European Journal of Educational Research
Volume 6, Issue 4, 495 - 508.
ISSN: 2165-8714
http://www.eu-jer.com/

Evaluation of the Concepts and Subjects in Biology Perceived to be Difficult to Learn and Teach by the Pre-Service Teachers Registered in the Pedagogical Formation Program

Sema Nur Gungor *
Uludag University, TURKEY

Muhlis Ozkan
Uludag University, TURKEY

Received: August 8, 2017 ▪ Revised: October 5, 2017 ▪ Accepted: October 10, 2017

Abstract: This study examines the subjects and concepts in biology perceived to be difficult to learn and teach by 759 pre-service biology teachers registered in the pedagogical formation program at Uludag University Faculty of Education in the academic year of 2005-2016, as well as the associations that word "biology" first calls to their mind. The study was designed as a survey model, and a questionnaire of three scaled questions was used as a data collection tool. The data were classified into 10 different categories based on different branches of biology: Anatomy-Morphology, Biotechnology, Ecology, Evolution, Physiology, Genetics, Histology, Cytology, Systematics and Reproduction and Development. Following the classification, the data were analyzed using frequency and percentages. The subjects and concepts perceived to be difficult to learn by the pre-service teachers are respectively as follows: photosynthesis and its stages, genetics, circulatory system, aerobic respiration, respiratory system, anaerobic respiration, protein synthesis, phanerogams, DNA structure and function, cryptogams, mitosis, plant systematics, endocrine system, meiosis, ETC, urinary system, plant physiology, taxonomy, evolution and digestive system. The subjects and concepts perceived to be difficult to teach by the pre-service teachers are respectively as follows: photosynthesis and its stages, protein synthesis, circulatory system, endocrine system, meiosis, plant systematics, evolution, mitosis, reproduction, genetic crossing over problems, Latinization of names, urinary system, genetics, ecology, aerobic respiration, DNA structure and function, plant tissues, glycolysis and anaerobic respiration. These findings confirm the need for developing undergraduate programs in biology and promoting the research culture at the secondary education level.

Keywords: *Biology, learning difficulties, pedagogical formation, teaching difficulties*

To cite this article: Gungor, S. N., & Ozkan, M. (2017). Evaluation of the concepts and subjects in biology perceived to be difficult to learn and teach by the pre-service teachers registered in the pedagogical formation program. *European Journal of Educational Research*, *6*(4), 495-508. doi: 10.12973/eu-jer.6.4.495

Introduction

By its comprehensive content and nature, the discipline of biology has close relations with the other disciplines and has to preserve and sustain these relations in an effective way. Since the field is developing rapidly in today's world, it is necessary to make up new terms. Therefore, the discipline is developing and prospering each passing day. This leads to the emergence of some new challenges in learning and teaching the subjects and concepts in biology. It is known that failure in associating some perceptions of daily life with the scientific knowledge network affects and even nurtures learning and teaching difficulties and misconceptions.

The broad and complicated pattern of content knowledge, together with teachers' lack of pedagogical knowledge, shows that the difficulties cannot be overcome only through identifying them or teaching certain subjects and concepts by using various methods. Besides, having pedagogical content knowledge does not really meet this need. This helical structure and some other dilemmas make it even harder to overcome the difficulties experienced in biology teaching and turn them into a collection of problems.

The presence of many terms about life and living organisms in the colloquial language and the use of these terms in a meaning other than their defined scientific equivalent can be said to be among the problems that make learning and teaching difficult.

* **Corresponding author:**
Sema Nur Gungor, Faculty of Education, Department of Science Education, Uludag University, Turkey.
Email: semanur.gungor@hotmail.com

The text contents included in the sources used as a teaching tool at the undergraduate level, the presentation techniques used for teaching them and the activities carried out or planned to be carried out using such visual materials as tables, figures and images all show that great efforts must be made to reach the expected level in biology teaching in Turkey.

It is clear that a teacher with insufficient competence in the field will have difficulties in putting the teaching methods into practice. The structure of biological events and the functional processes provide the suitable basis for experiencing learning and teaching difficulties.

It is not easy to train competent teachers, trainers or field researchers through a training where the trainees do not perceive holistically some biological events, phenomena and processes which have not been understood, have been insufficiently explained or are not permanent. However, it should be reminded that regular and continuous efforts must be made to overcome this situation at the higher education level.

The studies in the literature on secondary education report that students fail or have difficulty in learning, and even understanding some of the subjects in biology (Chuang & Cheng, 2003; Pelaez, Boyd, Rojas & Hoover, 2005; Sebitosi, 2007; Yesilyurt & Gul, 2012). This finding also corresponds to a great extent to the data collected from the pre-service teachers who graduated from a bachelor's degree program. Some special teaching methods can be helpful to overcome the difficulties experienced in learning certain subjects and concepts. To do so, it is necessary to take some measures at the undergraduate level.

This study aims to point out the necessity to pay more attention at the undergraduate level to various subjects and concepts which are perceived as difficult to teach and learn by the pre-service biology teachers registered to the pedagogic formation program and are not easy or even not possible to be compensated through in-service training. Therefore, we are of the opinion that the relevant institutions and organizations must be informed of the necessity to take action, so that theoretical and practical dilemmas which are nurtured by the teaching deficiencies and misperceptions at the undergraduate level that resulted from the very nature of subjects can be corrected without any delay.

Methodology

The descriptive survey model, a quantitative research model that aims to describe a past or present event without any change, was used in this study (Karasar, 2005).

In the study, the data were obtained using three questions designed to identify the *subjects and concepts perceived to be difficult to learn and teach by the pre-service teachers* and to determine *the associations that word "biology" first calls to their mind.* The answers were collected in a minute. It was ensured that they covered 10 subjects or concepts which did not have very close relation, or had weak thematic relation with each other. The sample of the study included 759 pre-service teachers (303 male, 429 female and 27 anonymous) who graduated from a Biology program at a university in Turkey in the last 10 years and registered in the Pedagogical Formation Program at Uludag University Faculty of Education in the 2005-2016 academic year.

Data Analysis

During the data analysis, the answer sheets of the participants were numbered from 1 to 759. The answer sheets of 17 pre-service teachers were called invalid on account of the fact that the answers were irrelevant. Therefore, they were not included in the analysis. The data obtained from 742 pre-service teachers were classified into 10 main categories: "*Anatomy-Morphology*", "*Biotechnology*", "*Ecology*", "*Evolution*", "*Physiology*", "*Genetics*", "*Histology*", "*Cytology*", "*Systematics*", "*Reproduction and Development*". Then the answers were analyzed using frequency and percentages.

Validity and Reliability

The data collection tool was submitted to a science teacher, two field trainers and a faculty member from the biology department for approval. The validity of the data was ensured upon approval of them. The answer sheet was organized in a way to allow for writing each answer on a separate line. The purpose of such organization was to ensure that each answer was affected from the previous or other answers as less as possible, and the data were as reliable as possible. Then the answers were listed and classified by the researchers based on the correlation between them, and draft themes were identified. The percentage of agreement of the themes and sub-themes was found to be 86.4% (Miles & Huberman, 1994). The groups which were not agreed upon were reviewed and the analysis was ended when all groups were agreed upon by the researchers.

Findings

In this section, the pre-service teachers were asked about the associations that word "biology" first calls to their mind and a total of 1,891 answers were collected. The answers were found to consist of 209 different subjects and concepts. Table 1 shows the top 20 answers based on frequency and percentage.

Table 1.Subjects or Concepts that the Word "Biology" First Calls to Mind

	Subjects or concepts that the word "Biology" first calls to mind	f	%
1	Cell	35	1.85
2	Genetics	28	1.48
3	Photosynthesis	26	1.37
4	DNA	21	1.11
5	Gene	20	1.06
6	Tissue	19	1.01
7	Living organisms	18	0.95
8	Species	18	0.95
9	Urinary system	17	0.9
10	Circulatory system	17	0.9
11	Ecology	17	0.9
12	Evolution	17	0.9
13	Reproduction	17	0.9
14	Krebs cycle	16	0.85
15	Vertebrates	16	0.85
16	Digestive system	16	0.85
17	Plants	16	0.85
18	Meiosis	15	0.79
19	Aerobic respiration	15	0.79
20	Protein synthesis	15	0.79

The answers of the pre-service teachers were found to be related to *cell* (1.85%), *genetics* (1.48%), *photosynthesis* (1.37%), *DNA* (1.11%), *gene* (1.06%), *tissue* (1.01%), *living organisms and species* (0.95%), *urinary system*, *circulatory system*, *ecology*, *evolution* and *reproduction* (0.9%), *Krebs cycle*, *vertebrates*, *digestive system* and *plants* (0.85%) and *meiosis*, *aerobic respiration* and *protein synthesis* (0.79%), respectively (Table 1).

The pre-service teachers were asked about the subjects and concepts in biology that they had difficulty in learning and teaching. 1561 answers included subjects and concepts perceived as difficult to learn, while 1410 answers included those perceived as difficult to teach. The answers were found to consist of 80 different subjects and concepts. They were classified into 10 main categories: "*Anatomy-Morphology*", "*Biotechnology*", "*Ecology*", "*Evolution*", "*Physiology*", "*Genetics*", "*Histology*", "*Cytology*", "*Systematics*", "*Reproduction and Development*". Table 2 shows the subjects and concepts listed based on frequency and percentage.

Table 2.Subjects and Concepts that the Pre-service Biology Teachers Have Difficulty in Learning and Teaching

	Subjects and concepts perceived to be difficult to learn	f	%	Subjects and concepts perceived to be difficult to teach	f	%
Anatomy-Morphology	Plant Anatomy	15	0.96	Plant Anatomy	18	1.28
	Plant Morphology	13	0.83	Plant Morphology	19	1.35
Biotechnology	Gene Technology	4	0.26	Radiobiology	7	0.49
	Radiobiology	3	0.19	Gene Technology	6	0.43
	Ecology	21	1.35	Ecology	27	1.92
	Nitrogen cycle	16	1.03	Nitrogen cycle	8	0.57
	Carbon cycle	15	0.96	Carbon cycle	7	0.49
Evolution	Evolution	25	1.6	Evolution	41	2.91

Continued Table 4.

	Subjects and concepts perceived to be difficult to learn	f	%	Subjects and concepts perceived to be difficult to teach	f	%
Physiology	Photosynthesis and its stages	132	8.46	Photosynthesis and its stages	141	10
	Circulatory system	78	4.99	Circulatory system	59	4.19
	Respiratory system	62	3.97	Endocrine system	56	3.97
	Endocrine system	37	2.37	Urinary system	30	2.13
	Urinary system	35	2.24	Digestive system	30	2.13
	Plant Physiology	33	2.12	Reproduction system	23	1.63
	Digestive system	25	1.6	Respiratory system	22	1.56
	Neural System	25	1.6	Plant Physiology	20	1.42
	Hormones	19	1.22	Neural System	19	1.35
	Enzymes	17	1.09	Enzymes	16	1.14
	Sense organs	15	0.96	Biochemical reactions	15	1.06
	Musculoskeletal system	12	0.77	Musculoskeletal system	12	0.85
	Water transport in plants	11	0.71	Support and movement system	10	0.71
	Systems	9	0.58	Systems	10	0.71
	Reproduction system	8	0.51	Respiratory reactions	9	0.64
	Biochemical reactions	7	0.45	Water transport in plants	8	0.57
	Chemosynthesis	6	0.38	Immune system	6	0.43
	Urea cycles	5	0.32	Sense organs	6	0.43
	Respiratory reactions	4	0.26	Hormones	4	0.28
	Metabolism	2	0.12	Metabolism	3	0.21
	Support and movement system	2	0.12	Chemosynthesis	3	0.21
	Immune system	1	0.06	Urea cycles	2	0.14
Genetics	Genetics	111	7.11	Protein synthesis	66	4.68
	Protein synthesis	51	3.27	Meiosis	53	3.76
	DNA structure and function	42	2.69	Genetic crossing over problems	36	2.55
	Meiosis	37	2.37	Genetics	30	2.13
	Genetic crossing over problems	25	1.6	DNA structure and function	25	1.77
	Crossing-over	13	0.83	Crossing-over	15	1.06
	The concept of gene	11	0.71	The concept of gene	10	0.71
	RNA	6	0.38	Mendelian inheritance	8	0.57
	Blood groups	5	0.32	Hereditary diseases	7	0.49
	Mendelian inheritance	3	0.19	Blood groups	6	0.43
	Translocation	3	0.19	RNA	4	0.28
	Hereditary diseases	2	0.12	Family tree	2	0.14
	Chromosome	1	0.06	Chromosome	1	0.07
	Family tree	1	0.06	Translocation	1	0.07
Histology	Plant tissues	21	1.35	Plant tissues	25	1.77
	Animal tissues	19	1.22	Animal tissues	23	1.63

Continued Table 4.

	Subjects and concepts perceived to be difficult to learn	f	%	Subjects and concepts perceived to be difficult to teach	f	%
Cytology	Aerobic respiration	65	4.17	Mitosis	41	2.91
	Anaerobic respiration	52	3.34	Aerobic respiration	26	1.85
	Mitosis	39	2.5	Glycolysis	24	1.7
	ETC	37	2.37	Anaerobic respiration	24	1.7
	Glycolysis	21	1.35	ETC	13	0.92
	ATP synthase	19	1.22	Organic compounds	10	0.71
	Proteins	7	0.45	Amino acids	8	0.57
	Fats	7	0.45	ATP	6	0.43
	Surface tension of water	4	0.26	Proteins	5	0.35
	Amino acids	3	0.19	Fats	4	0.28
	Cell	1	0.06	Cell	3	0.21
	Organic compounds	1	0.06	Surface tension of water	1	0.07
Systematics	Phanerogams	47	3.01	Plant systematics	52	3.69
	Cryptogams	40	2.56	Latinization of names	32	2.27
	Plant systematics	38	2.44	Phanerogams	22	1.56
	Taxonomy	30	1.92	Cryptogams	21	1.49
	Invertebrates	25	1.6	Entomology	11	0.78
	Latinization of names	15	0.96	Invertebrates	11	0.78
	Algaes	10	0.64	Taxonomy	10	0.71
	Vertebrates	10	0.64	Algaes	8	0.57
	Entomology	8	0.51	Botany	7	0.49
	Bacteria	5	0.32	Vertebrates	7	0.49
	Viruses	5	0.32	Microbiology	6	0.43
	Botany	4	0.26	Bacteria	4	0.28
	Protozoa	4	0.26	Protozoa	3	0.21
	Microbiology	3	0.19	Viruses	3	0.21
Reproduction and Development	Reproduction in cryptogams	17	1.09	Reproduction	37	2.63
	Plant life cycle	11	0.71	Plant life cycle	16	1.14
	Reproduction	9	0.58	Sexual reproduction	13	0.92
	Sexual reproduction	7	0.45	Asexual reproduction	13	0.92
	Asexual reproduction	5	0.32	Reproduction in cryptogams	10	0.71
	Embryology	3	0.19	Embryology	9	0.64
	Plant embryology	1	0.06	Plant embryology	1	0.07
Total		1561	100		1410	100

The findings show that the subjects and concepts perceived to be difficult to learn by the pre-service teachers are respectively as follows: *Photosynthesis and its stages* (8.46%), *genetics* (7.11%), *circulatory system* (4.99%), *aerobic respiration* (4.17%), *respiratory system* (3.97%), *anaerobic respiration* (3.34%), *protein synthesis* (3.27%), *phanerogams* (3.01%), *structure and features of DNA* (2.69%), *cryptogams* (2.56%), *mitosis* (2.5%), *plant systematics* (2.44%), *endocrine system* (2.37%), *meiosis* (2.37%), *ETC* (2.37%), *urinary system* (2.24%), *plant physiology* (2.12%), *taxonomy* (1.92%), *evolution* (1.6%) and *digestive system* (1.6%). Table 2 shows all of the answers received from the pre-service teachers.

The subjects and concepts perceived to be difficult to teach by the pre-service teachers are respectively as follows: *Photosynthesis and its stages* (10%), *protein synthesis* (4.68%), *circulatory system* (4.19%), *endocrine system* (3.97%), *meiosis* (3.76%), *plant systematics* (3.69%), *evolution* (2.91%), *mitosis* (2.91%), *reproduction* (2.63%), *genetic crossing over problems* (2.55%), *Latinization of names* (2.27%), *urinary system* (2.13%), *digestive system* (2.13%), *genetics* (2.13%), *ecology* (1.92%), *aerobic respiration* (1.85%), *structure and features of DNA* (1.77%), *plant tissues* (1.77%), *glycolysis* (1.7%) and *anaerobic respiration* (1.7%). Table 2 shows these answers and all other answers received from the pre-service teachers.

Table 3. The Top 20 Subjects and Concepts that the Pre-service Biology Teachers Have Difficulty in Learning and Teaching

	Subjects and concepts perceived to be difficult to learn	f	%	Subjects and concepts perceived to be difficult to teach	f	%
1	Photosynthesis and its stages	132	8.46	Photosynthesis and its stages	141	10
2	Genetics	111	7.11	Protein synthesis	66	4.68
3	Circulatory system	78	4.99	Circulatory system	59	4.19
4	Aerobic respiration	65	4.17	Endocrine system	56	3.97
5	Respiratory system	62	3.97	Meiosis	53	3.76
6	Anaerobic respiration	52	3.34	Plant systematics	52	3.69
7	Protein synthesis	51	3.27	Evolution	41	2.91
8	Phanerogams	47	3.01	Mitosis	41	2.91
9	Structure and features of DNA	42	2.69	Reproduction	37	2.63
10	Cryptogams	40	2.56	Genetic crossing over problems	36	2.55
11	Mitosis	39	2.5	Latinization of names	32	2.27
12	Plant systematics	38	2.44	Urinary system	30	2.13
13	Endocrine system	37	2.37	Digestive system	30	2.13
14	Meiosis	37	2.37	Genetics	30	2.13
15	ETC	37	2.37	Ecology	27	1.92
16	Urinary system	35	2.24	Aerobic respiration	26	1.85
17	Plant Physiology	33	2.12	Structure and features of DNA	25	1.77
18	Taxonomy	30	1.92	Plant tissues	25	1.77
19	Evolution	25	1.6	Glycolysis	24	1.7
20	Digestive system	25	1.6	Anaerobic respiration	24	1.7

According to Table 3, the following 14 subjects and concepts ranked in the top 20 subjects and concepts perceived as difficult both to learn and teach: *photosynthesis and its stages*, *genetics*, *circulatory system*, *aerobic respiration*, *anaerobic respiration*, *protein synthesis*, *structure and features of DNA*, *mitosis*, *plant systematics*, *endocrine system*, *meiosis*, *urinary system*, *evolution* and *digestive system.* This finding indicates that the subjects and concepts perceived to be difficult to learn and teach overlap to a great extent. Besides, *reproduction* and *reproduction system* were in the top 20 subjects and concepts perceived to be difficult to teach, while they ranked in a lower position in the list of the subjects and concepts perceived to be difficult to learn (Table 3).

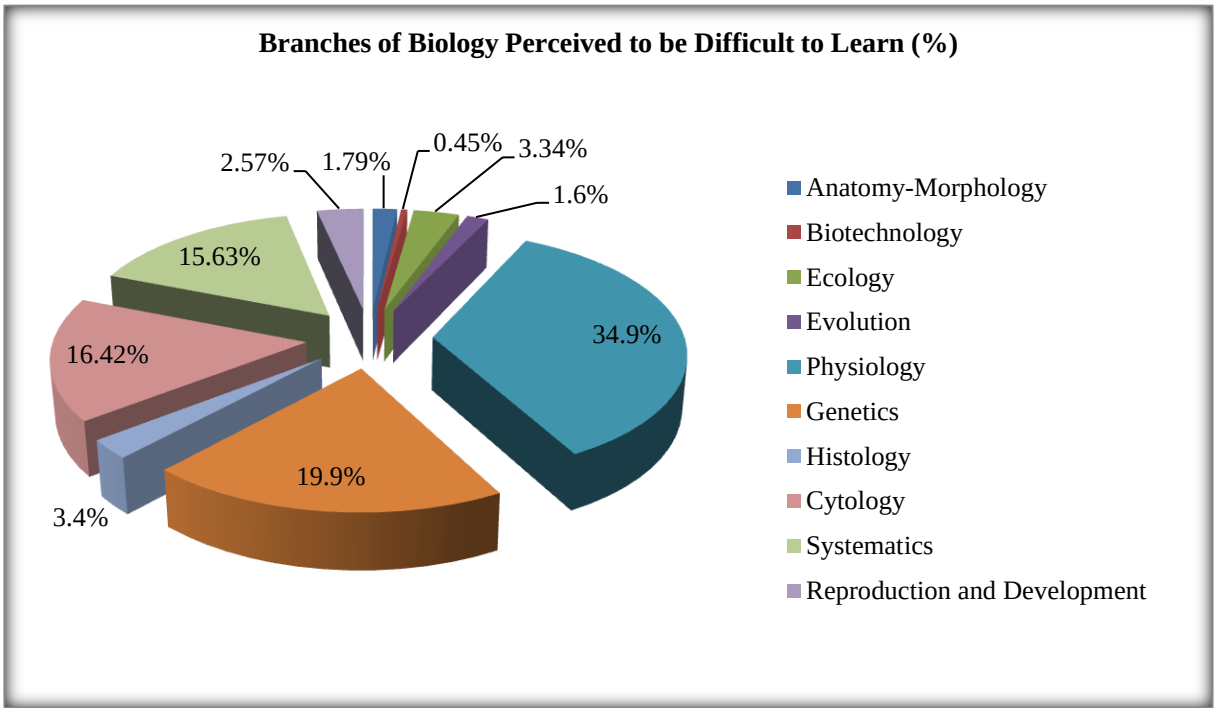

Figure 1. Distribution of the Subjects and Concepts Perceived to be Difficult to Learn by the Branches of Biology

According to Figure 1, the branches perceived to be difficult to learn are respectively as follows: *Physiology* (34.9%), *Genetics* (19.9%), *Cytology* (16.42%), *Systematics* (15.63%), *Reproduction and Development* (3.4%), *Ecology* (3.34%), *Histology* (2.57%), *Anatomy and Morphology* (1.79%), *Evolution* (1.6%) and *Biotechnology* (0.45%).

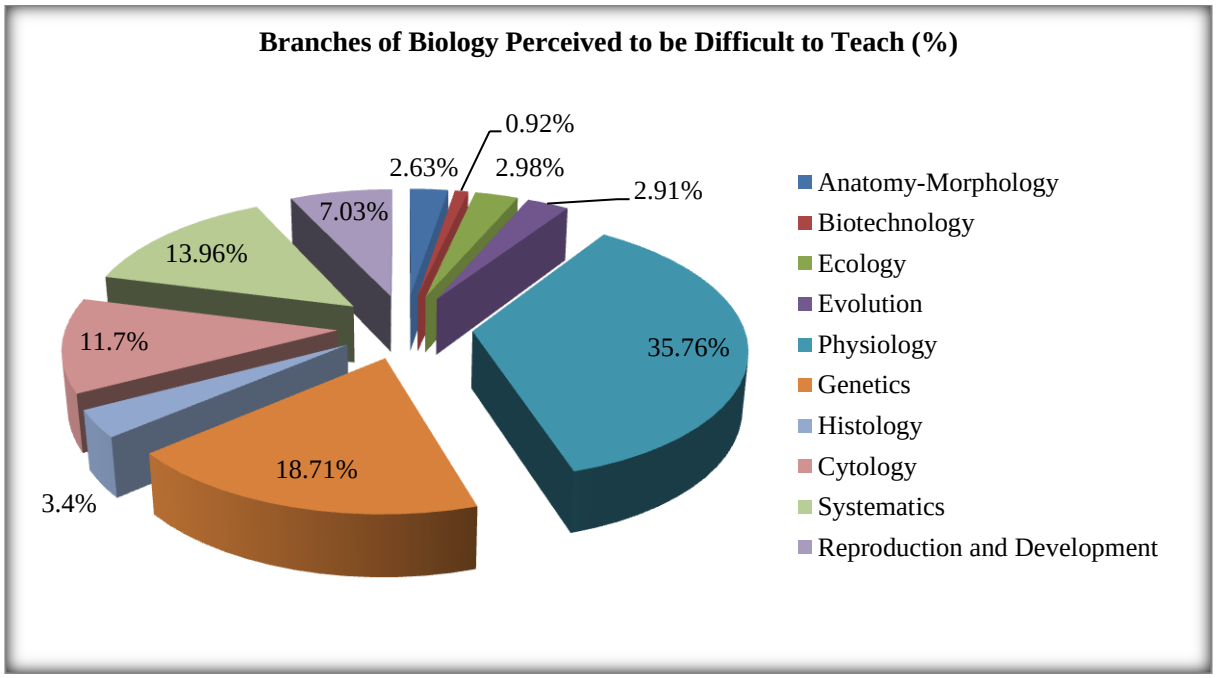

Figure 2. Distribution of the Subjects and Concepts Perceived to be Difficult to Teach by the Branches of Biology

According to Figure 2, the branches perceived to be difficult to teach are respectively as follows: *Physiology* (35.76%), *Genetics* (18.71%), *Systematics* (13.96%), *Cytology* (11.7%), *Reproduction and Development* (7.03%), *Histology* (3.4%), *Ecology* (2.98%), *Evolution* (2.91%), *Anatomy-Morphology* (2.63%) and *Biotechnology* (0.92%).

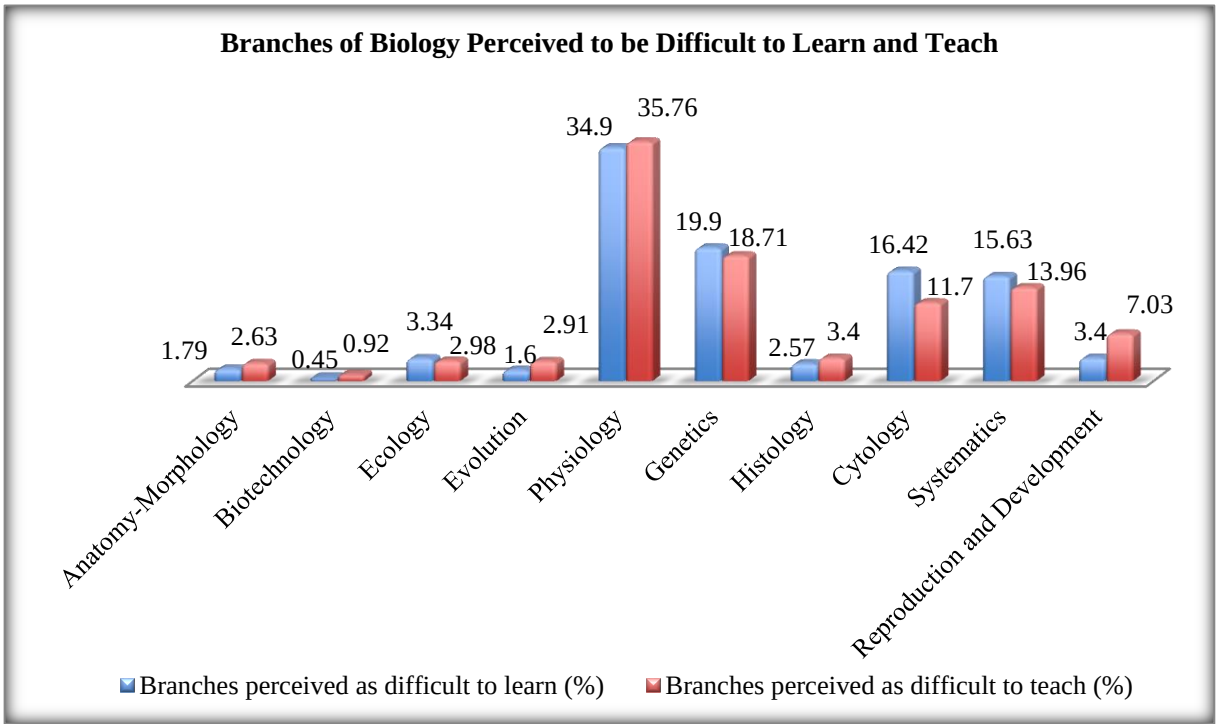

Figure 3. Distribution of the Subjects and Concepts Perceived to be Difficult to Learn and Teach by the Branches of Biology

According to Figure 3, the subjects and concepts perceived to be difficult to learn and teach are related to the following branches: *Anatomy-Morphology* (1.79/2.63%), *Biotechnology* (0.45/0.92%), *Ecology* (3.34/2.98%), *Evolution* (1.6/2.91%), *Physiology* (34.9/35.76%), *Genetics* (19.9/18.71%), *Histology* (2.57/3.4%), *Cytology* (16.42/11.7%), *Systematics* (15.63/13.96%), *Reproduction and Development* (3.4/7.03%).

Discussion and Conclusion

This study showed that the pre-service teachers who graduated from Biology programs at different universities in Turkey and registered to Pedagogical Formation program to become a biology teacher felt incompetent and had difficulty in 80 subjects and concepts in biology. This reveals tangibly that higher education in Turkey must be questioned at the undergraduate level. It is evident that the pre-service teachers who do not feel competent and equipped in the field have difficulty in achieving job satisfaction and the goals determined by the Secondary Biology Education Programs.

The pedagogical formation program covers evaluation of content knowledge, theoretical and practical knowledge about the field and the knowledge about the curriculum and management. Among these, the lack of content knowledge is extremely important for the pre-service teachers. Moreover, it is known that the challenges resulting from incorrect approaches in daily life, the misuses of concepts nurtured in and out-of-school learning environment, the ambiguities and the theoretical knowledge in the course books together with the preferred activities make the practice of teaching even more difficult. Therefore, the deep-rooted misperceptions in the field of biology seem more difficult to overcome compared to the other disciplines.

In this study, the subjects and concepts that word "biology" first calls to mind are listed as follows: *cell-genetics-photosynthesis-DNA-gene-tissue-living organisms-species-urinary system-circulatory system-ecology-evolution-reproduction-Krebs cycle-vertebrates-digestive system-plants-meiosis-aerobic respiration-protein synthesis* (Table 1). We can say that these are actually the subjects and concepts which were elaborated on by the pre-service teachers during their undergraduate studies and reinforced through a set of superficial revisions by adopting various teaching approaches in their later years. We are of the opinion that solutions to the challenges experienced in teaching the subjects and concepts which are lack of effective and deep learning and perceived as difficult to be associated with daily life must be looked for in the undergraduate education.

It is important to note that some common features shared by living organisms were not among the subjects and concepts that word "biology" first brings to the mind of pre-service teachers. Failure to perceive some common features of living organisms such as organization, hereditary information, reproduction, movement, metabolism, variation, excitability, evolution, development, diversification and having a certain chemical array and cellular structure as a whole seems as an important lack (Campbell & Reece, 2006; Czihak, 1984). It is possible to observe this from the courses offered in various undergraduate programs in Turkey, the course hours, theoretical and practical course contents which are published even partially and the scientific knowledge of the lecturers and faculty members about the field.

The institutions offering biology education must assume important responsibilities for turning the biologists trained with a point of view that discards details about the transitive and immersive compounds of the subjects and concepts in biology into modern individuals who can follow the developments both as a researchers and a teacher. The table constructed in this study allows us to see that individuals may have a good knowledge of and feel competent in some subjects and concepts, while there may also be subjects and concepts that they wonder about or have no idea of. This study does not dwell on the projection or reflection of the cognitive event or phenomena which led to the preparation of such a table.

The top 20 subjects and concepts perceived to be difficult to learn by the pre-service were found to be *photosynthesis and its stages*, *genetics*, *circulatory system*, *aerobic respiration*, *respiratory system*, *anaerobic respiration*, *protein synthesis*, *phanerogams*, *structure and features of DNA*, *cryptogams*, *mitosis*, *plant systematics*, *endocrine system*, *meiosis*, *ETC*, *urinary system*, *plant physiology*, *taxonomy*, *evolution* and *digestive system*, respectively (Table 3).

Photosynthesis and its stages, genetics, respiration, endocrine system and *circulatory system* came to mind as the first subjects and concepts perceived as difficult to learn and teach by the pre-service teachers. There are studies reporting that elementary and secondary school students have difficulty in understanding *photosynthesis* and *respiration* which are among the basic biology subjects that are hard to understand (Anderson, Sheldon & Dubay, 1990; Capa, 2000; Eisen & Stavy, 1988; Gunes, Sener Dilek, Hoplan & Gunes, 2014; Haslam & Treagust, 1987; Kose, Ayas & Usak, 2006; Ozay, 2001; Sensoy, Aydogdu, Yildirim, Usak & Hancer, 2005; Tekkaya & Balci; 2003). This also holds true for the undergraduate education and even for the period after graduation. We think that such difficulty in understanding is resulted from the teaching method, rather than the incomprehensible nature of the subjects. Such problems experienced by the pre-service teachers will obviously reflect on the teaching processes in the later years in a different way.

On the other hand, developments regarding the solution of environmental and health problems increase the importance of genetics education day by day (March-Ad, 2001). New developments in organ transplantation,

genetically modified organisms, gene therapy, human genome mapping, microorganism genetics, external fertilization and cancer might also be the reasons for having learning and teaching difficulties (Hurd DeHard, 1998; Uzun & Saglam, 2005). In order for the individuals to understand the studies in the field of biotechnology, they should have the basic knowledge of genetics and the related concepts, and should make correct interpretations by linking these concepts (Deboer, 1991; Tatar & Cansungu Koray, 2005). We believe that it is impossible for the pre-service teachers to attain the expected success without overcoming the difficulties experienced in teaching such new subjects and concepts. Thus, this should be understood and necessary measures must be taken in this regard.

Despite the vigorous efforts made for the elementary, secondary and higher education students, it is known that they have difficulty in understanding what hereditary information is and how it is preserved and passed on, and in solving heredity-related problems (Bahar, Johnstone & Sutcliffe, 1999; Cingil-Baris & Kirbaslar, 2015; Ekici, Ekici & Aydin, 2007; Gul, Ozay-Kose & Konu, 2014; Lewis, Leach & Wood-Robinson, 2000a; Lewis, Leach & Wood-Robinson, 2000b; Ozyilmaz-Akamca & Hamurcu, 2009; Saka, Cerrah, Akdeniz & Ayas, 2006; Sasmaz-Oren, Ormanci, Karatekin & Erdem, 2010; Tatar & Koray, 2005; Temelli, 2006). The findings of this study are in conformity with those of the previous studies. Some of the reasons why genetics is hard to learn and teach are as follows: the abstract nature of the subject matter; it is only possible to monitor or assess the subject using a continuum that contains both the previous and future generations; presence of abstract concepts; the concepts seem functionally and structurally similar; the subject covers relations between the events that occur at different levels; the subject requires examination of events that occur very fast or very slowly and cannot be observed directly; construction of wrong schemas on cognitive structures of the students; the subject matter is not suitable for performing an experiment (Bahar, Johnstone & Hansell, 1999; Cakir & Aldemir, 2011; Enrique & Enrique, 2000; Karagoz & Cakir, 2011; Tekkaya, Capa & Yilmaz, 2000). Since the pre-service teachers learn the concepts of genetics only by imagining and saving, they may be incapable of learning and associating them with other concepts, just like the elementary and secondary school students (Kilic & Saglam, 2004; Oztas & Oztas, 1998; Saka, 2006). We believe that the education provided to the pre-service teachers during their undergraduate studies is responsible for the existence of such problems in elementary and secondary education. Therefore, it is necessary to develop new teaching materials and feature teaching methods and approaches that could make the pre-service teachers learn the information provided to them in the course in a permanent and correct way, and could maintain their interest in the course.

There are some other studies, just like this study, reporting that endocrine system comes to the forefront as a subject which is difficult to understand (Gunes & Gunes, 2005; Ozcan, Ozgur, Kat & Elgun, 2013; Tekkaya et al., 2000). It is important to correctly learn the regulatory and supervisory function of the endocrine system and the structural features of the organs that take part in it. In this way, regulation of many metabolic events, together with the neural and muscular system, and even the structural differentiation of some physiological incidents in the developmental biology can be understood. It also helps the pre-service teachers teach the endocrine system correctly as well as understanding many other subjects in biology.

The top 20 subjects and concepts perceived to be difficult to teach by the pre-service teachers are respectively as follows: *photosynthesis and its stages*, *protein synthesis*, *circulatory system*, *endocrine system*, *meiosis*, *plant systematics*, *evolution*, *mitosis*, *reproduction*, *genetic crossing over problems*, *Latinization of names*, *urinary system*, *digestive system*, *genetics*, *ecology*, *aerobic respiration*, *structure and features of DNA*, *plant tissues*, *glycolysis* and *anaerobic respiration* (Table 3).

One of the subjects perceived to be difficult to teach is *protein synthesis*. Subjects such as movement of substance through a cell membrane, cell division and protein synthesis involve certain processes that include a great number of concepts and intra-conceptual relations. Such processes are not stationary and need to be updated continuously due to the nature of the relations. Besides, such processes involve a series of incidents that take place at a molecular level. Due to the changing and abstract structure of the subject, pre-service teachers have some difficulties in animating the mechanism and elements of *protein synthesis* only by using regular expressions, figures and images (Kasapoglu, 2011; Marbach-Ad & Stavy, 2000). On the other hand, *protein synthesis* ranked seventh among 80 subjects and concepts perceived to be difficult to learn, and second among those perceived to be difficult to teach, which we believe should be elaborated in terms of the teaching method (Table 3). This also indicates the existence of another discrepancy between the students and the pre-service teachers. A subject which is particularly difficult for the students to understand moved up the list of the subjects perceived as a little difficult to learn, but hard to teach by the pre-service teachers, which is a finding in conformity with the other findings in the literature. A study by Tekkaya et al (2000) reported that protein synthesis ranked sixth among 30 subjects perceived by the students as the most difficult subject to understand with a rate of 26.9%. In this study, protein synthesis ranked first and second among the subjects in the field of genetics perceived by the pre-service teachers as difficult to teach and learn, respectively (Table 2). The reasons for having difficulty can be listed as follows: the subject is in relation to other disciplines other than biology; the subject cannot be associated with daily life; failure to construct a sufficient cognitive infrastructure for the subject; proteins are

incorporated into the structure of hormones, enzymes and pheromones and they are used as a source of energy and function as receivers (Sinan, Yildirim, Kocakulah & Aydin, 2006; Yakisan, 2008).

Mitosis, one of the cytology subjects, ranked second among the subjects perceived as difficult to learn and first among those perceived as difficult to teach. We can see that the relationship between learning difficulty and teaching difficulty has been reflected as expected. Yakisan's study (2008) reported that cell division was among the subjects perceived to be difficult to learn. In terms of teaching, the events involved in cell division occur at the microscopic level and contain many concepts, thus making the subject more difficult to understand (Bahar, Johnstone & Hansell, 1999; Emre & Bahsi, 2006; Kilic & Saglam, 2004; Tasci & Soran, 2008; Tekkaya, Ozkan & Sungur, 2001). There are many misperceptions about cell division that play an important role in the creation of scientific resistance thresholds for learning and teaching (Atilboz, 2004; Tekkaya et al., 2000). However, this study does not involve questioning the reason why this field of biology which has been regarded as a basic biological science and incorporated in the curriculum of elementary, secondary and higher education institutions is perceived to be difficult to learn.

Evolution ranked nineteenth among the subjects perceived to be difficult to learn and seventh among the subjects perceived to be difficult to teach, which is a finding indicating an important difference (Table 3). This finding also points out that, although the subjects related to evolutionary relations, theory, evidence and mechanisms are easy to understand, teachers still have difficulty in teaching the subject due to the problem of social acceptance and social sensitivity about the subject. Especially the approach of the teachers is known to be important in teaching evolution (Kilic, 2012). It is also known that evolution is a special subject in biology teaching and teaching evolution can be problematic in Turkey. Besides, the subject was brought up for discussion through scientific meetings (Ergezen, 2007; Kilic, Soran & Graf, 2011; Ozyeral-Bakanay, 2008).

Among the subjects of *Anatomy-Morphology*, only *plant tissue* was reported to be perceived by the pre-service teachers as difficult to learn and teach to the same degree. However, the subject did not rank in the top 20 subjects and concepts perceived as difficult to learn, while ranking 18th (Table 3) among those perceived as difficult to teach. *Plant tissue* is among the subjects that are hard to understand in the second stage of elementary school, which is the result of the lack of performing experiments and using visual tools and equipment as well as the subject being based on memorization, rather than the incompetency of the teachers (Gunes & Gunes, 2005).

The study found that the following 14 subjects ranked in the top 20 subjects and concepts perceived as difficult both to learn and teach: *photosynthesis and its stages*, *genetics*, *circulatory system*, *aerobic respiration*, *anaerobic respiration*, *protein synthesis*, *structure and features of DNA*, *mitosis*, *plant systematics*, *endocrine system*, *meiosis*, *urinary system*, *evolution* and *digestive system.* It was observed that the subjects and concepts perceived to be difficult to learn and teach overlap to a great extent. However, their ranks were different due to the difference in their frequencies (Table 3). Moreover, *reproduction* and *reproduction system* were in the top 20 subjects and concepts perceived to be difficult to teach, while they ranked in a lower position in the list of subjects and concepts perceived to be difficult to learn. It was also observed that the pre-service teachers had little difficulty in learning the subjects within the scope of *reproduction and development*. The sub-themes *reproduction in cryptogams* (1.09%) and *plant life cycle* (0.71%) were ranked higher among the subjects in the branch *reproduction and development* (Table 2). However, they were not in the top 20 (Table 3) and had a higher rate of being perceived as difficult to teach. The pre-service teachers reported that they had difficulty in teaching *reproduction* (2.63%) and covering the subject of *plant life cycle* (1.14%). These rates are not realistic and the reproduction and development mechanisms are both hard to understand and express. Besides, the mechanisms within the scope of this subject are both difficult to learn and teach in the elementary and secondary education as well as the higher education. Therefore, it is known that there is a need to design new teaching methods intended to solve this problem. The studies about this are still ongoing (Korkut, 2000; Zeren, 2005).

Distributions of the answers of the pre-service teachers by the branches of biology seem to be in conformity with each other. It is noteworthy that the branches perceived as difficult to learn and teach are centered on the explanations about the mechanisms in *Physiology, Genetics, Systematics* and *Cytology* and on understanding of the order introduced by the basic approaches of *systematics*. Especially the failure in fully understanding the terms used in *Genetics* and *Physiology*, together with the development of new theoretical concepts, leads to the emergence of new challenges. Besides, this study revealed that the pre-service teachers had most difficulty in teaching the subjects and concepts of *Anatomy-Morphology*, *Biotechnology*, *Evolution*, *Physiology*, *Histology*, *Reproduction and Development* and in learning the subjects and concepts of *Ecology*, *Genetics*, *Cytology* and *Systematics.* The reason for the little difference between the difficulty rates is another important point to note (Figure 3).

Since there is no study in the literature which examines the difficulties experienced by the pre-service teachers in teaching and learning most of the 80 different subjects and concepts in biology perceived to be difficult to teach and learn, this study was limited to a survey study and some generalizations about the main reasons of having difficulties. Indeed, the difficulties experienced by the pre-service teachers indicate that undergraduate programs must be

questioned and the gaps in teaching certain concepts must be filled. This problem is also ongoing at the undergraduate level, pointing out that Turkey has a serious issue with the field of biology.

Given the time and efforts spent in teaching these subjects and concepts which have an important place in the high school curriculum, obtaining such findings reveals the necessity of taking some measures at the undergraduate level in Turkey.

Obviously, it is not easy to train researchers to study in this field and its sub-fields which are hard to teach. The learning deficiencies and the misperceptions gained during learning lead to even greater gaps and problems in teaching. We believe that solutions like in-service trainings or similar approaches and allocating time and resources for them will not be sufficient to fill this gap.

It is probable that this situation will turn into a can of worms when the graduates of related programs are appointed as teachers or those who graduated from different programs are involved in biology teaching. It should be noted that the attitudes, efforts and anxiety levels of the teachers during teaching and learning are as important as the content knowledge.

We believe that the difficulties experienced by the pre-service biology teachers during their study as well as the potential difficulties they will have while teaching biology in the future must be dealt with seriously as an institutional self-criticism and biology teaching must be questioned, especially at the undergraduate level.

References

Anderson, C. W., Sheldon, T. H., & Dubay, J. (1990). The effects of instruction on college nonmajors' conceptions of respiration and photosynthesis. *Journal of Research in Science teaching*, *27*(8), 761-776.

Atilboz, G. N. (2004). Lise 1. sinif ogrencilerinin mitoz ve mayoz bolunme konulari ile ilgili anlama duzeyleri ve kavram yanilgilari [9th grade students' understanding levels and misconceptions about mitosis and meiosis]. *Gazi Universitesi Egitim Fakultesi Dergisi, 24* (3), 147-157.

Bahar, M., Johnstone, A. H., & Hansell, M. H. (1999). Revisiting learning difficulties in biology. *Journal of Biological Education, 33*(2), 84-86.

Bahar, M., Johnstone, A. H., & Sutcliffe, R. G. (1999). Investigation of students' cognitive structure in elementary genetics through word association tests. *Journal of Biological Education, 33*(3), 134-141.

Cingil Baris, C., & Kirbaslar, F. G. (2015). A study of certain biology and biotechnology concepts in secondary school and high school course books in terms of scientific competency. *Procedia - Social and Behavioral Sciences, 174*, 420-426. doi: 10.1016/j.sbspro.2015.01.684

Campbell, N. A., & Reece, J. B. (2006). *Biyoloji (6).* (E. Gunduz, A. Demirsoy & I. Turkan, Cev.). Ankara: Palme Yayincilik.

Chuang, H. F., & Cheng, Y. J. (2003). A study on attitudes toward biology and learning environment of the seventh grade students. *Chinese Journal of Science Education, 11*(2), 171–194.

Czihak, G. (1984). *Johann Gregor Mendel (1822–1884). Dokumentierte Biographie und Katalog zur Gedächtnisausstellung anläßlich des hundertsten Todestages mit Facsimile seines Hauptwerkes: "Versuche uber Pflanzenhybriden"* [Documented biography and catalog of the memorial exhibition on the centenary of the death with facsimile of his main work: "Experiments on plant hybrids"]. Salzburg: Im eigenen Verlag.

Cakir, M., & Aldemir, B. (2011). Iki asamali genetik kavramlar tani testi gelistirme ve gecerlik calismasi [Developing and validating a two tier mendel genetics diagnostic test]. *Mustafa Kemal Universitesi Sosyal Bilimler Enstitusu Dergisi, 8*(16), 335-353.

Capa, Y. (2000). *An analysis of 9th grade student's misconceptions concerning photosynthesis and respiration in plants.* Master thesis, Middle East Technical University, Ankara.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice*. Teachers College Press, 1234 Amsterdam Avenue, New York, NY 10027.

Eisen, Y., & Stavy, R. (1988). Students' understanding of photosynthesis. *The American Biology Teacher, 50*(4), 209-212.

Ekici, F., Ekici, E., & Aydin, F. (2007). Utility of concept cartoons in diagnosing and overcoming misconceptions related to photosynthesis. *International of Journal of Environmental & Science Education, 2*(4), 111-124.

Emre, I., & Bahsi, M. (2006). Fen bilgisi ogretmen adaylarinin hucre bolunmesiyle ilgili kavram yanilgilari [Misconceptions of science teacher candidates about cell division]. *Dogu Anadolu Bolge Arastirmalari, 4*(3), 70-73.

Enrique, B., & Enrique, A. (2000). Teaching genetics at secondary school: A strategy for teaching about the location of inheritance information. *Science Education, 84*(3), 313-352.

Ergezen, S. S. (2007). Biyoloji egitiminde evrim konusunun ogretimi ve lise biyoloji ogretmenlerinin yeterlikleri [Teaching of evolution topics in biology education and competencies of high school biology teachers]. *Biyoloji Egitiminde Evrim Sempozyumu*, 173-178.

Gul, S., Ozay Kose, E., & Konu, M. (2014). Genetik unitesinin ogretiminde kavram karikaturu kullaniminin biyoloji ogretmeni adaylari uzerine etkisi [The effect of using concept cartoons on pre-service biology teachers in teaching genetic unit]. *Fen Egitimi ve Arastirmalari Dernegi Fen Bilimleri Ogretimi Dergisi, 2*(1), *1-22.*

Gunes, M. H., & Gunes, T. (2005). Ilkogretim ogrencilerinin biyoloji konularini anlama zorluklari ve nedenleri [Difficulties and their reasons in learning biology concepts in primary school students]. *Gazi Universitesi Kirsehir Egitim Fakultesi, 6*(2), 169-175.

Gunes, T., Sener Dilek, N., Hoplan, M., & Gunes, O. (2014). Ilkogretim 8. sinif ogrencilerinde fotosentez ve solunum konusunda olusan kavram yanilgilari [The misconceptions of grade 8 primary school students about photosynthesis and respiration]. *Journal of Educational and Instructional Studies In The World, 2*(1), 42-47.

Haslam, F., & Teagust, D. F. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two tier multiple choice instrument. *Journal of Biological Education, 21*(3), 203-211.

Hurd DeHard, P. (1998). Scientific literacy: New minds for a changing world. *Science Education, 82*(36), 407-416.

Karagoz, M., & Cakir, M. (2011). Genetikte problem cozme: kavramsal ve surecsel zorluklar [Problem solving in genetics: conceptual and procedural difficulties]. *Kuram ve Uygulamada Egitim Bilimleri, 11(3), 1651-1674.*

Karasar, N. (2005). *Bilimsel arastirma yontemleri [Scientific research methods].* 15. Baski. Ankara: Nobel Yayin Dagitim.

Kasapoglu, E. (2011). *Lise 12. sinif biyoloji dersi protein sentezi konusunun kavram haritalariyla ogretiminin ogrencilerin akademik basarilarina ve tutumlarina etkisi [The effect of teaching protein synthesis using concept maps on the academic achievement and attitudes of 12th grade high school students]*. Selcuk Universitesi, Egitim Bilimleri Enstitusu, Yuksek Lisans Tezi.

Kilic, D., & Saglam, N. (2004). Biyoloji egitiminde kavram haritalarinin ogrenme basarisina ve kaliciligina etkisi [The effect of the concept maps on achievement and retention of learning in biology education]. *Hacettepe Universitesi Egitim Fakultesi Dergisi, 27*, 155-164.

Kilic, D. S., Soran, H., & Graf, D. (2011). Evrim ogretimini etkileyen faktorler [Factors influencing the teaching of evolution]. *Hacettepe Universitesi Egitim Fakultesi Dergisi, 41,* 255-266.

Kilic, D. S. (2012). Biyoloji ogretmen adaylarinin evrim ogretimi niyetleri [Pre-service biology teachers' intentions to teach evolution]. *Hacettepe Universitesi, Egitim Fakultesi Dergisi, 42,* 250-261.

Korkut, S. (2000). *Canlilarda ureme ve gelisme unitesinin unite program tasarisinin hazirlanmasi [Reproduction at the vigorous and preparation of the growth unit with its programe project organism].* Yuksek Lisans Tezi, Balikesir Universitesi Fen Bilimleri Enstitusu.

Kose, S., Ayas, A., & Usak, M. (2006). Fen bilgisi ogretmen adaylarinda fotosentez ve bitkilerde solunum konularinda gorulen kavram yanilgilarinin giderilmesinde kavram degisim metinlerinin etkisi [The effect of conceptual change texts instructions on overcoming prospective science teachers' misconceptions of photosynthesis and respiration in plants]. *International Journal of Environmental and Science Education, 1(*1), 78-103.

Lewis, L., Leach, J., & Wood-Robinson, C. (2000a). What's in a cell?-Young people understanding of the genetic relatioship between cells, within an individual. *Journal of Biological Education, 34*(3), 129-133.

Lewis, L., Leach, J., & Wood-Robinson, C. (2000b). CAll in the genes?- Young people understanding of nature of genes. *Journal of Biological Education, 34*(2), 74-79.

Marbach-Ad, G., & Stavy, R. (2000). Students' cellular and molecular explanations of genetic phenomena. *Journal of Biological Education, 34*(4), 200-206.

Marbach-Ad, G. (2001). Attempting to break the code in student comprehension of genetic concepts. *Journal of Biological Education, 35*(4), 183-190.

Miles, M. B., & M. Huberman. (1994). *Qualitative data analysis: a sourcebook of new methods*. 2d Edition. Beverly Hills, CA: Sage Publications.

Ozay, E. (2001). *Fotosentez konusunda lise ogrencilerinde karsilasilan kavram yanilgilari uzerine arastirmalar [The investigations into high school students'misconceptions of photosynthesis].* Yuksek Lisans Tezi, Ataturk Universitesi Fen Bilimleri Enstitusu, Erzurum.

Ozcan, T., Ozgur, S., Kat, A., & Elgun, S. (2013). Identifiying and comparing the degree of difficulties biology subjects by adjusting it is reasons in elemantary and secondary education. *Procedia - Social and Behavioral Sciences, 116*, 113-122.

Oztas, H., & Oztas, F. (1998). Farkli seviyelerdeki ogrencilerin bazi temel biyolojik terimleri kavrayabilme yetenekleri ile ilgili bir arastirma [A study of the ability of students in different levels to understand some basic biological terms]. *III Ulusal Fen Bilimleri Egitimi Sempozyumu, Bildiriler Kitabi,* 184-187.

Ozyeral-Bakanay, C. D. (2008). *Biyoloji ogretmen adaylarinin evrim teorisine yaklasimlari ve bilimin dogasina bakis acilari [Prospective biology teachers? approaches to the theory of evolution in relation to their understandings of the nature of science].* Yuksek Lisans Tezi, Marmara Universitesi.

Ozyilmaz-Akamca, G., & Hamurcu, H. (2009). Analojiler, kavram karikaturleri ve tahmin-gozlem-aciklama teknikleriyle desteklenmis fen ve teknoloji egitimi [Science and technology education based on analogies, concept cartoons and predict-observe-explain techniques]. *E-Journal of New World Sciences Academy, 4*(4), 1186-1206.

Pelaez, N. J., Boyd, D. D., Rojas, J. B., & Hoover, M. A. (2005). Prevalence of blood circulation misconceptions among prospective elementary teachers. *Advances in Physiology Education, 29*(3), 172-181.

Saka, A. (2006). *Fen bilgisi ogretmen adaylarinin genetik konusundaki kavram yanilgilarinin giderilmesinde 5E modelinin etkisi [The effect of 5E model on removing science student teachers' misconceptions about genetics]*. Doktora Tezi, Karadeniz Teknik Universitesi Fen Bilimleri Enstitusu, Trabzon.

Saka A., Cerrah, L., Akdeniz, A. R., & Ayas, A. (2006). A cross-age study of the understanding of three genetic concepts: How do they image the gene, DNA and chromosome? *Journal of Science and Technology Education, 15*(3), 192-202.

Sebitosi, E. K. (2007). Understanding genetics and inheritance in rural schools. *Journal of Biological Education, 41*(2), 56-61.

Sinan, O., Yildirim, O., Kocakulah, M. S., & Aydin, H. (2006). Fen bilgisi ogretmen adaylarinin proteinler, enzimler ve protein sentezi ile ilgili kavram yanilgilari [Preservice primary science teachers' misconceptions about proteins, enzymes and protein synthesis]. *Gazi Egitim Fakultesi Dergisi, 26*(1), 1-16.

Sasmaz-Oren, F., Ormanci, U., Karatekin, P., & Erdem, S. (2010). Ilkogretim 6. 7. ve 8. sinif ogrencilerinin fotosentez-solunum konusundaki kavram yanilgilarinin kavram karikaturleriyle belirlenmesi. *International Conference on New Horizons in Education, Famagusta, North Cyprus*.

Sensoy, O., Aydogdu, M., Yildirim, H. I., Usak, M., & Hancer, A. H. (2005). Ilkogretim ogrencilerinin (6., 7. ve 8. siniflar) fotosentez konusundaki yanlis kavramlarin tespiti uzerine bir arastirma [An investigation to identify the misconceptions of elemantary school students (sixth, seventh and eighth grades) about photosynthesis]**.** *Milli Egitim Dergisi, 33*(166), 213-223.

Tasci, G., & Soran, H. (2008). Hucre bolunmesi konusunda coklu ortam uygulamalarinin kavrama ve uygulama duzeyinde ogrenme basarisina etkisi [The effects of multimedia applications in cell division subject on the comprehension and application levels of learning achievement]. *Hacettepe Universitesi Egitim Fakultesi Dergisi, 34*, 233-243.

Tatar, N., & Cansungu Koray, O. (2005). Ilkogretim sekizinci sinif ogrencilerinin 'genetik' unitesi hakkindaki kavram yanilgilarinin belirlenmesi [Determination of the misconceptions of the 8th grade students in primary school about "genetics" unit]. *Kastamonu Egitim Dergisi, 13*(2), 415-426.

Tekkaya, C., Capa, Y., & Yilmaz, O. (2000). Biyoloji ogretmen adaylarinin genel biyoloji konularindaki kavram yanilgilari [Preservice biology teachers' misconceptions in general biology concepts]. *Hacettepe Universitesi Egitim Fakultesi Dergisi, 18*, 140-147.

Tekkaya, C., Ozkan, O., & Sungur, S. (2001). Biology concepts percieved as difficult by Turkish high school students. *Hacettepe Universitesi Egitim Fakultesi Dergisi*, 21, 145-150.

Tekkaya, C., & Balci, S. (2003). Ogrencilerin fotosentez ve bitkilerde solunum konularindaki kavram yanilgilarinin saptanmasi [Determination of students' misconceptions concerning photosynthesis and respiration in plants]. *Hacettepe Universitesi Egitim Fakultesi Dergisi, 24,* 101-107.

Temelli, A. (2006). Lise ogrencilerinin genetikle ilgili konulardaki kavram yanilgilarinin saptanmasi [Determination of misconceptions concerning genetic subjects of high school students']. *Kastamonu Egitim Dergisi, 14*(1), 73-82.

Uzun, N., & Saglam, N. (2005). Genetik konularinin ogreniminde deney uygulamalarinin akademik basariya etkisi [The effect of experimental applications on academic achievement in the learning of genetics]. *Hacettepe Universitesi Egitim Fakultesi Dergisi 28*, 196-200.

Yakisan, M. (2008). *Biyoloji ogretiminde bilgisayar animasyonlarinin kullanilmasinin ogrencilerin basari, tutum ve kavram yanilgilari uzerine etkisi (hucre konusu ornegi) [Effect of computer animations upon achievement, attitute and misconceptions of biology education (cell topic)].* Doktora Tezi. Gazi Universitesi, Egitim Bilimleri Enstitusu, Ankara.

Yesilyurt, S., & Gul, S. (2012). Ortaogretim ogrencilerinin tasima ve dolasim sistemleri unitesi ile ilgili kavram yanilgilari [Secondary school students' misconceptions about the "transportation and circulatory systems" unit]. *Afyon Kocatepe Universitesi Kuramsal Egitimbilim Dergisi, 5(*1), 17-48.

Zeren, D. (2005). *Ilkogretim fen bilgisindeki ureme ve gelisme konusunun duzenlenmesi ve ogretimine yonelik program gelistirme uzerine bir calisma [A study on the curriculum design for the organization and the teaching on the subject 'reproduction and growth' in primary education science courses].* Yuksek Lisans Tezi. Uludag Universitesi Sosyal Bilimler Enstitusu, Bursa.