cavello, A. M. L., & Schafer, L. E. (1994). Relationship between student's meaningful learning orientation and their understanding of genetic topics. *Journal of Research in Science Teaching*, *31*, 393-418.

Chi, M. (2001, April 10–14). *Why do students fail to understand complex dynamic concepts?* Paper delivered to American Education Research Association, Seattle.

Colley, K. E. (2006). Understanding ecology content knowledge and acquiring science process skills through project-based science instruction. *Science Activities: Classroom Projects and Curriculum Ideas*, *43* (1), 26–33.

Cremer, M., Dingshoff, D., de Beer, M., & Schoonen, R. (2011). Do word associations assess word knowledge? A comparison of L1 and L2, child and adult word associations. *International Journal of Bilingualism*, *15* (2), 187–204.

Daskolia, M., Dimos, A., & Kampylis, P. G. (2012). Secondary teachers' conceptions of creative thinking within the context of environmental education. *International Journal of Environmental and Science Education*, *7* (2), 269–290.

Dawson, V. (2007). An exploration of high school (12-17 year old) students' understanding of and attitudes towards biotechnology processes. *Research in Science Education*, *37* (1), 59-73.

Dreyfus, A., & Jungwirth, E., (1988). The cell concept of 10th graders: curricular expectations and reality. *International Journal of Science Education*, *10*, 221-229.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Eylon, B., & Linn, M. C. (1988). Learning and instruction: An examination of four research perspectives in science education. *Rewiev of Educational Research, 58* (3), 251-301.

Fisher, K. (1985). A misconception in biology: Amino acids and translation. *Journal of Biology Education*, *22*, 53-62.

Fletcher, H., & Hickey, I. (2012). *Bios instant notes in genetics, (4th Ed.)*. London, UK: Taylor & Francis.

Francis, J.W., & Sellers, J.A. (1994). Studying amino acid sequence using word processing programs. *American Biology Teacher*, *56* (8), 484-87.

Gelbart, H., & Yarden, A. (2006). Learning genetics through an authentic research simulation in bioinformatics. *Journal of Biological Education*, *40* (3), 107-111.

Gilbert, J.K., & Watts, D.M. (1983). Concepts, misconceptions and alternative conceptions: Changing perspectives in science education. *Studies in Science Education*, *10*, 61-98.

Flories, F. (2003). Representation of cell and its processes in high school students: an integrated view. *International Journal of Science Education, 25* (2), 269-286.

Hovardas, T., & Korfiatis, K. J. (2006). Word associations as a tool for assessing conceptual change in science education. *Learning and Instruction*, *16*, 416-432.

Lazarowitz, R., & Penso, S. (1992). High school student's difficulties in learning biology concepts. *Journal of Biological Education*, *26* (3), 215-223.

Lazarowitz, R., & Naim, R. (2013). Learning the cell structures with three-dimensional models, students' achievement by methods, type of school and questions' cognitive level. *Journal of Science Education and Technology*, *22* (4), 500-508.

Kargbo, D. B., Hobbs, E. D. & Erickson, G. L. (1980). Children' s beliefs about inherited characteristics. *Journal of Biological Education*, *14*, 137-146.

Keeton, W. T., Gould, J. L., & Gould, C. G. (1993). *Biological Science, (5th Ed.).* New York, NY: W. W. Norton & Company Inc.

Kinchin, I. M. (2001). If concept mapping is so helpful to learning biology, why aren't we all doing it? *International Journal of Science Education*, *23* (12), 1257-1269. doi: 10.1080/09500690010025058.

Kinchin, I. M. (2011). Visualising knowledge structures in biology: Discipline, curriculum and student understanding. *Journal of Biological Education*, *45* (4), 183–189.

Klug, W. S., Cummings, M. R., & Spencer, C. A. (2006). *Concepts of genetics, (8th Ed.)*. Upper Saddle River, NJ: Pearson Education.

Kostova Z., & Radoynovska B. (2010). Motivating students' learning using word association test and concept maps. *Bulgarian Journal of Science and Education Policy*, *4* (1), 62-98.

Marek, E. A., Cowan, C. C., & Cavallio, A. M. L. (1994). Students' misconceptions about diffusion: How can they be eliminated. *The American Biology Teacher*, *56*, 74-77.

Marek, E. A. (1986). Understandings and misunderstandings of biological concepts. *The American Biology Teacher*, *48*, 37-40.

Ministry of National Education of Turkey [MONE] (2013a). Fen Bilimleri Dersi (3, 4, 5, 6, 7 ve 8. Sınıflar) Öğretim Programı [Elementary School Science Curriculum (Grades 3^{th}–8^{th})]. Retrieved from http://ttkb.meb.gov.tr/program2.aspx.

Ministry of National Education of Turkey [MONE] (2013b). Biyoloji Dersi (9, 10, 11 ve 12. Sınıflar) Öğretim Programı [Secondary Education, Curriculum of Biology Course (Grades 9th-12^{th})]. Retrieved from http://ttkb.meb.gov.tr/program2.aspx.

Novak, J. D. (1990). Concept mapping: A useful tool for science education. *Journal of Research in Science Teaching, 27* (10), 937-949.

Olitsky, S., & Milne C. (2012). Understanding engagement in science education: The Psychological and the Social. In Fraser B. J., Tobin K. G., & McRobbie, C. J. (Eds.). *Second international handbook of science education* (pp. 19-20). Dordrecht, The Netherlands: Springer.

Osborne, R. J., & Gilbert J. K. (1980). A technique for exploring students' views of the world. *Physics Education*, *15*, 376-379.

Özcan, Ö. (2013). Investigation of mental models of Turkish pre-service physics students for the concept of "spin". *Eurasian Journal of Educational Research*, *52*, 21-36.

Pines, A. L., & West, L. H. T. (1986). Conceptual understanding and science learning: a sources of knowledge framework. *Science Education*, *70*, 583- 604.

Reece, J. B., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V. & Jackson, R. B. (2011). *Campbell biology, (9th Ed.)*. Upper Saddle River, NJ: Pearson Education.

Sadler, P. M., Coyle, H., Cook Smith, N., Miller, J., Mintzes, J., Tanner, K. & Murray, J. (2013). Assessing the life science knowledge of students and teachers represented by the k–8 national science standards. *CBE Life Sciences Education*, *12*, 553–575.

Snow, R. E. (1989). Toward assessment of cognitive and conative structures in learning. *Educational Research, 18* (9), 8-14.

Stewart, J., Hafner, B., & Dala, M. (1990). High school students understanding of chromosome /gene behavior during meiosis. *Science Education*, *73*, 501-521.

Şimşek, H., & Yıldırım, A. (2013). *Soysal bilimlerde nitel araştırma yöntemleri* [Qualitative research methods in social sciences]. Ankara, Turkey: Seckin.

Taber, K. S. (2000), Multiple frameworks? Evidence of manifold conceptions in individual cognitive structure. *International Journal of Science Education*, *22* (4), 399–417.

Temel, S., & Özcan, Ö. (2016). The analysis of prospective chemistry teachers' cognitive structure: The subject of covalent and ionic. *Eurasia Journal of Mathematics, Science and Technology Education*, *12* (8), 1953-1969. doi: 10.12973 / eurasia.2016.1273a.

Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education, 10*, 159-169.

Trowbridge, J. E., & Mintzes, J. (1988). Alternative conceptions in animal classification: a croo-age study. *Journal of Research in Science Teaching*, *25*, 547-571.

Tsai, C. C., (2000). The effects of STS-oriented instruction on female tenth graders' cognitive structure outcomes and the role of student scientific epistemological beliefs. *International Journal of Science Education*, *22*, 1099–1115.

Tsai, C. C., & Huang, C. M. (2001). Development of cognitive structures and information processing strategies of elementary school students learning about biological reproduction. *Journal of Biological Education*, *36*, 21–26.

Tsai, C. C. (2001). Probing students' cognitive structures in science: the use of a flow map method coupled with a meta-listening technique. *Studies in Educational Evaluation, 27*, 257-268.

Tsai, C. C., & Huang, C. M. (2002). Exploring students' cognitive structure in learning science: a review of relevant methods. *Journal of Biological Education, 36*, 163-169.

Vance, K., Miller, K., & Hand, B. (1995). Two examples of using constructivist approaches to teach ecology at the middle school level. *The American Biology Teacher*, *37* (4), 244-249.

Waheed, T., & Lucas, A. M., (1992). Understanding interrelated topics: photosynthesis at age 14+n. *Journal of Biological Education*. *26* (3), 193-199.

Westbrook, S. L., & Marek, E. A. (1991). A cross-age study of student understanding of the concept of diffusion. *Journal of Research in Science Teaching*, *28*, 649-660.

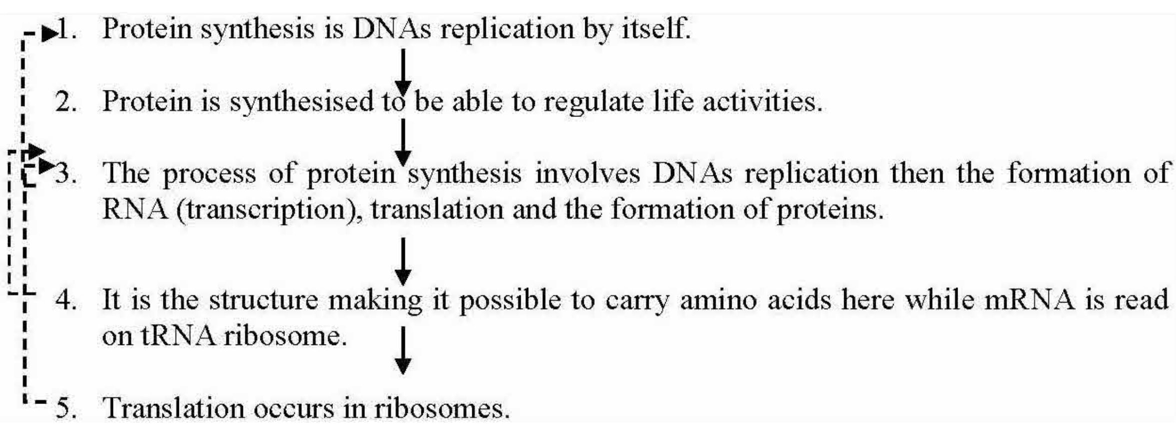
Wilson, C. D., Anderson, C. W., Heidemann, M., Merrill, J. E., Merritt, B. W., Richmond, G. (2006). Assessing students' ability to trace matter in dynamic systems in cell biology. *CBE-Life Sciences Education*, *5* (4), 323–331.

Wu, Y. T., & Tsai, C. C. (2005). Effects of constructivist oriented instruction on elementary school students' cognitive structures. *Journal of Biological Education*, *39* (3), 113-119.

Yin, R. K. (1984). *Case study research: Design and methods.* Beverly Hills, CA: Sage.

Yip, D.Y. (1998). Teachers' misconceptions of the circulatory system. *Journal of Biological Education*, *32* (3), 207-215.

APPENDIX 1. The flow map of PT11



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APPENDIX 2. The flow map of PT17

1. Protein synthesis is the synthesis of RNA from DNA and then the synthesis of proteins.
2. After the replication of DNA, the mRNA is obtained.
3. Protein synthesis is necessary for living organisms. Living organisms perform protein synthesis to meet their needs.
4. Replicated DNA pieces go through transcription and then turn into RNA.
5. Then, mRNA chain goes out of nucleus pores.
6. At this stage of protein synthesis, tRNA (transfer RNA) performs duty.
7. It is the structure making it possible to carry amino acids here while mRNA is read on tRNA.

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