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MISCONCEPTIONS IN BIOLOGY EDUCATION: A REVIEW OF RELEVANT RESEARCH

A MASTER'S THESIS

BY

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THE PROGRAM OF CURRICULUM AND INSTRUCTION
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To my family

MISCONCEPTIONS IN BIOLOGY EDUCATION: A REVIEW OF RELEVANT RESEARCH

The Graduate School of Education

of

İhsan Doğramacı Bilkent University

by

Bahar Kumandaş

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Bahar Kumandaş

May 2015

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Curriculum and Instruction.

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ABSTRACT

MISCONCEPTIONS IN BIOLOGY EDUCATION: A REVIEW OF RELEVANT RESEARCH

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May 2015

Misconceptions are an obstacle to comprehend scientific phenomena. Since misconceptions are a significant problem at all levels of education, studies have been increasing in the field of biology education. The aim of the study was to explore the patterns of the articles about biology misconceptions in Turkey and to reveal general tendencies. To meet this aim, 67 articles were selected through ISI Web of Knowledge, Scopus, EBSCOhost, ULAKBİM and ASOS Index databases published from 2000 to 2014. Meta-synthesis (thematic content analysis) method was used to explore characteristics, purposes, themes and patterns, data collection tool types, research methods, sample and sample sizes, and data analysis methods of these articles. Selected articles were subjected to the adapted version of the Paper Classification Form developed by Sözbilir, Kutu & Yaşar (2012). The results show that articles about misconception in biology are mostly published in international journals and written in Turkish. These articles mainly focus on identifying misconceptions. Most of the studies' samples were pre-service teachers. The sample

size of the studies varied between 31-100. Qualitative and quantitative research methods were equally dominate over mixed method, which was less preferred. The findings also indicate that more studies have been undertaken in environment and ecology, and genetics and cell division. Achievement and diagnostic tests were the most common data collection tools and used multiple choice and open-ended question types. This review is expected to inform educators, teachers, pre-service teachers and curriculum developers about themes and patterns in misconception research.

Key words: misconception, biology education, content analysis

ÖZET

BİYOLOJİ EĞİTİMİNDE KAVRAM YANILGILARI: İLGİLİ ARAŞTIRMALARIN İNCELEMESİ

Bahar Kumandaş

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Kavram yanılgıları, bilimsel olguların anlaşılması için bir engeldir. Söz konusu kavram yanılgıları eğitim hayatının her aşamasında belirgin bir sorun olduğundan, biyolojide kavram yanılgıları alanında yapılan çalışmalar artmaktadır. Bu çalışmanın amacı, biyolojide kavram yanılgıları alanında Türkiye' de yapılmış olan çalışmaları incelemek ve bu alanda yaygın olan eğilimleri belirlemektir. Bu amaç doğrultusunda, ISI Web of Knowledge, Scopus, EBSCOhost, ULAKBİM ve ASOS Index veri tabanlarında 2000 ile 2014 yılları arasında yayımlanan 67 makale incelenmiştir. Makalelerin özellikleri, konuları, amaçları, veri toplama araçları, araştırma yöntemleri, örneklem özellikleri ve veri analiz yöntemlerini incelemek için meta-sentez (tematik içerik analizi) yöntemi kullanılmıştır. Seçilen makaleler, Sözbilir, Kutu & Yaşar (2012) tarafından geliştirilen " Makale Sınıflandırma Formu" nun bu çalışmaya uyarlanmış biçimi ile incelenmiştir. Araştırma bulgularına göre, biyolojide kavram yanılgıları ile ilgili makalelerin birçoğu uluslararası dergilerde Türkçe olarak yayınlanmıştır. Makaleler, çoğunlukla kavram yanılgılarını belirlemeye

odaklanmaktadır. Örneklemlerin çoğunu hizmet öncesi öğretmenler oluşturmaktadır. Çalışmaların örneklem büyüklüğü 31 ile 100 arasında değişmektedir. Nicel ve nitel araştırma yöntemleri, daha az tercih edilen karma yönteme kıyasla eşit bir üstünlük sağlamaktadır. Ayrıca söz konusu bulgular, çevre, ekoloji, hücre bölünmesi ve genetik konularının daha yaygın olarak çalışılan alanlar olduğunu göstermektedir. Başarı ve kavram yanılgıları testleri en yaygın kullanılan veri toplama aracı olurken, bu testler çoğunlukla çoktan seçmeli ve açık uçlu sorulardan oluşmaktadır. Bu çalışmanın, araştırmacılara, öğretmenlere, hizmet öncesi öğretmenlere ve eğitimcilere bu alandaki eğilimlerin neler olduğu konusunda yardımcı olması beklenmektedir.

Anahtar Kelimeler: kavram yanılgıları, biyoloji eğitimi, içerik analizi

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CHAPTER 1: INTRODUCTION

Introduction

This study aims to explore research articles about biology misconceptions in Turkey, looking for patterns to reveal general tendencies. Since misconceptions are a significant problem at all levels of education, studies about this issue have been increasing in the field of biology education. It is hoped that this review will inform educators, teachers, pre-service teachers, textbook writers and curriculum developers about themes and patterns in misconception research. This chapter includes the background of the study, the statement of the problem, and the purpose, the research questions, the significance and definition of the key terms.

Background

Concepts represent common changeable features of objects, events, ideas, thoughts and actions (Malatyalı & Yılmaz, 2010). Students develop concepts at an early age when they explore their physical and social world. If these concepts are different from scientific thoughts they are referred to as misconception. Especially when these misconceptions make perfect sense to learners they are difficult to change or shed (Allen, 2010). A misconception can be defined as the knowledge of an individual about a concept that is essentially different from the commonly endorsed scientific implication of this concept (Yağbasan & Gülçiçek, 2003).

A misconception compromises the learning process. Meaningful learning eliminates information that confuses students and promotes meaningful connections between previous and new knowledge. The Ministry of National Education (MoNE) describes

In the early 1980s, the importance of meaningful learning was associated with constructivist learning (Özgür, 2004). According to cognitive constructivism, learners construct their own knowledge. Piaget (1972) defined constructivist learning as acquisition of knowledge through independent investigation and curiosity and developing methodology to serve these knowledge rest of the life. Learning is an active process. Allowing students to build the ideas on their minds freely is a crucial role to support meaningful learning. Hence, teaching correctly is not enough to be sure knowledge are acquired and constructed by the students meaningfully (Piaget, 1972).

In 2004, MoNE implemented new curriculum reforms in science education based on the constructivist approach (MoNE, 2005). The approach asserts that knowledge cannot be transferred from teacher to students directly; it is re-constructed by students and converted into a new format. Science and Technology Curriculum (2005) provides the following principles of constructivism:

- The learning processes of the students are affected by their prior knowledge, their attitudes, their values, their point of views and their aims
- Information and abilities are not transferred from teachers to students through educational applications
- Learning is not a passive process so it requires the effective participation of the student which forms "student-centred" education
- The aim of science education should be not only to develop current knowledge, but also to ensure being regulated and re-constructed ineradicably
- People may internalize, organize or refuse as evolution of new information while they try to make sense of the world (MoNE, 2005, p.13).

Biology is an integral part of science education. Science is introduced to students first in elementary school in Life Science. Students cover basic science concepts and increase awareness of their bodies and the environment (MoNE, 2009). Students are taught specific biology topics in middle school in science and technology. Then, at the high school level, science is divided into physics, chemistry and biology. Since elementary school constitutes the foundation of science education, constructing correct and meaningful information about biology at this stage has a significant role to avert misconceptions. Moreover, teachers need to have higher knowledge levels and correct ideas in order to prevent and correct student misconception. In the literature many studies conducted in Turkey have shown that teachers and pre-service teachers hold some misconceptions as well as students (Çelikler & Aksan, 2011; Güneş et. al., 2010; Tekkaya, Çapa, & Yılmaz, 2000; Yakışan, Selvi, & Yürük, 2007). The number of studies about misconceptions in biology is significant part of biology education. Hence, identifying an overall image of related studies and classifying them systematically have gained importance.

Problem

There are many factors that affect the learning process of students and their performance in educational settings. One of the major factors that affect students' learning processes is the scientifically inaccurate conceptions (misconceptions) of students. Students retain their misconceptions throughout their school life unless they are corrected in a timely manner.

Several studies in Turkey have been conducted in the field of biology and most of them showed that teachers, teacher candidates and students held some misconceptions about some biology topics such as photosynthesis (Köse, Ayas & Taş, 2003; Özay & Öztaş,

2003), the greenhouse effect (Arsal 2010; Çelikler & Aksan, 2011), osmosis - diffusion (Cinici, Sözbilir & Demir, 2011; Köse, 2007), aerobic and anaerobic respiration (Yürük & Çakır, 2002), enzymes (Atav, Erdem Yılmaz & Gücüm , 2004; Kurt, 2013; Selvi & Yakışan, 2004). However, no studies have been conducted to review all of these studies.

In order to promote efficient and meaningful learning, describing the origins of misconceptions and finding ways to correct them or prevent them from developing are important (Tekkaya, 2002). Given that misconceptions are significant problems for all levels of education, it is understandable that the numbers of academic studies about this topic have increased. These studies identify methods to elicit misconceptions, identify the kind of misconceptions students and pre-service teachers have, and prevent them from being created in the first place. This study presents a general overview of the patterns for academic research in the related area.

Purpose

The purpose of this study is to analyse studies that were conducted in the area of misconceptions in biology according to their characteristics, research topics, sample and grouping, methodologies and data collection methods. Hence descriptive statistics is used to illustrate a general overview of the patterns for academic studies in this area. Published articles are analysed in this study.

Research questions

The following research questions are explored in this study:

1) What are the characteristics of research studies about misconceptions in biology in terms of the language, year of the articles, type and name of the journals in which articles are published?

2) What are the purposes of research studies about misconceptions in biology?
3) What are the themes and patterns in research studies about misconceptions in biology?
4) What research methods are used in research studies about misconceptions in biology?
5) What data collection tools are used in research studies to investigate misconceptions in biology?
6) What are the sample and size of the conducted studies about misconceptions in biology?
7) What data analysis methods are used in studies about misconceptions in biology?

Significance

Although there are several studies that have been conducted in the area of misconceptions in biology, a comprehensive review of these studies in Turkey has yet to be conducted. This study aims to explore the patterns of the research articles about biology misconceptions in Turkey and to reveal general tendencies in the area of research topics, types, and methodology. It is hoped that this review will inform educators, teachers, pre-service teachers and curriculum developers about themes and patterns in misconception research. This collection of articles and reviewed literature provides information about the following:

- Which biology topics have more misconceptions
- What kind of misconceptions students have
- How teachers can handle the misconceptions of students
- Which methods are preferred for correction of misconceptions

Studies based on pre-service science or biology teachers' misconceptions are analysed in the study. This is because the first stage in avoiding students' misconceptions is to ensure that teachers have no such misconceptions.

Finally, collecting these studies gives an idea about gaps in the research such as missing topics or strategies that could be considered for future research.

Definition of key terms

Biology: Biology is the science of life.

Concept: Carnap (1967) calls the word of concept also as object and defined as "properties and classes, relations in extension and intension, states and events, what is actual as well as what is not" (Carnap, 2003, p.5).

Conceptual change: Hewson (1992) defines the conceptual change as possibility of reconstructing the concept for the better.

Constructivism: Piaget (1972) clarified the definition of constructivism as "A student who achieves a certain knowledge through free investigation and spontaneous effort will later be able to retain it; he will have acquired a methodology that can serve him for the rest of his life" (p.93).

Misconception: Misconceptions are incorrect ideas which distant from the actual scientific phenomena. Driver (1988) defines misconceptions as children's ideas about natural phenomena before they learn science in school.

Meaningful learning: Meaningful learning is defined as "new information is linked with existing concepts in existing cognitive structures through an interactive process in which the new information changes slightly; the new information is subsumed" (Moe, 2011, p.32).

CHAPTER 2: REVIEW OF RELATED LITERATURE

Introduction

The purpose of the literature review is to provide information and a framework about the current study. First, literature on biology education in Turkey is analysed. Second, content analysis studies about biology education in Turkey are investigated. Then, teaching biology concepts in general is analysed. Finally the definition of, sources of, methods to identify and ways to correct misconceptions are explored.

Biology education

Biology education in Turkey

The purpose of Turkish national education is to educate individuals to feel responsible toward society, to respect human rights, and to have mentally, morally, spiritually, physically and emotionally balanced and healthy personalities as well as to think scientifically (Basic Law of National Education, 1973; No: 1739). Turkish national education aims to pursue innovation in the area of science and technology according to the needs of the country (Basic Law of National Education, 1973; No: 1739). Especially in recent years, with advances in technology and adaptation to a constructivist approach, Turkey has been undergoing innovation and development in science education that affects our everyday lives. With biology being an integral part of science education, these innovations and developments influence patterns in biology education as well. The biology curriculum had already been renewed periodically starting from 1993 (Gül & Sözbilir, 2015). Nevertheless, at the present time, one of the main problems that confronts advances in the education system in Turkey is still dedication to traditional means of instruction. For instance, the experiments in the laboratory classes in Turkey

are mostly conducted under the supervision of teachers; this demonstration of the method makes students passive learners. However, as a solution to the problems faced, the education system is innovated by updating the curriculum (Akçay, 2014).

The latest change of the biology curriculum provides students to be more involved to their learning (MoNE, 2013). The new biology curriculum helps students make connections between daily life experiences and biological concepts; this enables students to have an active role in their learning processes (MoNE, 2013). Furthermore, the curriculum has been organized in a fashion that encourages experiments and laboratory studies (MoNE, 2013).

Biology is obligatory in the 9^{th} and 10^{th} grades. The primary purpose of the new biology curriculum is to motivate students with concrete examples. Later, students in the upper grades develop more abstract and in-depth concepts (MoNE, 2013). Moreover, the new biology curriculum strives to empower students to make their own decisions for their future by providing them with a broad perspective (MoNE, 2013). MoNE (2013) states the objectives in the new biology curriculum educate individuals to:

- Have sufficient knowledge, skills and understanding about basic theories, concepts, processes and practices in biology
- Participate actively in biological discussion and evaluate issues accordingly
- Be conscious consumers of scientific knowledge and practices, that are encountered in daily life
- Become willing to learn science as a lifelong process (pp.i).

Biology education provides an understanding of universe and life, so it has an important science field in people's lives (MoNE, 2013). Scientific researches in the field of

biology education lead to develop efficient education and to evaluate current aspects (Basic Law of National Education, 1973; No: 1739).

Content analysis studies about biology education in Turkey

In order to interpret the development of science education as well as to visualize patterns in science education content analysis studies of science papers have been done (Çalık, Ünal, Coştu & Karataş, 2008; Evrekli, İnel & Deniş & Balım, 2011; Sözbilir, Kutu & Yaşar, 2012; Topsakal, Çalık, & Çavuş, 2012).

However, few of the studies are focused in biology education. Gül and Sözbilir (2015) analysed 633 biology education research articles published Turkey from 1997 to 2012 under different categories. A total of 143 articles were classified as "learning" as subject matter and 10.90 % of the articles focused on misconceptions. The findings showed that environmental issues, cells, animal structure and functions were the most researched topics.

The study of Köse, Gül and Konu (2014) provides an analysis of research published during the years 2002-2013 about biology education from ULAKBIM database. A total of 251 studies were examined according to the key words of biology education. Results showed that the most studied biology topics were evolution and environment with nine and eight instances respectively. There were 16 studies of misconceptions in the area of studies about education teaching-learning.

Topsakal, Çalık and Çavuş (2012) determined trends in Turkish biology education by analysing 138 graduate theses according to year, research interest, sampling method and research methodology. Researchers suggested that further studies should be carried out to identify patterns in Turkish biology education.

Güven et al. (2014) reviewed 112 environmental education studies published in Turkey between 2007 and 2011. The studies were grouped by: publication year, language, participants, research design, research topic, data collection tools and data analysis methods. Most of the studies were at university level. Researchers suggested that further studies should be done in the area of environmental education.

Bozdoğan (2011) investigated studies about global warming conducted between 1992 and 2009. A total of 62 scientific publications were analysed in the world and in Turkey. The studies reported a large number of misconceptions about environmental issues at all levels of education.

Erdoğan, Marcinkowski and Ok (2009) analysed environmental education research published over the years 1997-2007 in Turkey. They categorized 53 studies according to research method, socio-demographic characteristics of the subjects, and environmental literacy constituents. Results showed that knowledge of ecology and natural history, and knowledge of environmental problems and issues, were taken into consideration as main parts of environmental education. On the other hand, cognitive skills and environmentally responsible behaviours were given less importance. Erdoğan, Marcinkowski and Ok (2009) suggested, in order to reveal and correct students' misconceptions and develop their cognitive skills about environment and ecology, conceptual-change oriented instructional methods should be integrated into the curriculum.

Teaching concepts in biology

According to the researchers such as Ayas (2012), a concept means the first association that comes to one's mind when a substance or object is mentioned. Carnap (1967)

describes concepts as “properties and classes, relations in extension and intension, states and events, what is actual as well as what is not ’’ (p.5).

Some of the events and experiences we encounter in our daily lives are related to biology. Hence, students encounter biological concepts in their daily lives and may construct idiosyncratic ideas that are different from accepted knowledge. When students come to the class, they experience cognitive dissonance. They develop new information on previous experiences, probably adapted from the situations that they encounter inside and outside of school (Driver, 1988).

In order to provide correct scientific knowledge, to reconstruct or remove pre-existing knowledge, teaching concepts is an important role for teachers. Driver (1988) believed teaching should not only give direct knowledge, but also provide discussion of the meanings. Mintzes, Wandersee and Novak (2001) suggest “quality over quantity, meaning over memorizing, and understanding over awareness” help students to acquire “real understanding” of biology concepts (p.118). As Ayas (2012) states teaching concepts should not be taught by giving their definitions. Teachers who teach biology should give information based on students’ needs and expectations and help students to alter their experiences to given information levels that allow them to establish relationship with daily life (Yağbasan & Gülçiçek, 2003).

Teachers’ ideologies in terms of respect to science, learning environment, and teaching material may influence students’ meaningful learning biological concepts. Therefore, lesson materials and teaching methods should be taken into consideration regarding students’ motivation and interest towards learning biology. Atıcı and Bora (2004) investigated the most used teaching methods in biology education and found that

explanation was the predominant teaching method, over demonstration and question-answering. In their research, Kaya and Gürbüz (2010) reported that teachers began to give more importance to instructional materials according to high school students' perceptions through survey. Teachers with low confidence about subject knowledge apply basic teaching techniques such as simple practical work, questioning and prescriptive texts (Jarvis & Pell, 2004). Students' understanding of concepts may relate to their teachers' content knowledge. In the literature, some studies showed teachers' positive attitudes, beliefs and perceptions towards biology and content knowledge increased their students' interest in learning, and thinking scientifically (Akar & Yıldırım, 2011; Fulmer, 2013; Jarvis & Pell, 2004).

As Yağbasan and Gülçiçek (2003) state, applying conceptual change strategies (e.g., concept mapping, concept cartoons, conceptual change texts) in classroom teaching supports meaningful learning and eliminates misconception. Lappi (2013) explains conceptual change as "Students sometimes misunderstand or misinterpret scientific content because of persistent misconceptions that need to be overcome by science education—a learning process typically called conceptual change." (p. 1347). According to Tekkaya (2003), conceptual change is effective and logical, replacing existing inaccurate knowledge and ideas with scientifically acceptable information.

Misconceptions

A misconception can be identified as something that people believe, but that are not actually correct. In broad terms, misconceptions correspond to the ideas that have personal perceptions and meanings in students' articulations that are defective (Bahar, 2003). In the literature, misconceptions are also indicated to as "alternative conception"

(Kurt & Ekici, 2013, p.885; Kurt, 2013, p. 211; Dikmenli, Çardak & Öztaş, 2009, p.429; Cinici, 2013, p.645), "misunderstanding" (Kılıç & Sağlam, 2009, p.227; Kırbaşlar, Barış & Ünal, 2009, p.158), "students' non-scientific conceptions (Cinici, 2013, p.646), "children's informal ideas" (Mak, Yip & Chung, 1999, p.161).

Yip (1998) explains misconception as the numerous concepts and ideas posed by students that are inconsistent with scientific knowledge. According to Tekkaya, Çapa and Yılmaz (2000) definition of misconception is students' alternative ideas or solutions against scientific concepts and methods. Driver (1988) defines misconception as children's ideas about natural phenomena before they learn science in school. Sanders (1993) define misconception as "incorrect mental constructs that are firmly held by the learner and thus resistant to change" (pp.919).

Sources of misconceptions

Misconceptions are the output of a divergent set of current daily language, direct observation of natural objects and acts, formal instructional interference and the mass media which are shaped by personal experiences (Moe, 2011). Misconceptions may come from certain experiences that are commonly shared by many students. Aşçı, Özkan and Tekkaya (2001) indicate that children hold misconceptions that are advanced before and during their formal educational settings. Social interaction and daily life conversation causes spreading misconceptions. Novak (1987) believes social environments such as school and classroom are important roles to facilitate or inhibit acquiring or modifying and correcting misconceptions.

Students' misconceptions may arise from acquisition of inadequate and incorrect information before the instruction. (Novak, 1987). Murat, Kanatlı and Ünişen (2011),

reported cartoons are effective in the formation of misconceptions. For example, students may acquire inaccurate information about animals' gestation, eating habits and behaviours (Murat, Kanatlı & Ünişen, 2011). As Yip (1998) points out, some biological concepts, -such as the quality of life, animals and plants, photosynthesis, respiration, gas exchange and inheritance- are most affected by real-life experiences prior to instruction. Another origin of misconception is teachers' insufficient subject area knowledge and competence (Mak, Yip & Chung, 1999; Sanders, 1993). In addition, teachers' preferred books that are used in the classes may have some confusing and incorrect sections with long and baffling questions.

When students encounter new knowledge they may think it is unfamiliar and hard to understand. Students' biases to the new knowledge may cause to reject understanding of actual meaning of scientific phenomena. In order to prevent acquisition of such incorrect or distorted knowledge, it is essential for the teacher to ascertain whether students have lectured the anchoring concepts before instruction (Yip, 1998).

Students may need to have pre-requisite knowledge for the construction of a new concept. Absence of these concepts may be caused developing distorted views. When students combined newly learned concepts with their undeveloped concept, it may cause misconceptions (Aşçı, Özkan & Tekkaya, 2001). In addition, Yağbasan and Gülçiçek (2003) state students' pre-knowledge may cause inaccurate learning while they construct new information on existing ones.

Since biology topics are mostly related to each other, current misconceptions prevent meaningful learning for the next steps of instructions. Therefore, before introducing and scientific concepts, students' current ideas about these concepts can be discovered (Allen, 2010).

Methods to identify misconceptions

The identification of students' misconceptions is critical to effective teaching and learning in science. Hence, the fundamental stage to promote accurate learning outcomes is preventing the misconception before it develops (Allen, 2010). In this stage, teachers have an important role to recognize students' ideas, to appreciate ideas that students bring to the classroom and to search and apply which processes fit for reconstructing students' conceptions (Driver, 1988).

Several strategies and techniques that are used for exploring students' cognitive structures and ideas also help to modify existing incorrect ideas. Elicitation methods inform educators and teachers about what students actually believe about the scientific phenomena. Posner, Strike, Hewson, and Gertzog (1982) believe that learning arises against the background of students' present ideas. When students encounter new concepts, they grasp them or change their existing ones; they call this process conceptual change. Çakır (2008) defines conceptual change as recognizing, evaluating and reconstructing. He explained that the first step to correct existing concepts requires recognition of the nature and presence of the current conceptions. It seems that students can develop their metacognition to acquire new and correct knowledge. Metacognition is being aware of individual's learning process. It is defined by Flavell (1979) as the ideas we have about our own cognitive processes in terms of experiences and knowledge (as cited in Schwartz & Timothy, 2002).

There are some conceptual change strategies that are also use to elicit students' cognitive structures. These include following: word association tests (Kurt, 2013; Kurt & Ekici, 2013), prediction-observation and explanation (Bilen & Köse, 2013), concept mappings (Köse, 2007; Tekkaya, 2003) , students' drawings and writings (Kurt, 2013;

Kurt & Ekici, 2013), classroom debates, laboratory and computer based instruction (Maraş & Akman, 2009) and conceptual change texts(Akyürek & Afacan, 2013; Aydın & Balım, 2013; Keleş & Aydın 2012; Tekkaya 2003).

The ways to correct misconceptions

After the recognition of misconceptions, the next step is correcting them (Allen, 2010). Hence, students' misconceptions carried through their educational life are a significant barrier for their achievements and learning processes.

If teachers are to diagnose or become familiar with their students' views, they can apply some strategies accordingly (Çakır, 2008). A constructivist teaching approach is useful to prevent and fix students' misconceptions. Constructivist theories support learning as a social improvement involving language, real world situations and cooperation among learners (Özgür, 2004). Jean Piaget proposed that a constructivist education allows students to increase their ability to discover new ideas and construct new knowledge with regarding their personal interests and different level of intelligences (Özgür, 2004). According to this constructivist theory, teachers should allow students to be in an effective learning environment in order to gain meaningful and persistent knowledge. As Çakır (2008) indicates, the classroom environment is the essential factor in which students should feel free to express their ideas about the concept without concern for the rightness or wrongness of these ideas.

Students' existing knowledge should be revealed; if they have current misconceptions, they should be resolved and missing information supplemented. Since some topics have abstract terms and students have difficulty comprehending them, different teaching methods and techniques should be applied as much as possible. Further, appropriate

activities should be developed for each student's level and the relevant models, experiments, educational games, concept maps should be prepared to increase students' understanding of and attention to the lesson (Tatar & Koray, 2005).

Allen (2010) asserts that some explicit ideas to correct misconceptions and facilitate students' individual construction of knowledge include using a social setting for learning, allowing student autonomy, engagement and motivation, providing open-ended questions, promoting higher-order thinking, and increasing peer dialogue with group activities. In addition, some techniques that are used to determine misconceptions may be applied to treat students' incorrect beliefs. In conclusion, several studies have shown that treatment with conceptual change strategies are helpful for eliminating on the present misconceptions of students (Bilen & Köse, 2013; Keleş & Kefeli, 2010; Köse, 2007; Sesli & Kara, 2012).

Misconceptions in biology

Many students have misconceptions about what science actually is and how it works. Biology is one of the courses in which students experience difficulty (Keleş & Kefeli, 2010). The content and complexity of biological notions, common ideas, deficiency of biological knowledge and additionally the hidden nature of many key processes cause biology to be an especially hard subject to teach and to learn (Sesli & Kara, 2012). Moreover, its abstract nature and scientific terminologies make biology confusing. As Tekkaya (2002) indicates:

> Many world*[sic]* in biology are used in an alternative way in daily life, for this reason, some misconceptions may arise from the use of words that mean one thing in everyday life and another in a scientific context such as food, respiration, and population.(p. 260)

Undoubtedly, students hold some difficulties about understanding of certain concepts. Bahar (2002) interviews with pre-service teachers resulted in a list of the most difficult topics in biology concepts for students to comprehend. Genetic engineering, mitosis, gametes, alleles and genes came to the top of the list while diffusion and osmosis and obtaining food by animals and plants were perceived as the least difficult topics. The study included reasons why learning genetics was difficult and students reported language and terminology, lack of teacher confidence, content and time allowance, mathematical expression and numeracy and confusion between the similar topics. Tekkaya, Özkan and Sungur (2001) also found in their study that genes, chromosomes, mitosis and meiosis, Mendelian genetics, hormones and nervous system were the topics Turkish high school students found to be difficult to learn.

In the literature, many studies show that teachers and pre-service teachers, as the students, hold some misconceptions (Artun &Coştu, 2011; Kırbaşlar, Barış & Ünal, 2009; Kurt, 2013; Yakışan 2013; Yakışan, Selvi & Yörük 2007). Furthermore, it has been found that biology textbooks contain important misconceptions that affect learning (Çobaonoğlu & Şahin, 2009; Dikmenli, Çardak & Öztaş 2009).

Tekkaya, Çapa and Yılmaz (2000) suggest that one of the important reasons for misconception is differences between scientific terminology and use of these terms in daily life languages, such as “respiration” and “breathing” and “seal” and “sea dog” (p.145). Another example is confusing vegetables and fruits. Everyone in society calls some plants vegetables such as aubergine, cucumber and tomato, when in scientific terms they are fruits because they bear seeds (Yangın, Sidekli & Gökbulut, 2014). It is highly possible that students’ misconceptions may be oriented by daily life conversations.

Related literature shows that student misconceptions may arise from their experiences, the language used during daily communications, their teachers' content knowledge and their textbooks. Teaching strategies and the students' learning environment play an important role in identifying and correcting misconceptions. As misconceptions have an impact on students' learning processes and are a significant problem at all levels of education, studies about misconception have been increasing in the field biology education. The review of the literature provided information about what kind of misconceptions students have, which methods are preferred to elicit and correct misconceptions and how these misconceptions are originated. Given the increase in research related to biology misconceptions, there is a need to review these studies to better inform teacher educators, teachers and pre-service teachers about themes and patterns, we can more effectively address student misconceptions, and ideally prevent them from forming in the first place.

CHAPTER 3: METHOD

Introduction

This part of the study gives information about the methodology for the current study. First the research design is explained in detail, and the target sample is defined. Next, the instrumentation used is identified along with reliability and validity strategies. Finally, the data collection and data analysis methods are explained.

Research design

In recent years, many research studies have been done to determine and address students' and pre-service teachers' misconceptions in Turkey. However, there is not yet any research which completely includes and reviews these studies. The purpose of this study is to investigate a number of articles that were conducted in that area and to analyse them accordingly.

In this study, content analysis method is used. The method is based on the analyses and presentation of collected information. Neuendorf (2002) defines content analysis as "a summarizing, quantitative analysis of messages that relies on the scientific method and is not limited as to the types variables that may be measured or the context in which the message are created or presented'' (p.10). Krippendorff (2004) states that content analysis is "a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the context of their use'' (p.18) Moreover, content analysis has been described as "research methodology that applies a set of procedures to make valid inferences from text" (Weber, 1985, p.9).

Sarantakos (1998) indicates content analysis is a documentary method that studies the "content" of documents and analyse them in a qualitative or/and quantitative way. As Falkinghan and Reves (1985) indicate, content analysis provides a general framework to quantify the studies of a particular field: For example, what research methods are preferred, what are themes and patterns being followed, and what types of output arise. They explain that the method consists of creating a database of attributes designated to each paper or study by the reviewer and then examine the relationships in the data. Collecting data provides ways to make comparisons about the attitudes of various groups of people separated by date, geographic location, culture, or country (Fraenkel & Wallen, 1985). In this study, selected articles are systematically analysed through content analysis.

Overall, various researchers concur that articles are reviewed to identify and underline their specific focus. Çalık and Sözbilir (2014) have grouped content analysis under three subheadings; these are meta-analysis, meta-synthesis and descriptive content analysis. In this study, the meta-synthesis is used as the research design. Meta-synthesis involves analysing and evaluating a group of studies that are conducted within the same domain (Çalık & Sözbilir, 2014). For this study, however, a limited number of articles *(n*=67) were analysed; therefore a more apropos description of this design is an in-depth investigation and interpretation of selected articles through meta-synthesis.

Selecting sample studies

In this study, biology misconception research studies by Turkish educators were subjected to a content analysis. To identify the target population, first, key words germane to *misconceptions* in biology education were identified including,

alternative conception and *misunderstanding*. The timeframe for the study was designed to be from 2000 to 2014. Database search engines such as; ISI Web of Knowledge, Scopus, EBSCOhost, ULAKBİM and ASOS Index databases were reviewed according to determined key words above.

Second, it was decided to limit the search to research-based studies rather than theoretical studies. Furthermore, the study focused research on with pre-service teachers and elementary, middle and high school students; therefore, studies with different populations (e.g., university students other than pre-service teachers) were eliminated. Finally, 67 articles were reviewed and analysed according to the different categories in the code book.

Instrumentation

In this study, each selected article was subjected to an adapted version of the "Paper Classification Form (PCF)" developed by Sözbilir, Kutu and Yaşar (2012). Some categories were modified according to meet the needs of this study. The instrumentation is explained below, as well as its coding and classification.

Instrument design, coding and classification

Content analysis method requires designing and implementing a coding scheme. The form used for this study was composed of seven parts, labelled parts A through G.

- Part A includes some descriptive information about the studies such as title, author/s name, authors' nations, journal name including year, volume, issue and pages, journal type as national and international, and language of articles.
- Part B was used to classify the studies according to their purposes. The part is divided into 6 sections; investigation cognitive structure, treatment of

students, identifying misconception, conceptual understanding difficulties, determination causes of misconception and others.

- Part C was used to identify the biological topic that was being investigated, such as cell biology, cell division and/ or genetics, environment and ecology, chemistry of life, classification of living organisms, world of living creatures and photosynthesis and respiration. The topics were classified according to Ministry of National Education high school curriculum.
- In Part D, the research methods were categorized as qualitative, quantitative or mixed.
- Part E provides information about the number and types of data collection tools. The articles which use achievement, diagnostic and attitude and conceptual understanding tests. are categorized their question types in this part.
- Part F gives information about the sample size and grouping.
- Part G classifies studies according to data analysis method including qualitative and quantitative analysis.

Method of data collection

As it is stated above a total of 67 research articles are listed in "Appendix A" were selected for this study and subjected to content analysis. Following the key word search, the title, date and the content of the articles were examined. The research questions and the following exclusion criteria were used to eliminate articles that did not meet the needs of the study;

- The studies did not consider elementary, middle and high school students and pre-service teachers.
- The studies were theoretical approach rather than empirical.

- The studies were about misconception but did not include requested key words.

Method of data analysis

This study used descriptive content analysis method, conducted according to following procedures defined by Fraenkel and Wallen (2009):

1. Determine purpose
2. Select units of analysis
3. Develop coding categories
4. Code the material
5. Analyse and interpret the results

Data analysis methods were explained according to Fraenkel and Wallen (2009)'s procedures:

Determine purpose: Content analysis begins with determination of specific objectives concerning what the researcher want to study. In this study, the purpose of the research was determined and the research questions were formulated.

Select units of analysis: The relevant units to be used for conducting and reporting the analysis should be selected before the researcher begins the analysis (Fraenkel &Wallen, 2009). As stated before, content analysis is used in this research with the unit of articles that selected according to the some features.

Develop coding categories: Categories might orient from research question and should be anchored in a review of relevant literature and similar studies (Prasad, 2008). While developing coding categories, new categories are added to the code book and some of them are changed according to the needs of this study.

Code the material: Coding the unit of selected studies into categories is called coding and individuals who do coding are called coders (Prada, 2008). Careful training of coders is essential to reliable coding. In this study, however, the target articles are subjected to the coding by the researcher and 12 % of the articles are checked and discussed by other investigators.

Analyse and interpret the results: The end product of the coding process must be numbers to visualize general patterns and characteristics of the studies (Fraenkel &Wallen, 2009). In this study, data are analysed through the descriptive statistics by using the Statistical Package for Social Science (SPSS) package, version 19.0 and excel.

Çalık and Sözbilir (2014) list some essential components for meta-synthesis that needs to be taken into consideration during the data analysis:

- Analysis and coding processes applied in the meta-synthesis should be explained
- The limitations of meta-synthesis should be clearly stated (i.e., narrowing key words for the studies that are subjected)
- The precautions taken for validity and reliability of meta-synthesis should be clarified (p. 35)

Validity and reliability

In content analysis, reliability and validity are paramount to the integrity and strength of the research (Neuendorf, 2002; Sarantakos, 1998). Validity is checked by comparing expected and acquired results while reliability is ensured by comparing the results of two independent coders. In order to ensure valid and reliable

classification, a code book was created for the study and more than one coder conducted the coding.

Fraenkel and Wallen (2009) define the term validity, in research to indicate the usefulness, meaningfulness and correctness of any instrument used by a researcher to access and interpret. Neuendorf (2002) states validity aims to answer "Are we really measuring what we want to measure?"(p.12). In this research, the adapted version of "Paper Classification Form (PCF)" developed by Sözbilir, Kutu and Yaşar (2012) was used. According to the needs of the study, some categories were added while some were changed or shortened. To ensure the validity of the adapted instrument, the researcher read the articles and compared how they could be coded by the PCF. The target of the article, topics and types of questions were added while data collection tools, research method and data analysis method were changed or shortened (see Appendix B).

The term reliability has been defined by Fraenkel and Wallen (2009) as "The consistency of scores or answers provided by an instrument" (p.154). A coding tool is reliable if it produces consistent results at different times, even when used by different researchers (Krippendorff, 1986; Sarantakos, 1998). Bauer (2000) defines reliability as "agreement among interpreters" (p.143). In this study, intercoder reliability was used. It sometimes called *reproducibility* (Krippendorf, 1986, p.130; Weber, 1985, p.16) which refers to use of a coding procedure by more than one individual producing similar results (Prasad, 2008; Weber, 1985). To measure reliability, first, 12 % of the sampled articles were selected randomly, and along with the instrument, given to other educators and master students. They were instructed to use the instrument to analyse the articles. The results were compared with the

researcher's findings and any differences were discussed. Any disagreements about the classifications were addressed by a meeting of the graduate committee to come to consensus.

CHAPTER 4: RESULTS

Introduction

This chapter gives detailed information about the findings of the study that was obtained from a content analysis of the articles related to misconception in biology. The results of each research question are presented using percentages and frequencies in tables and figures.

Findings of the study

The data were obtained from research studies about misconception in biology published in Turkey from 2000 to 2014. A total of 67 research articles were subjected to content analysis and coded using an adapted version of the Paper Classification Form (PCF) developed by Sözbilir, Kutu and Yaşar (2012).

Research Question 1: What are the characteristics of research studies about misconceptions in biology in terms of the language, year of the articles, type and name of the journals in which articles are published?

In this study, the characteristics of the studies were analysed by identifying the language of the articles, publication year, type and the name of the journal. The list of the articles that were subjected to the content analysis are given in Appendix A.

Table 1
Languages of the articles

	f	*%*
English	27	40.3
Turkish	40	59.7
Total	67	100

Regarding the languages of articles, Table 1 above indicates that the percentage of the articles published in Turkish (59.7%) is higher than the articles published in English (40.3%). Figure 1 presents the number of Turkish and English articles and distribution of languages by the journal types as national and international.

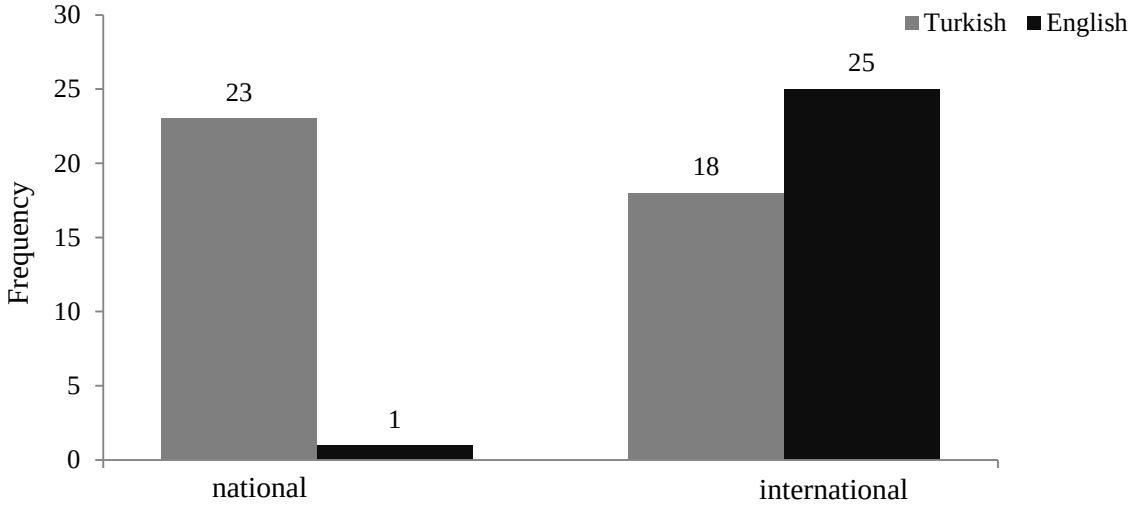

Figure 1. Language of the articles over national and international journals

Regarding national journals, more articles were published in Turkish (*n*=23) while there was only one article written in English. As shown in Figure 1, amount of articles written in Turkish within international journals is much higher than the amount of articles in English published in national journals. There were 25 articles in English published mostly in international journals although there was a large number of articles in Turkish (*n*=18) in international journals as well.

The studies were mostly published in international journals including *Journal of Baltic Science Education* (10.4%), *Hacettepe University Journal of Education Faculty* (9.0%) and *Journal of Turkish Science Education* (7.5%) (See Appendix C).

Figure 2 below shows the percentage of articles published about misconception in biology from 2000 to 2014. The results found remarkable fluctuations; of the articles

investigated for this study, most were published in 2013 (20.9%). There were also notable amount of studies in 2012 (13.5%) and 2009 (12%), while 2004 has lowest numbers of articles published with 1.5%. Moreover, there was a sharp decrease in the amount of articles published in 2014 and no study was published 2001.

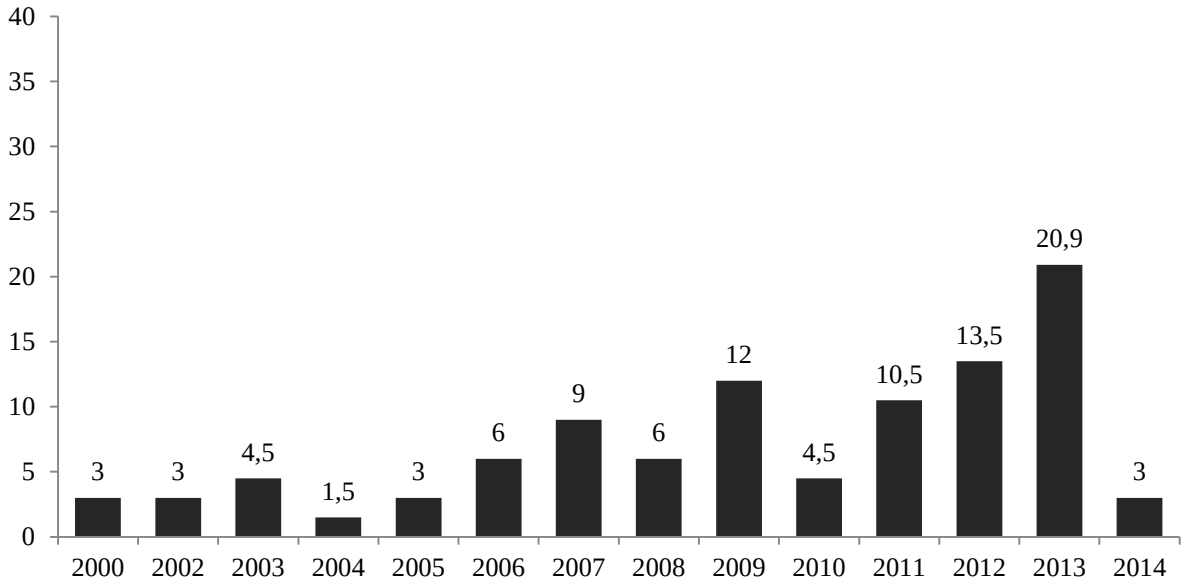

Figure 2. Percentages of studies across years (2000-2014)

Research Question 2: What are the purposes of research articles about misconceptions in biology?

The analysis of the purpose of the articles, involved classifying them into six targets areas:

- Identification of the misconception
- Investigation of cognitive structure
- Treatment with conceptual change strategies
- Determining causes of misconception
- Investigation of books and
- Other areas

As seen from Figure 3, the identification of the misconception is the main target area for most of the articles (44.1%). Around 20.2% of the articles focused on a treatment to observe the effectiveness of an instructional strategy for preventing or eliminating misconceptions. A similar amount of the articles (19.1%) investigated cognitive structures.

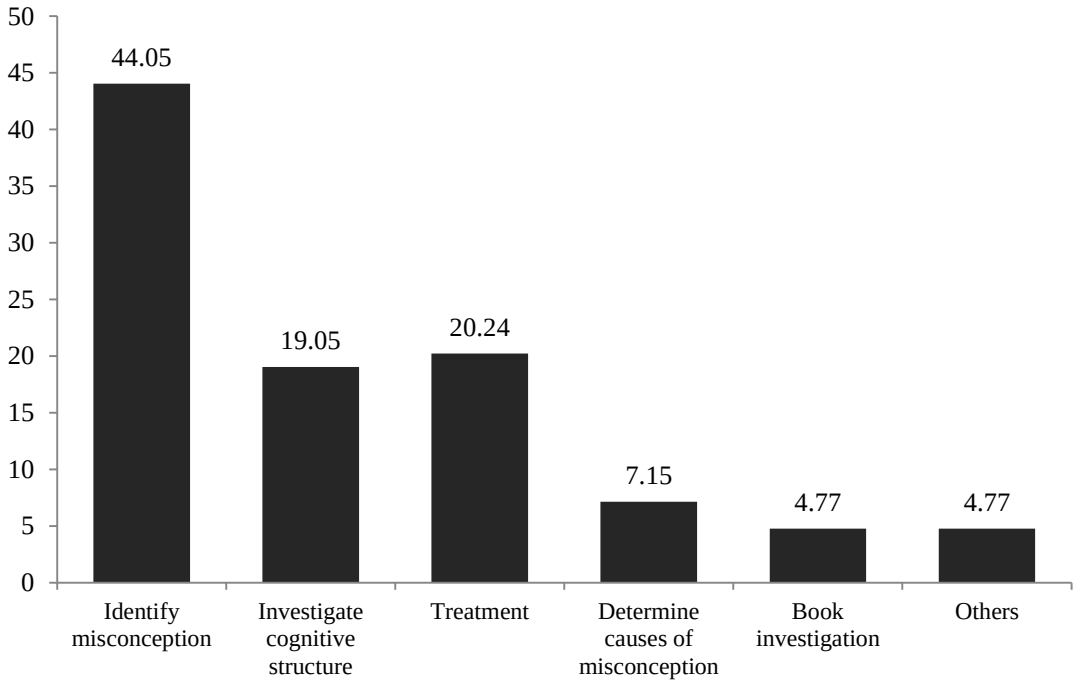

Figure 3. Purposes of research studies (%)

The articles that focused on treatment by conceptual change strategies were classified according to the following methods:

- Analogy and modelling
- Computer and laboratory
- Concept cartoon
- Concept mapping
- Conceptual change text
- Cooperative learning

- Dual situated learning model
- Mind map
- POE (Prediction- Observation- Explanation)

The distributions of the articles that focused on these methods are represented in Table 3 below. As seen from the table, concept mapping (*n*=6) is the most popular method used to prevent or eliminate misconceptions. It is notable that, the amount of articles that focus on treatment increases from the period of 2000-2004 (*n*=2) to the period of 2010-2014 (*n*=14) sharply.

Table 2
Treatment methods

Year	2000-2004	2005-2009	2010-2014	Total
Analogy and modelling	0	0	1	1
Computer and laboratory	1	1	0	2
Concept cartoon	0	0	2	2
Concept mapping	0	2	4	6
Conceptual change text	1	0	3	4
Cooperative learning	0	1	1	2
Dual situated learning	0	1	0	1
Mind map	0	0	1	1
POE(Prediction- Observation- Explanation)	0	0	2	2
Total	2	5	14	21

Research Question 3: What are the themes and patterns in research studies about misconceptions in biology?

Table 4 represents the distribution of themes and patterns throughout the years and Figure 4 shows the topics that were studied during the period from 2000 to 2014. For Table 4, the articles were divided into four main areas: General topics, Cell biology,

Human health and physiology, and Environment and ecology. More specific topics were categorized within these main areas.

Table 3
Distribution of themes and patterns over the years (2000-2014)

	Year			Total
	2000-2004	2005-2009	2010-2014	
General topics	8	20	20	48
Biology as a science	0	1	0	1
Genetic and/or cell division	2	5	7	14
Biotechnology	0	2	0	2
Chemistry of life	1	3	2	6
Microbiology	0	0	3	3
Plant biology	2	3	1	6
Classification of living organism	0	2	5	7
Respiration and photosynthesis	3	4	2	9
Cell Biology	1	4	4	9
Cell structure and organelles	0	2	1	3
Diffusion and osmosis	1	2	3	6
Human health and physiology	2	2	7	11
Endocrine glands	0	0	1	1
Immune system	0	0	1	1
Excretion system	1	0	2	3
Blood circulatory system	0	0	2	2
Reproductive system	1	1	1	3
Digestive system	0	2	0	2
Environment and Ecology	5	5	6	16
Greenhouse Effect and/or global warming	1	1	5	7
Ozone layer depletion	0	1	0	1
World and living things	2	1	0	3
Transformation of energy	2	2	1	5
Total	16	32	37	85

Overall, the main topic of environment and ecology (n=16) was most popular. Within this area, interest in the Greenhouse Effects and/or global warming increased sharply while others fluctuated during 2010-2014 periods. Among the general topics, genetic and cell division (n=14) included the most topics studied from 2000 to 2014. Human health and physiology became more popular to investigate over time,

especially peaked in the period of 2010-2014. The topics in the human health and physiology fluctuated throughout the years.

Notable among the specific topics, interest in studying misconceptions related to microbiology and classification of living organisms increased throughout the timeframe used for this study. Investigations of the cell biology topics remained the same for the last two periods while only one article was published in the 2000-2004 period. The total amount of articles increased from the period of 2000-2004 (*n*=16) to the period of 2010-2014 (*n*=37).

When Figure 4 is examined, it indicates that the most popular area of researched is the environment and ecology topic since 18% of the studies fall within this category. Within this topic area, the Greenhouse Effect and global warming (7.2%) is widely studied. The next most popular area researched is a general topic area, genetic and cell division (15.7%). Another general biology topic that was the focus of research was respiration and photosynthesis (10.8%). The main topic area of human health and physiology comprises 14.4% of the studies.

In addition, biology as a science, endocrine glands, immune system and ozone layer depletion are the less preferred topics to study with 1.2% proportions for each.

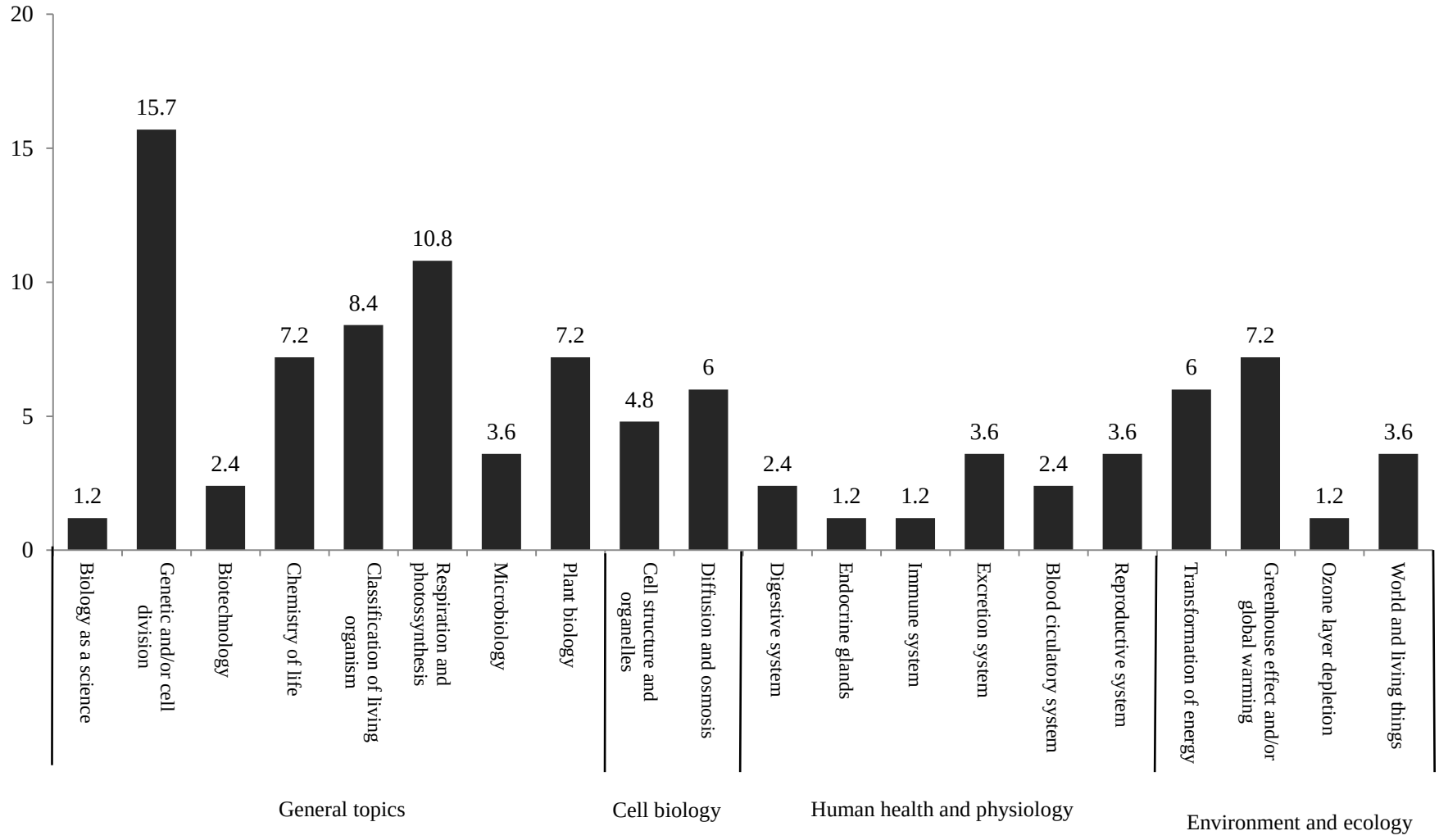

Figure 4. Themes of studies (%)

Research Question 4: What research methods are used in studies about misconceptions in biology?

In order to analyse research methods used, articles were classified as qualitative, quantitative and mixed research methods. Figure 5 compares the percentages of applied research methods. Among the articles investigated, 43% were qualitative and 45% quantitative; only 12% used mixed methods.

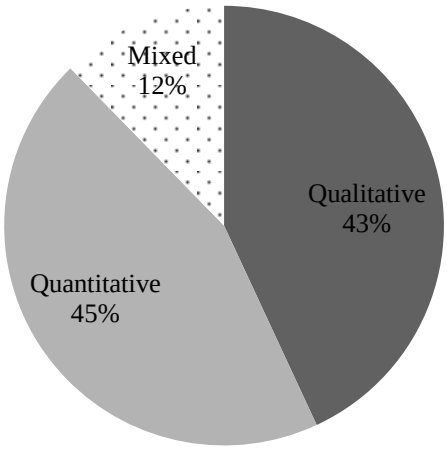

Figure 5. Research methods

Research Question 5: What data collection tools are used in research studies to investigate misconceptions in biology?

In terms of classification of data collection tools, articles were classified according to the following categories: questionnaire, conceptual understanding test, achievement test, diagnostic test, attitude test, drawing- writing, a free word association test, concept cartoons, interview, roundhouse diagraming, observation, documents and other areas.

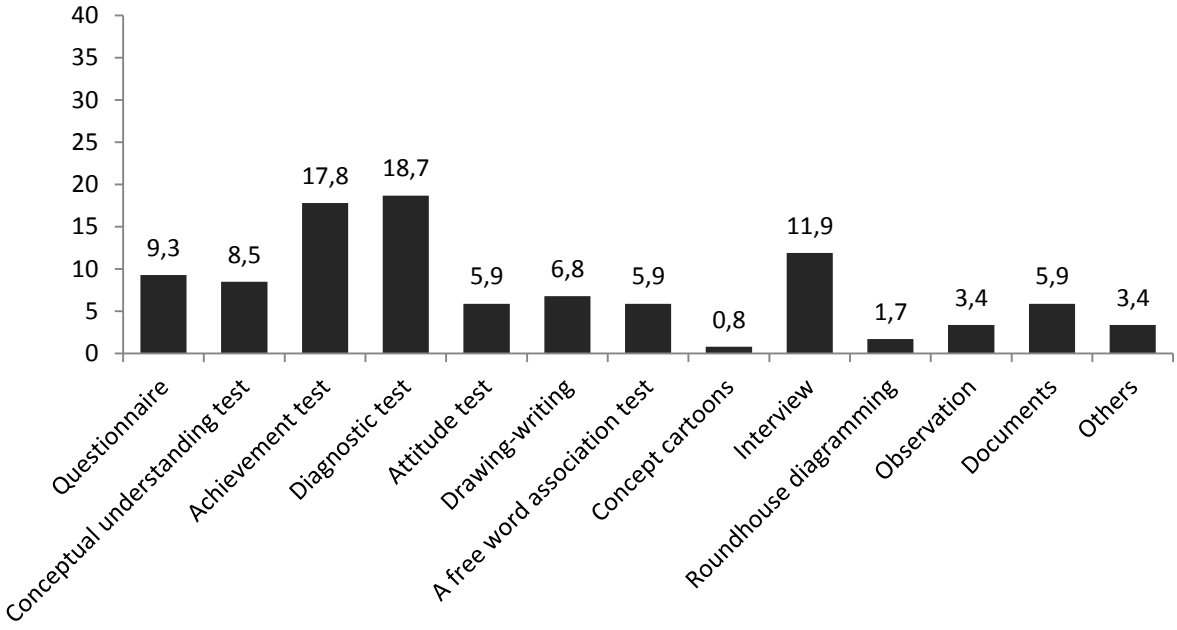

Figure 6. Data collection tools (%)

The analysis shows that the most popular data collection tools were achievement tests (17.8%), diagnostic tests (18.7%) and interviews (11.9%). Among other data collection tools, concept cartoons and roundhouse diagraming have slightly usage with 0.8% and 1.7% respectively.

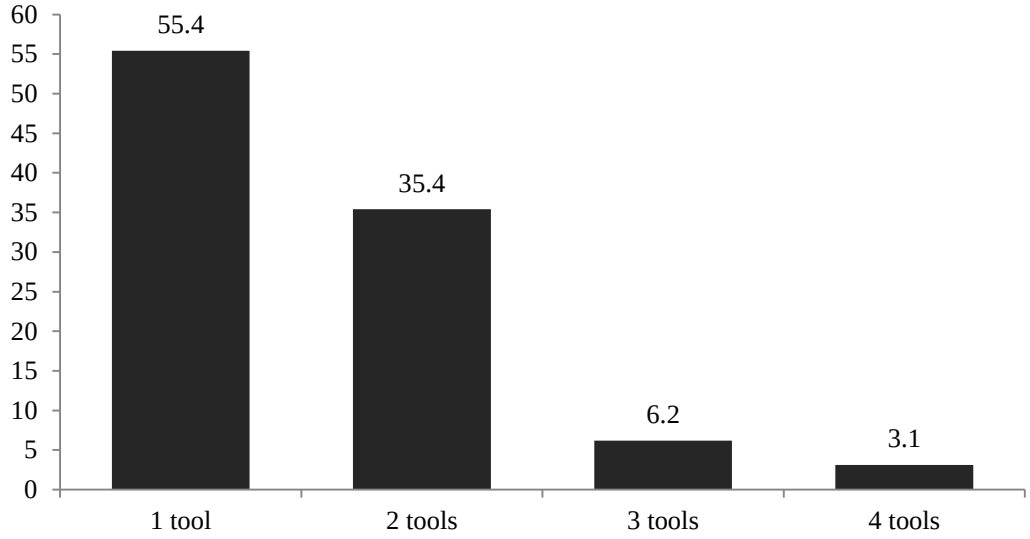

Figure 7.Number of data collection tools (%)

With regard to the number of data collection tools, Figure 7 above indicates that most of the reviewed studies were conducted using a single data collection tool (55.4%), while 35.5% used combination of two different data tools. Just over 9% of the studies relied on three or four data collection tools.

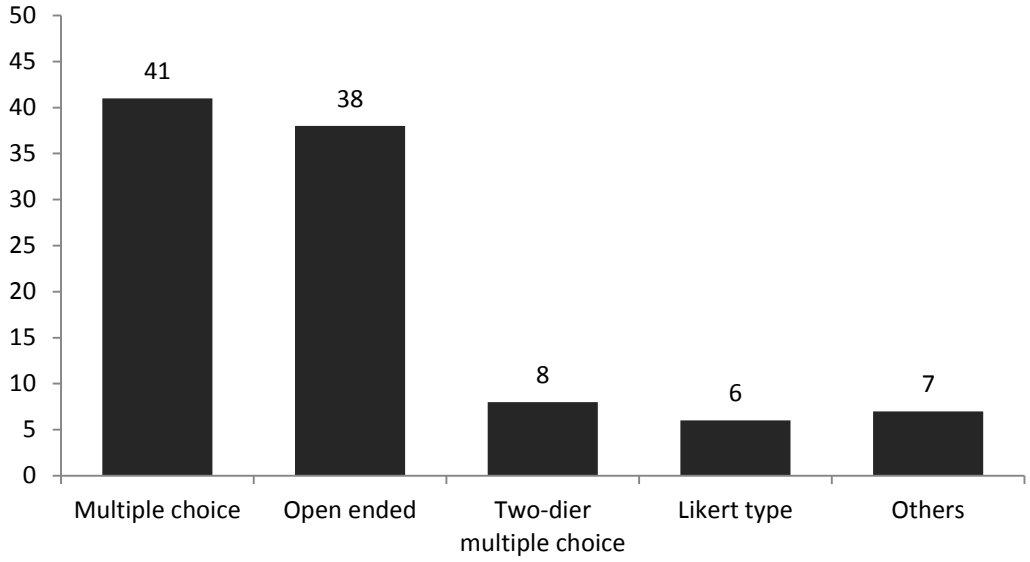

Figure 8.Types of questions (%)

Figure 8 shows the types of questions used within achievement, diagnostic, attitude and conceptual understanding tests. The studies that use these types of data collection methods were categorized based on the following question types: multiple choice, open ended, two-dier multiple choice and Likert type. The most popular question types were multiple choice (41%) and open-ended (38%). Two-dier multiple choice (8%) and Likert type (6%) questions were used less frequently.

Research Question 6: What is the sample and size of the conducted studies about misconceptions in biology?

When Figure 9 is investigated, it appears that 41.2% of the articles were conducted with pre-service teachers. There were also studies targeting middle (25%) and high school (23.5%) students. A few of the studies (5.9%) collected data from elementary school students.

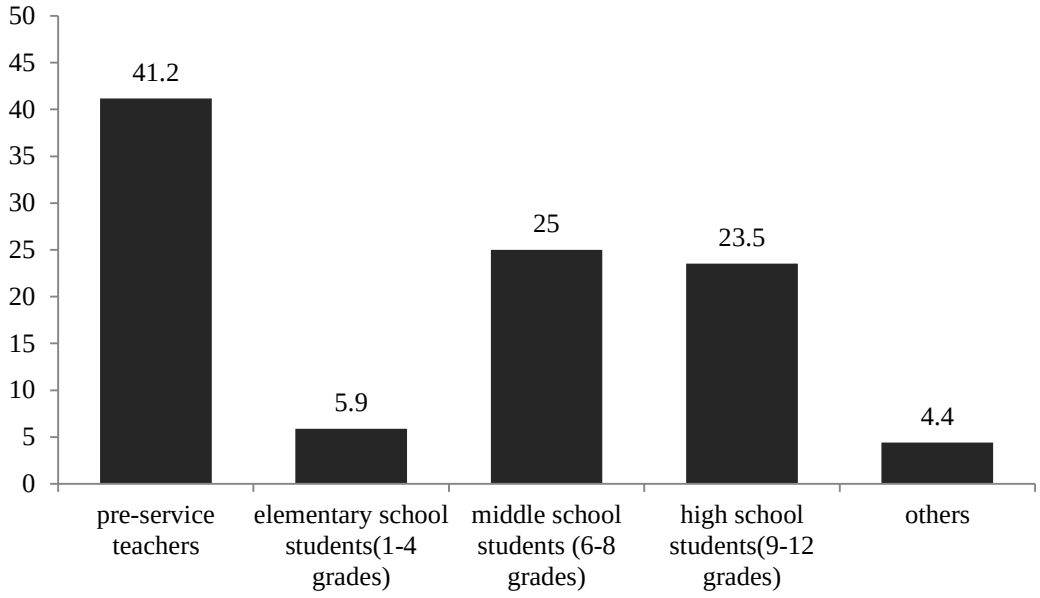

Figure 9. Studied samples in research studies about misconception in biology (%)

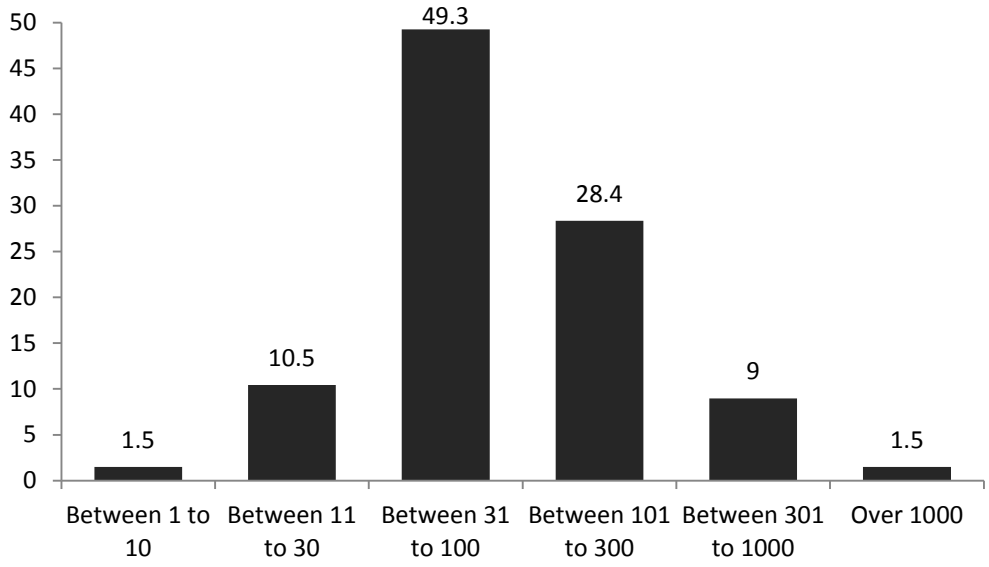

Figure 10. Sample size in research studies about misconceptions in biology (%)

Concerning the sample sizes of the articles, a significant proportion of the studies were with sample sizes ranging from 31 to 100 as shown at Figure 10. The next most frequently used sample size was from 101- 300 (28.4%).Very few of the studies sampled less than 10 participants or over 1.000 (1.5% each).

Research Question 7: What data analysis methods are used in studies about misconceptions in biology?

Regarding to the data analysis methods, studies were classified using quantitative methods with descriptive and/or inferential statistics or using qualitative methods. Table 5 indicates that more than half of the studies were analysed with quantitative methods, the remainder used qualitative data analysis methods. Articles belonging quantitative analysis method employed descriptive (25.4%) and inferential (28.2%) statistics.

Table 4
Data analysis methods

	f	*%*
Quantitative	40	54.0
Descriptive Statistics	19	25.7
Inferental Statistics	21	28.3
Qualitative	34	46.0
Total	75	100

Summary

This chapter provided detail information about the analysis of 67 articles about misconception in biology published between 2000 and 2014 in Turkey.

In order to determine the status of articles, findings were showed by tables and figures.

CHAPTER 5: DISCUSSION

Introduction

In this chapter, the results that were provided in the previous chapter are discussed. First, a general explanation of the results is given, along with the major findings for the seven research questions are discussed. Second, the implications for practice and further research are discussed. Last, the limitations of the study are stated.

Overview of the study

The aim of this study was to review articles about misconceptions in biology published from 2000 to 2014 in Turkey. To meet this aim, 67 articles were selected through ISI Web of Knowledge, Scopus, EBSCOhost, ULAKBİM and ASOS Index databases. Meta-synthesis (thematic content analysis) method was used to explore characteristics, purposes, themes and patterns, data collection tool types, research methods, sample and sample sizes, and data analysis methods of these articles. Selected articles were subjected to the adapted version of a Paper Classification Form developed by Sözbilir, Kutu & Yaşar (2012); see Appendix B. Findings for the data analysis were given in Chapter 4 in detail. The results show that articles about misconception in biology are mostly published in international journals and written in Turkish. These articles mainly focus on identifying misconceptions. Most of the studies' samples were pre-service teachers. The sample size of the studies varied between 31-100. Qualitative and quantitative research methods were equally dominate over mixed method, which was less preferred. The findings also indicate that more studies have been undertaken in environment and ecology and genetic and cell division. Achievement and diagnostic tests were the most common data

collection tools and used multiple choice and open-ended question types.

In the following section, the major findings and possible reasons for these findings are discussed under seven sub-sections:

1. Characteristics of articles about misconceptions in biology
2. Purposes of articles about misconceptions in biology
3. Themes and patterns in articles about misconceptions in biology
4. Research methods in articles about misconceptions in biology
5. Data collection tools in articles to investigate misconceptions in biology
6. Samples and sample sizes of articles about misconceptions in biology
7. Data analysis methods in studies about misconceptions in biology

The major findings

Characteristics of articles about misconceptions in biology in terms of the language, year of the articles, type and name of the journals in which articles are published

For this study, 67 articles were analysed to identify in which journals they were published, their language and in which years they were published during the study period.

According to the results, the articles were mostly published in international journals including *Journal of Baltic Science Education* (10.4%), *Hacettepe University Journal of Education Faculty* (9.0%) and *Journal of Turkish Science Education* (7.5%). In their research, Köse, Gül and Konu (2014) reported that *Hacettepe University Journal of Education Faculty* came to the top of the list as it published

most articles about biology education. In addition, as this study has shown, 24 articles were published in national journals while 43 were published in international journals. In the literature, content analysis studies for the field of science and biology education supports that the number of articles published in international journals has been increasing in recent years (Gül & Sözbilir, 2015; Sözbilir, Kutu & Yaşar, 2012). On the other hand, of the 24 articles published in national journals, 23 were written in Turkish. That is, Turkish educators seem to prefer writing in Turkish if they aim to address Turkish readers. Even though there were a high number of articles published in international journals, a considerable amount of these articles were written in Turkish. These results are supported by other studies (Gül & Sözbilir 2015; Güven et al., 2014; Sözbilir, Kutu & Yaşar 2010).

According to the distribution of articles about misconception in biology across years, it seems that the percentage of articles fluctuates remarkably from 2000 to 2014, with a sharp decrease in the amount of articles from 2013(20%) to 2014 (3.1%). It is possible that the focus on misconception is declining and other topics related to improvement and application of new teaching strategies such as problem or project based learning, place based learning, cooperative learning etc. are becoming more popular to investigate (Sözbilir & Kutu, 2008). In their research, Sözbilir and Gül (2015) showed that "teaching-focused" biology education papers dominated over learning and attitudes, perceptions and, opinions subject matters. Most of the "teaching-focused" biology studies were based on comparing teaching methods, there was also large number of articles that focused on teaching materials. Köse, Gül and Konu (2014) categorized 215 biology education researchers according to their studied domains and reported that most of the studies conducted were concerned

with the effect of teaching methods on student achievement and attitude. It seems that investigation effectiveness of variety of teaching methods and materials has gained importance among biology researchers. On the other hand, since the articles collected from April 2014 to February 2015, this intense difference between the amounts of articles in these two years could merely be influenced by publication periods and were not available for the current investigation.

Purposes of articles about misconceptions in biology

The articles investigated for this study were classified in to the following six categories based on their purpose. Each of these categories is discussed further below:

- Identification of a misconception
- Investigation of cognitive structure
- Treatment by conceptual change strategies
- Determination causes of misconception
- Investigation of books
- Others

Identification of a misconception

Misconceptions create a negative impact on students' learning processes. In order to engage students' persistent and meaningful learning, teachers should be aware of students' misconceptions before beginning to teach (Tatar & Koray, 2005). According to the results, the majority of publications analysed focused on identifying one or more misconceptions (42.4%). Gül & Sözbilir (2015) classified 633 biology education research papers according to the subject matters and reported that 69 of 143 "learning-focused" biology studies were done on the identification of misconceptions.

Studies that aim to identify misconceptions of pre-service teachers have an important role on increasing awareness the learning needs of pre-service teachers; these studies will facilitate identifying possible solutions to eliminate students' misconceptions (Tekkaya, Çapa & Yılmaz, 2000). Also, identification of misconceptions may increase the consideration of conceptual awareness needed for teachers (Yakışan, 2013). The studies in this field inform teachers what kind of misconceptions students have and raise teachers' recognition of how they can handle the misconceptions of students.

Investigation of cognitive structure

Investigating cognitive structures shows teachers and educators the ways students think about a concept. Some teaching strategies and methods help to assess students' understanding biological concepts. Kurt and Ekici (2013), for example, used a word association test and the drawing-writing technique to understand pre-service teachers' cognitive structures. They aimed to understand how pre-service teachers constructed knowledge and how they structured the concepts in their minds, beyond what they know about the concepts.

As this study has shown, around 19% of the reviewed articles focused on the investigation of cognitive structure. In the literature, several studies have shown that investigation into the cognitive structure has gained importance among science researches (Cinici, Sözbilir & Demir, 2011; Çakmak & Alçöltekin, 2012; Kostova & Radoynovska, 2010). Chang et al. (2010) classified 1,401 science education articles according to their research topics and reported that articles mainly focused on students' conceptual understandings and conceptual change in learning process. Investigation of cognitive structure aims to understand how students associate

concepts in their minds, and helps students to visualise what kind of misconceptions they have.

Treatment by conceptual change strategies

The aim of education should not only focus on eliminating the misconceptions; it should also allow students to develop new information correctly (Gökmenoğlu, 2011). Conceptual change provides the opportunity to elicit students' prior conceptions (Fulmer, 2013). Lappi (2013) defines conceptual change as a transformation of prior conception to new concepts. Conceptual change strategies are mostly used to change students' incorrect scientific believes. According to the results, around 20.2% of the articles focus on treatment to observe effectiveness of conceptual change strategies on preventing or eliminating misconceptions.

In this study, articles were classified according to the following conceptual change strategies:

- Analogy and modelling
- Computer and laboratory
- Concept cartoon
- Concept mapping
- Conceptual change text
- Cooperative learning
- Dual situated learning
- Mind map
- POE(Prediction-Observation- Explanation)

As this study has reported, concept mapping is the most popular method to change students' incorrect scientific believes and support meaningful learning. Köse, Gül

and Konu (2014), however, classified biology education articles according to their study domains. They report that laboratory and computer based instruction seem to be the most preferred methods in biology education studies, while concept mapping was given less importance.

In conclusion, studies focusing on treatment to observe effectiveness of conceptual change strategies on preventing or eliminating misconceptions have been increasing over the period of 2000-2014 (see Table 3). A content analysis studies about biology education show that investigating the effect of different teaching methods on instruction are foremost domain (Köse, Gül & Konu, 2014; Sözbilir & Gül, 2015). Conceptual change strategies are expected to be used more as for instruction as well as for a treatment method.

The determination of causes of misconception and an investigation of books

As this study has shown, only 7.15% of the articles focused on the determination of the causes of misconceptions. The causes of misconceptions might originate because of certain reasons such as the media, teachers' insufficient subject area knowledge, daily language, experiences and students' biases to learn biology. The determination of the causes of misconception may provide getting to the root of the problems and help preventing possible misconceptions at an early stage of education.

Another finding of this study was that only 4.7% of the articles focused on investigating conceptual problems and misconceptions in biology textbooks. Since textbooks are significant resources for teachers and students, misconceptions in textbooks influence teachers' effectiveness in teaching and students' learnings.

Consequently, textbooks should be reviewed in terms of content and interrelationship among topics. (Tekkaya,Çapa & Yılmaz, 2000). So, teachers can select using textbooks accordingly (Dikmenli, Çardak & Öztaş, 2009).

Themes and patterns in articles about misconceptions in biology

In terms of themes and patterns in articles about misconceptions in biology, this study showed that a considerable proportion of the articles (18%) focused on the topics of environment and ecology. In the literature, a few content analysis studies show environment and ecology are the most studied topics in biology education in Turkey (Gül & Sözbilir, 2015; Köse, Gül & Konu, 2014).

Environment is the natural habitat of living organisms. In the literature, studies aim to identify misconceptions about environment and ecology to prevent misconceptions and develop meaningful learning (Arsal, 2010; Bozkurt & Koray 2002; Çakmak & Akçöltekin, 2012; Erdoğan & Özsevgeç, 2012). MoNE (2013) aims to improve students' awareness about the negative effects of human activities on the environment and to be able to offer solutions to these problems in the new biology curriculum. Science and Technology Curriculum (2013) provides the following principles to educate students:

- To acquire information and develop inquiry about environmental sciences
- To acquire scientific research skills and offer solutions to environmental problems in the process of discovering the nature and understanding the human-environment relationship
- To be aware of human, society and environment interaction and to develop awareness of the sustainable resources (p.ii)

Misconception studies in this area intend to help students respect nature and recognize that they are part of it. They also seek to raise students' awareness of environmental issues.

The second most popular area (15.7%) was genetics and cell division. There have been a number of research studies that report genetic and cell division as the most difficult topics to learn (Bahar, 2002; Tekkaya, Özkan & Sungur, 2001). Therefore, studies in this area may have increased to further understand why and how students have difficulty with these topics.

When the literature was reviewed, it was found that Asshoff and Hammann (2008) provided an analysis of articles about biology education published in European Researchers in Didactics of Biology (ERIDOB) conferences and compared them with the International Journal of Science Education (IJSE). They found that ERIDOB involved more articles about dealing with students' misconceptions in the fields of genetics than IJSE. On the other hand, IJSE contained more articles about misconception in the field of ecological topics. As parallel to the Asshoff and Hammann (2008)'s result, this study also has reported that the most popular studied topics were genetics and environment.

Generally, biology as a science, endocrine glands, immune system and ozone layer depletion were the least preferred topics to study, with each comprising 1.2% of articles investigated for this study. Students are introduced to the topic "Biology as a Science" in 9^{th} grade. The topic basically covers the following disciplines: interests of biological sciences, historical development of biology, the contribution of biology to humanity, key features of living and non-living things and importance of inorganic and organic compounds found in living things (MoNE, 2013). So, this topic provides

students with the main concepts about biology, and can aid students in developing positive attitudes towards biology and support meaningful learning. Since biology concepts are introduced to students in middle school through Science and Technology lessons, researchers may think students have already gotten basic biology concepts. Consequently, very few studies have been done in this area.

The aim of this study was to show gaps in the studies about misconceptions in biology. Based on Ministry of National Education biology high school curriculum (see Figure 4), 20 topics were used to classify articles in this study. According to the current classification, this study found that in Turkey, no misconception study in the following biology topics:

- Nervous system
- Sensory organs
- Support and movement system
- Evolution

Moreover, the result of this study has shown that articles about the environment and ecology have mostly focused on the Greenhouse Effect and global warming. However, some topics such as biodiversity, sustainability, natural resources, and human effects on pollution, are not given enough importance. In their studies, Erdoğan, Marcinkowski and Ok (2009) report that environmentally responsible behavior and socio-political knowledge received very little attention in the area of environment and ecology studies.

As is stated in Chapter 2, biology topics are mostly related to each other; hence, current misconceptions about one concept prevent meaningful learning of other

concepts. The findings from this study indicate that publications about misconceptions in biology have been increasing (see Table 4). This growth may provide researchers and teachers with better understanding about core points of students' difficulties and origins of misconceptions.

Research methods in articles about misconceptions in biology

In this part of the study, articles were classified according to their research methods: quantitative, qualitative and mixed. Patton (1987) defines the quantitative method as the standardization of various opinions and experiences into determined categories. He also defines the qualitative method as direct observation and description of events, people, behaviours, and situations. Mixed research involves the mixing of quantitative and qualitative research methods.

In the literature, content analysis studies show that researchers widely preferred quantitative methods in biology and science education in Turkey (Erdoğan, Marcinkowski & Ok, 2009; Güven et. al., 2014; Sözbilir & Gül, 2015; Sözbilir, Kutu & Yaşar, 2012). Güven et. al. (2014) suggested that qualitative methods require more time to conduct than quantitative and mixed method. However, this study found that qualitative (43%) and quantitative (45%) research were employed with similar proportions. It may be that the nature of misconception studies requires deeper investigation into cognitive structures than on interpreting numerical values. In addition, mixed (12%) method was used least frequently. Mixed method may provide even deeper understanding of the study and support the validity of the research. As Schram (2014) states interview with a sample group before a survey provide answers to why and how questions are answered in a certain way can help researchers decide what to include in the survey.

Data collection tools in articles to investigate misconceptions in biology

Types of data collection tools

In terms of data collection tools, the articles were classified according to the following categories: questionnaire, conceptual understanding test, achievement test, diagnostic test, attitude test, drawing- writing, a free word association test, concept cartoons, interview, roundhouse diagraming, observation, documents and other areas. The result of the classification showed that diagnostic test, achievement test and interviews were the most commonly used tools to investigate students' and pre-service teachers' misconceptions in biology.

Achievement tests and diagnostic tests were mostly developed by researchers and aimed to learn students' understandings of the related concepts. In the literature, many studies report that achievement tests were frequently used data collection tools in biology education (Göktaş et al. 2012; Kızılaslan, Sözbilir & Yaşar, 2012; Sözbilir, Kutu & Yaşar, 2012). However, test-like assessment tools evaluate *what* students know about the concepts instead of *how* they know (MoNE, 2015). It seems that researchers prefer to use test-like assessments because they are easy to prepare and mark (Sözbilir, Kutu & Yaşar, 2012).

In this study, the third most popular method was interviews. Face-to-face interactions with students might be the easiest way to understand their thinking. However, they may reflect what somebody wants to hear instead of what they actually believe (Allen, 2010). On the other hand, students may be more able to express concepts with their own words (Tatar & Koray, 2005). Moreover, the interview format allows students to give feedback and correct any inaccurate beliefs about the phenomena immediately.

Additionally, concept cartoons and roundhouse diagraming were the least methods in the studies. As stated above, conceptual change strategies have been mostly used to change students' incorrect scientific beliefs. In the literature, some studies showed these strategies are used to discover students' cognitive structures (Akyürek & Afacan, 2013; Ekici, Ekici & Aydın, 2007; Kurt, 2013; Ratinen, Viiri, & Lehesvuori, 2013).

Number of data collection tools

Regarding to the number of data collection tools, most of the studies used a single data collection tool (55.4%), while 35.5% used the combination of two different data tools (see Figure 7). Content analysis studies in the literature show that studies tend to use one data collection tool (Gül & Sözbilir, 2015; Sözbilir & Kutu, 2008; Sözbilir, Kutu & Yaşar, 2012). Sözbilir, Kutu and Yaşar (2012) argue that to improve reliability and validity, more than one data collection tool should be employed. Especially, using a single data collection tool in studies that investigate cognitive structures is not enough to acquire in-depth and strong results (Kurt & Ekici, 2013). In the literature, some misconception studies use more than one data collection tools to support results (Akyürek & Afacan, 2013; Cinici, 2013; Kurt, 2013).

Types of questions

When investigating the types of questions (see Figure 8), multiple choice questions (41%) were the most popular question types used for achievement, diagnostic, attitude and conceptual understanding tests. In the literature, some content analysis studies found that multiple choice type achievement tests are widely used (Gül &

Sözbilir, 2015; Sözbilir, Kutu & Yaşar, 2012). Er, Ramamurthy and Pook (2014) argue that multiple choice type questions can efficiently assess students' cognitive skills, such as analysis, synthesis and evaluation. Although multiple choice questions can assess students' level of knowledge and cognitive skills, they may not provide enough information to discover students' cognitive structures. Sanders (1993) indicates that not all incorrect answers identified during research studies necessarily show students have misconceptions. He goes on to further comment that while researchers perform tests during their studies and report the results accordingly, they should discriminate between true misconceptions and wrong answers. Therefore, test type questions may not provide adequate evidence to understand students' misconceptions and their cognitive structures.

Open ended questions (38%) were the second most popular question types on the tests for this study. In their research, Gül and Sözbilir (2015) reported that only 42 of 231 achievement tests consisted of open-ended questions in biology education. Hence, open-ended questions might be the most preferred method of data collection in misconception studies.

Samples and sample sizes of articles about misconceptions in biology

As this study has shown, the majority of the studies (40.9%) sampled pre-service teachers. The reason for this result is probably that teachers' insufficient subject area knowledge and misconceptions may be an origin of misconception.

If pre-service teachers' misconceptions are not revealed or corrected, when they become teachers they may transfer their misconceptions to students (Yangın, Sidekli & Gökbulut, 2014). Increasing the number of studies done by pre-service teachers helps them to become aware of and eliminate their misconceptions (Yakışan, 2013).

Biology is introduced to students in middle school in the classes of science and technology. Then at the level of high school, science is divided into physics, chemistry and biology. So, middle school establishes the foundation of biology education. Subsequently, this study found that 24.2% of the articles sampled middle school students and the same amount sampled high school students. The reasons for their selection of this population may be that this is the age when students are constructing meaning and understanding about biology, and is an ideal time to avoid misconceptions. On the other hand, even though students are not introduced to biology in elementary school, they still meet some concepts about biology. Unfortunately, only a few articles (6.1%) focused on elementary students' misconceptions about biology.

Data analysis methods in studies about misconceptions in biology

Compared to the number of data analysis methods, the number of quantitative analysis method (*n*=38) was slightly more than qualitative analysis method (*n*=33). The reason is probably that in quantitative method researchers can interpret the data numerically and can measure the effect of an independent variable on dependent variables (Fraenkel & Wallen, 2009) Especially, studies that used experimental design may aim to compare new attempts with old ones (Çalık, Ünal, Coştu & Karataş, 2008).

Implications for practice

Misconceptions are a major factor that affects students' learning processes. Students retain their misconceptions throughout their schooling unless they are corrected in a timely manner. In order to attain effective learning process for students the following actions are suggested:

- Curriculum developers, educators and teachers should give more importance to content of biology curriculum and textbooks; they should arrange seminars or meetings to discuss and evaluate current subject matter.
- In order to prevent misconceptions and promote meaningful learning, conceptual change strategies such as concept mapping, concept cartoon, word association test should be supported in classrooms as alternative teaching methods and assessments.
- Students' misconceptions in biology may originate from other subjects, such as chemistry, physics and physical education. Supporting interdisciplinary training with activities and examples may support students' meaningful learning and help teachers observe students' learning processes efficiently.

Implications for further research

- At the present, there are not enough studies that investigate how the social environment affects students' misconceptions. As a result, studies should be increased on this area.
- More studies should be conducted on how students' communication influences misconceptions and how parents affect students' misconceptions.
- For further studies, how misconceptions in specific topics influence learning in other biology should be investigated.
- Important concepts in biology, such as the nervous system, sensory organs, support and movement system, evolution are under-investigated regarding misconceptions. Future studies should focus on these topics
- Finally, studies focusing on the causes of misconceptions and studies with elementary school students should be considered important and increased.

Limitations

There were number of limitations in this study:

- The study was limited to digital media and electronic databases of scientific publications in the field of education. Therefore, articles published in scientific journals between 2000- 2014 were used for this.
- Since there are several studies about misconceptions, only key words (*misconception*, *alternative conception* or *misunderstanding* and *biology* or *biology education*) of the articles were scanned to select the studies
- Only research-based articles were examined in this study. Theoretical research and studies with university students other than pre-service teachers were not explored even if they included the key words misconception and biology or biology education.
- The studies' samples considered elementary, middle and high school students and pre-service teachers.

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APPENDICIES

Appendix A: List of articles

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Appendix B: Paper classification form

This code book prepared to guide the content analysis study about the dissertations and thesis. There are seven main parts in this code book and each of them designed to gather information about the features of the documents. The operational definitions of the categories provided in this code book and while coding the documents use these definitions.

<table>
<tr><td colspan="2">A. Information about article;</td></tr>
<tr><td>1. Title:

2. Author:

3. Author nation
□ 31. Turkish
□ 32.Foreign
□ 33.Mixed</td><td>4. Journal name:
a. Year:
b. Volume:
c. Issue:
d. Pages:

5. Journal type
□ 51. National
□ 52. International

6. Language
□ 61. Turkish
□ 62.English
□ 63. Other</td></tr>
<tr><td colspan="2">B. Target of the article</td></tr>
<tr><td colspan="2">□ 1. Investigate cognitive structure
□ 2.Treatment
□ 3.Identify misconception
□ 4.Conceptual understanding difficulties
□ 5.Determine causes of misconception
□ 6. Book investigation</td></tr>
</table>

□ 7.Other

Please write the title……

C. Topic

□ 1. Biology as a science
□ 2. Cell biology
  □ 2.1. Cell structure and organelles
  □ 2.2.Diffusion and osmosis
□ 3. Genetic and/ or cell division
□ 4.Biotechnology
□ 5. Chemistry of life
□ 6. Classification of living organism
□ 7. World of living creatures
□ 71. Microbiology
□ 72.Plant biology
□ 8. Human health and physiology
  □ 8.1. Endocrine glands
  □ 8.2. Immunity
  □ 8.3. Excretion system
  □ 8.4. Blood circulatory system
  □ 8.5. Reproductive system
  □ 8.6. Digestive system
□ 9. Environment and ecology
  □ 9.1. Greenhouse effect and/or global warming
  □ 9.2. Ozone layer depletion
  □ 9.3. World and living things
  □ 9.4.Transformation of energy
□ 10. Respiration and photosynthesis

D. Research Method

□ 1.Quantitative
□ 2.Qualitative
□ 3.Mixed

E. Data Collection Tools

A. Number of data collection tools

□ 1 □ 2 □ 3 □ 4 □ 5

B. Types of data collection tools

□ 1. Questionnaire □ 2. Achievement test □ 3.Conceptual understanding test □ 4.Diagnostic test □ 5. Drawing-writing □ 6. A free word association □ 7. Roundhouse diagramming □ 9.Concept cartoons □ 10. Attitude test (Please write the title……)	□ 11. Interview □ 12.Observation □ 13.Documents □ 14.Other Please write the title……
	Types of questions □ a. Multiple choice □ b. Open-ended □ c. Likert □ d. Two-dier multiple choice □ e. Others

F. Sample	
A. Sample	B. Sample size
□ 1.Pre-service teachers □ 2.Elementary school (1-4 grades) □ 3.Middle school (5-8 grades) □ 4.High school (9-12 grades) □ 5. Others Please write the title…….	□ 1.Between 1 to 10 □ 2.Between 11 to 30 □ 3.Between 31 to 100 □ 4.Between 101 to 300 □ 5.Between 301 to 1000 □ 6.Over 1000

G. Data Analysis	
1. Quantitative	□ 11.Descriptive statistics (frequency/percentage tables, charts, central tendency measures)
	□ 12.Inferential statistics (t-test, ANOVA/ANCOVA, correlation, factor analysis, regression)
2. Qualitative	

Appendix C: List of journals

Title of Journal	*f*	%	*Language of study*	*Journal Type*
Afyon Kocatepe University Journal of Social Science	1	1.5	Turkish	National
Biotechnology & Biotechnological Equipment	1	1.5	English	International
Dicle University Journal of Ziya Gökalp Education Faculty	2	3.0	Turkish	National
Dicle University Journal of Social Science	1	1.5	Turkish	National
Dokuz Eylül University Journal of Buca Education Faculty	2	3.0	English	National
Eastern Anatolia Region Research Journal	1	1.5	Turkish	National
Ecology Journal	1	1.5	English	International
Education and Science	1	1.5	English	National
Educational Sciences: Theory & Practice	1	1.5	English	International
Ege University Journal of Education	1	1.5	Turkish	National
Elementary Education Online	2	3.0	Turkish	International
Erzincan University Journal of Education Faculty	2	3.0	Turkish	National
Eurasian Journal of Educational Research	2	3.0	English	International
Gazi University Journal of Education Faculty	3	4.5	Turkish	National
Hacettepe University Journal of Education Faculty	6	9.0	Turkish	International
International Journal of Academic Research	1	1.5	English	International
International Journal of Environmental & Science Education	4	6.0	English	International
International Journal on New Trends in Education and Their Implications	1	1.5	English	International
International Online Journal of Educational Sciences	1	1.5	Turkish	International
International Periodical For The Languages, Literature and History of Turkish or Turkic	1	1.5	Turkish	International

Appendix C: List of journals (cont'd)

Journal of Baltic Science Education	7	10.4	English	International
Journal of Biological Education	2	3.0	Turkish	International
Journal of Educational and Instructional Studies in the World	1	1.5	Turkish	International
Journal of Kırşehir Education Faculty	1	1.5	Turkish	National
Journal of Research in Education and Teaching	2	3.0	Turkish	National
Journal of Turkish Science Education	5	7.5	English	International
Kastamonu University Journal of Education Faculty	3	4.5	Turkish	International
Mehmet Akif Ersoy University Journal of Education Faculty	1	1.5	Turkish	National
National Education Journal	1	1.5	Turkish	National
Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education	1	1.5	Turkish	International
On Dokuz Mayız University Journal of Education Faculty	1	1.5	Turkish	National
Pamukkale University Journal of Education Faculty	1	1.5	Turkish	National
Pamukkale University Journal of Social Science Faculty	1	1.5	Turkish	National
Scientific Research and Essay	1	1.5	English	International
The Turkish Online Journal of Educational Technology	1	1.5	English	International
Turkish Journal of Education	1	1.5	Turkish	International
Uludağ University Journal of Education Faculty	1	1.5	Turkish	National
World Applied Sciences Journal	1	1.5	English	International
TOTAL	67	100.0		