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# School Students' Conceptions about Biodiversity Loss: Definitions, Reasons, Results and Solutions

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**Abstract** Environmental degradation stemming from anthropocentric causes threatens the biodiversity more than ever before, leading scholars to warn governments about the impending consequences of biodiversity loss (BL). At this point, it is of great importance to study the public's conceptions of BL in order to identify significant educational implications. However, a review of the literature reveals a relatively small body of research about the public understanding of BL. In this qualitative study, we thus strived to elicit Turkish school students' conceptions about BL using a written questionnaire including open-ended questions with respect to the definition of biodiversity as well as reasons for, results of and solutions to BL. The sample consisted of 245 school students in a relatively small city. A two-staged content analysis was run on the responses. The results showed that school students most commonly preferred species-focused definitions of biodiversity and understood BL through such various conceptual patterns as, 'balance of nature', 'forest', 'global warming', 'hunting' and 'indirect conservation'. At the end of the paper, the possible educational implications and future perspectives were discussed.

**Keywords** Biodiversity · Biodiversity loss · Conceptions · School students

## Introduction

Human activities are altering the planet's biota in a number of ways. Commercial hunting, habitat destruction through activities such as deforestation or agricultural land use (Snaddon, Turner &

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Foster, 2008), pollution and urbanisation play major roles in biodiversity loss (BL). It is also believed that global environmental problems such as ozone layer depletion and global warming indirectly endanger species further (Ashworth, Boyes, Paton & Stanisstreet, 1995). In the case of global warming, for example, robust evidence has been presented supporting multiple scenarios that are likely to affect biodiversity. Examples of such scenarios include changes in species distribution and genetic traits; habitat fragmentation and a lack of migration corridors; changes in timing of seasonal events such as migration; rising ocean temperatures and sea level and ocean acidification (Intergovernmental Panel on Climate Change [IPPC], 2001). The experts stress that humans must cope with not only ecological but also social, economic and political results of BL (Novacek, 2008).

In response to these problems, the Convention on Biological Diversity (CBD) was endorsed at the United Nations Conference on Environment and Development (UNCED) and made international law in 1993. The objectives of the CBD are the slowing of BL, the sustainable use of resources and the fair and equitable sharing of the benefits arising from the utilisation of genetic resources, including by appropriate access to genetic resources and the appropriate transfer of relevant technologies, taking into account all rights to those resources and to technologies, and by appropriate funding (United Nations Environment Programme [UNEP], 1993). The CBD brought the issue of biodiversity to the attention of scientists, educators, policymakers and the public worldwide (Kassas, 2002).

The topic of biodiversity has an important place in Education for Sustainable Development (ESD) because it reflects the interaction of many dimensions, such as ecological, economic, political and social (Grace, 2009; Hellden & Hellden, 2008; Menzel & Bögeholz, 2009). ESD enables people to develop the knowledge, values and skills necessary to participate in decisions (both locally and globally) that will improve their quality of life without damaging the planet or its future (Dawe, Jucker & Martin, 2005). Therefore, in attaining the goals of ESD at a personal level, people need to understand what is meant by biodiversity, its value to humans, how to protect it and the reasons to do so, as well as consequences and remedies for BL (Hunter & Brehm, 2003; Knight, 2008; Prokop, Kubiatko & Fancovicova, 2009). However, there has been little effort to describe conceptions of the general public and school students regarding endangered species, managing biodiversity and the reasons for species' extinction (Hunter & Brehm, 2003; Mankin, Warner & Anderson, 1999). To this end, in the present study, we try to elicit conceptions about BL in school-aged children, who will become decision makers in the near future.

## Theoretical Background

In the present study, we have adopted a constructivist perspective based on conceptual change. Constructivist theory suggests that knowledge is constructed by learners as they attempt to make sense of their experiences. Learners, therefore, are not blank vessels waiting to be filled but, rather, active organisms seeking meaning (Driscoll, 2000). In addition, conceptual change has become the term denoting the process of learning science from constructivist approaches (Duit & Treagust, 2003). Scholars have proposed theoretical perspectives such as the analogy with science (Carey, 1999), the theory approach (McCloskey, 1983), rational perspective (Strike & Posner, 1992), knowledge in pieces (diSessa & Sherin, 1998) and hot conceptual change (Pintrich, Marx & Boyle, 1993) to understand the process of conceptual change. These perspectives use their own terminologies to represent children's ideas about nature and science. Misconceptions, alternative conceptions, naive theories, framework theories, specific theories, mental models, facets and p-prims are some examples. In addition, different theoretical approaches define conceptual change in different ways even though they use very similar

arguments. Duit and Treagust (2003) considered that conceptual change approaches that were developed during the 1980s and 1990s have a number of limitations and show one-sidedness because they particularly embraced monistic views of learning. They suggested that a multiple perspective based on the relationships between different conceptual change approaches and oriented towards social-constructivist views of learning was a promising approach to the improvement of science teaching and learning. Given the richness of theoretical perspectives regarding students' conceptions and the suggestions of Duit and Treagust (2003), we have decided to construct a multi-perspective approach based on the following key points of view:

- We use the term 'conception' in the present study in the sense of students' naive mental structures that represent natural phenomena and processes. These structures are included in a knowledge system and are connected to each other by causal webs. The conceptions are developed through observation of the natural world, informal reasoning, social interaction and instructional interventions (diSessa & Sherin, 1998; Strike & Posner, 1992). In the case of biodiversity, we believe that children develop conceptions regarding natural phenomena from birth. These conceptions are constructed via personal experiences with nature. Pleasure, joy, interest and pride in being able to identify organisms are important parts of such experiences. In addition, experiences with peers, family members and schoolteachers in the early years of education are also influential in constructing individuals' conceptions of nature. Opportunities for education have become more frequent with the advent of mass media and electronic communication. For many people, nature shows on television and stories of environmental destruction in the mass media and on the Internet may be as important as or more important than hands-on outdoor experiences in forming a consciousness about nature and biodiversity. In addition, formal education is also considered a major source of information about BL.
- Children have many conceptions about nature and science, and these conceptions work as a system that evaluates incoming information. They have certain conceptions that adhere to accepted scientific understanding and certain conceptions (misconceptions) that would represent barriers to the accommodation of scientific information. Conceptual change covers learning pathways from students' pre- and/or post-instructional conceptions to the scientific concepts to be learned. This is a restructuring process that allows an understanding of the intended scientific knowledge (Driver et al. 1985; Strike & Posner, 1992). We consider that school students most likely have many incorrect conceptions about BL and that a restructuring process is needed. We can classify these incorrect structures as 'misunderstandings' and 'misconceptions' (Zoller, 1990). Misunderstandings are easily removed through purposeful intervention, whereas misconceptions are resistant to change.

## Previous Research

Four main trends related to BL are observed in the existing literature: conceptions of ecological concepts, reasons for conserving endangered species, values that are influential in conservation and conceptions about biodiversity and BL. In the first trend, researchers have focused on students' conceptions of some ecological concepts that are closely related to BL, including food chains, food webs, matter recycling and the balance of nature. Palmer (1997), for example, demonstrates that students are conscious about the interdependence among species in an ecosystem. They also understand that all species have important roles in vital ecological processes. In contrast, Grotzer and Basca (2003) argue that students have difficulties understanding ecosystem concepts. The researchers point out that students not only have difficulty viewing the biotic factors of an ecosystem as interconnected but also fail

to acknowledge the effects of abiotic components on the ecosystem. The authors also note that, before the intervention to increase the awareness of causal reasoning underlining ecosystem concepts, students reasoned about the connections in ecosystems based on salient experiences. Most of the connections were expressed at the one-step linear level, specifying predator–prey relations. Perhaps because of this simplistic reasoning, students have a variety of misunderstandings about ecosystems and species' roles therein (Barman, Griffiths & Okebukola, 1995; Munson, 1994; Palmer, 1997; Stamp, 2004; Stamp, Armstrong & Biger, 2006). Stamp (2004), for example, shows that undergraduate students have some misconceptions regarding interactions between plants and herbivores, especially with regard to plant defences. In addition, Barman and others (1995) argue that students believe that a change in the size of a prey population has no effect on its predator's population. Furthermore, Novacek (2008) reveals that people consider the wave of current extinctions as part of the normal turnover in the history of life.

In the study of the second trend, the emphasis is placed on students' reasons for saving individual endangered species. Many criteria for deciding which organisms should be protected are used by school students. In terms of physical appearance, visual attractiveness (Ashworth et al., 1995; Grace & Ratcliffe, 2002; Kellert, 1996; Knight, 2008; Lindeman-Matthies, 2005; Lindeman-Matthies & Boes, 2008; Natarajan, Sugra, Apte & Rehaodes, 2002) and size (Ahworth et al, 1995; Collins, 1976; Eroğlu, Kilinc, Boyes & Stanisstreet, 2010; Lindeman-Matthies, 2005; Snaddon, Turner & Foester, 2008) attract students' attention. In addition, usefulness of the species to humans is also considered as a reason for conserving species (Ashworth et al., 1995; Lindeman-Matthies, 2005; Menzel & Bögeholz, 2009; Yörek, Aydin, Ugulu & Dogan, 2008). Food and transport in the case of animals and food and medicine in the case of plants are useful characters mentioned by students (Jimenez, 2008). Another factor is intelligence. Some children believe that human-like animals deserve conservation because of these species' intelligence (Ashworth et al., 1995). Species' roles in prey–predator relations are also rated as a reason for conservation. In this case, students give more credit to prey species relative to predators (Collins, 1976; Prokop, Kubiatko & Fancovicova, 2009). Domestication of a species is another criterion for children. Domesticated animals such as dogs, birds, horses and cats are the top species that children believe should be conserved (Collins, 1976). Children also rate rarity as an argument for conservation (Knight, 2008; Yörek et al., 2008). Furthermore, students are usually willing to protect fragile ecosystems such as rain forests and coral reefs because these areas include a range of species and play important roles in maintaining the balance of nature (Eroğlu et al., 2010; Greaves, Stanisstreet, Boyes & Williams, 1993; Snaddon, Turner & Foster, 2008).

In the third trend, the research demonstrates that individuals use many values in decision-making processes regarding biodiversity conservation. Grace and Ratcliffe (2002), for example, note that the values that students use in discussions about biological conservation are ecocentric (biocentric) and anthropocentric (aesthetic, enjoyment) and are related to economic concerns, effectiveness and altruism (caring for future generations). In addition, moral values are important components of people's understanding of BL. Generally, people believe that individuals have a moral obligation to protect the natural environment (Hunter & Brehm, 2003; Novacek, 2008; Palmer, 1997). In addition, Menzel and Bögeholz (2009) show that students use both utilitarian (food and medicine sources, tourist attractions, aesthetic beauty) and ecocentric (the ability to survive in different conditions due to genetic flexibility) values in understanding BL. Furthermore, there is a consensus that individuals with ecocentric values place greater priority on species preservation relative to those with anthropocentric and egocentric values (Grace, 2009; Grace & Ratcliffe, 2002; Hunter & Rinner, 2004).

In the final trend, individuals' conceptions about biodiversity and BL are the main focus. Hunter and Brehm (2003), for example, declare that students are conscious of the need to conserve endangered species, whereas they do not have sufficient information about the reasons for and possible results of BL. Erdoğan and others (2008) conclude that students believe that an excessive amount of hunting, water and air pollution, changes in the climate as a result of global warming, construction of factories in natural areas and uncontrolled waste management are the main environmental problems directly influencing the loss of endangered species and threatened environments. Eroğlu and others (2010) also reveal that students associate global warming with BL. They stress that students use 'physico-geographic' reasoning to explain global warming's effects on species; the students believe that species living in cold and wet environments would suffer more harm from global warming relative to species living in warm places. In addition, Dervişoğlu (2007) argues that the students do not seem to be aware of the importance of their personal actions, such as recycling, consumption habits and so on, to conserving biodiversity. However, she notes that when students consider that the harmful consequences of BL will affect themselves and their families, their desire to become involved in some organisations targeting species conservation increases.

## Problem

Upon reviewing the existing literature, we noticed some important gaps on which we base our research. First, we chose BL as a research topic because it is an urgent problem with destructive consequences for nature and humans' well-being in the present and future. A major report by the Millennium Ecosystem Assessment (2005), to which more than 1,000 experts contributed, notes that the majority of biomes have been greatly modified by humans; among a range of higher taxa (amphibians, African mammals, water birds, butterflies, Caribbean corals and fishery species), the majority of species are currently in decline, and between 12 and 52 % of species within well-studied higher taxa are threatened with extinction. Although BL is a crucial threat, the topic is relatively new to formal school environments, educational research (Lindeman-Matthies, 2005) and even pure scientific inquiry (Hunter & Brehm, 2003; Kassas, 2002). Therefore, the more scientific focus, social or pure, that is directed to this problem, the better we will come to understand the problem and suggest better solutions.

The sample's context is also intriguing for this study. Turkey is one of the most biologically diverse countries in the temperate world. One-third of the 9,000 plant species found in the country are exclusive to Turkey. Turkish flora, for example, includes many wild relatives of important domestic species (e.g. wheat, barley, chickpea, lentil and cherry). In addition to agricultural species, the Turkish flora also includes many commercially important timber species as well as medicinal, aromatic, industrial and ornamental plants. Furthermore, one of the three major flyways for millions of migratory birds that move between the Western Palearctic and Africa each year passes through Turkey. Moreover, because the country is predominantly semi-arid, Turkish wetlands are of crucial importance for many of these migrants and for breeding of many species of water birds, including a significant proportion of the global populations of some species (World Bank, 2000). However, the rapid industrialisation, urbanisation, deforestation, unsustainable agriculture, tourism policies that destroy coastal habitats, problematic legal regulations, environmental pollution, the use of some species for medical purposes, over-exploitation and illegal species transport for scientific research threaten Turkey's rich biodiversity (Demirsoy, 2000; Türkiye Bilimler Akadamisi [TÜBA], 2006; Yılmaz, 2000). In addition to these reasons, a lack of awareness among the Turkish public regarding biodiversity and its conservation is frequently mentioned by the authorities as a problem (TÜBA, 2006). According to the

World Bank Project Report (2000), for example, one of the challenges in protecting nature in Turkey is that Turkish society does not have enough knowledge about the importance of local biodiversity and the urgent need for effective conservation initiatives. From the Turkish literature, it appears that student teachers (Uzun, Özsoy & Keleş, 2010) and school students (Erdogan et al., 2008) are aware of the fact that Turkey has substantial biodiversity, but these groups do not have enough information regarding endangered species in Turkey. Nevertheless, school students seem to have a strong intrinsic motivation to engage in responsible behaviours to conserve species (Erdogan et al., 2008). Thus, it is important to understand what students in such a biodiverse country know about BL; this knowledge will enable the implementation of educational strategies to foster students' existing positive attitudes toward conservation of biodiversity.

Although the four main trends cited previously provide valuable information that may be used for curriculum planning, we believe that these trends approached crucial dimensions of BL separately by adopting different methodological approaches. The researchers representing the first trend, for example, did not investigate BL as a *core* topic. As a result, BL assumed a place by itself as a sub-category of other ecological terms, such as the balance of nature. Within the second trend, the principal issue was the identification of the organisms that deserved conservation efforts. We argue that it is essential to adopt a *holistic* approach emphasizing the mechanisms and causal webs regarding the reasons for, results of and solutions to BL rather than focusing on the reasons for conserving individual species. The holistic approach would already serve to provide detailed information for individual species conservation. The researchers representing the third trend sought to understand the values underlying the decisions regarding conservation of species. We view this trend as a crucial contribution to the BL literature in terms of affective dimensions; however, it does not specify any way to embed these values in the knowledge systems of students or the types of relationships that join values and knowledge about BL. Therefore, a *conceptual* type of research incorporating both cognitive and affective structures would provide a stronger framework for curricular activities. The fourth trend is very similar to the approach used in the present investigation but consists of only a few studies. In addition, these studies included small samples and limited (i.e. not open-ended) questionnaires that would not provide deep information regarding the mechanisms underlying the conceptions of BL. To some extent, therefore, it is necessary to plan a study that is focused on BL as a *core* topic via a *holistic conceptual* approach. A study of this type can fill the gaps in the current knowledge of students' understanding of BL.

Our final and most important point is the power of studies focusing on conceptions. If teaching is to be effective, understanding students' preconceptions regarding the target topic is of great importance. Curriculum makers can thus plan programs based specifically on these conceptions and take care to address in their designs any misconceptions and misunderstandings that require close attention. The content of science courses can be determined taking into account existing conceptions and necessary analogies, metaphors and models that target anomalies in conceptual ecologies of students. In addition, knowledge of students' conceptions enables educators to choosing teaching strategies which are likely to suit and/or challenge student's existing cognitive frameworks by means of experiences which provoke students to reconsider their conceptions (Driver, Guesne & Tiberghien, 1985; Menzel & Bögeholz, 2009; Zimmerman & Cuddington, 2007).

In sum, we focused on Turkish school students' conceptions about BL in the present research. The questions guiding the study are as follows:

1. What are school students' definitions of BL?
2. What are the reasons for BL according to school students?

3. What are the results of BL according to school students?
4. What are the solutions to BL according to school students?
5. How can we use students' conceptions about BL to inform curricula?

## Methods

### Sample

We used a homogeneous sampling strategy, which is a form of purposeful sampling, in the present study. In homogeneous sampling, researchers purposefully sample individuals or sites based on membership in a subgroup that has defining characteristics (Creswell, 2008). We decided to study school students in Grades 7 to 10 since especially these grades involve courses about BL. In each grade, we chose two classrooms each from primary schools, which serve students from kindergarten to Grade 8, and from secondary schools, which begin with Grade 9 and end with Grade 12. At the suggestion of three teachers who work in the local representative institution of the Ministry of Turkish National Education, we decided to study two primary schools (for Grades 7 and 8) and two secondary schools (for Grades 9 and 10) located in the urban areas of Kırşehir, Turkey. We chose one school for each grade. In selecting these schools, the main criterion we used was whether each school was approximately average compared to all schools in Kırşehir in terms of academic achievement, socio-economic statuses of the parents, the availability of teaching materials and the number of students enrolled. The principal reason for selecting mid-level students was our belief that they would potentially represent the majority of the general public, i.e. those individuals who would make personal decisions regarding the environment and biodiversity in the near future. After that, we chose two classrooms of the target grade in each school. In this process, as in that of school selection, the main criterion was the comparability of the characteristics of the classroom to all classrooms of the same grade in the school. At this stage, we consulted school principals and classroom teachers to identify mid-level classrooms in terms of academic achievement and socioeconomic statuses of the parents. We administered the questionnaire to 245 school students (130 males [53 %] and 115 females [47 %]) living in Kırşehir. The numbers of students in Grades 7, 8, 9 and 10 were 58 (24 males [41 %] and 34 females [59 %]), 58 (30 males [52 %] and 28 females [48 %]), 62 (41 males [66 %] and 21 females [34 %]) and 67 (35 males [52 %] and 32 females [48 %]), respectively.

Two concerns regarding the sample deserve attention because they might affect the results of the present study: the Turkish education system and the features of the sample city. The Turkish education system adopted constructivist approaches in 2005, and the Ministry of Turkish National Education has overhauled the curricula, textbooks, teaching materials and teacher guidebooks according to these approaches. In the science curricula of the sample Grades, the topic of biodiversity is discussed under different themes. In the Grade 7 science curriculum, the topic of biodiversity is presented under the main topic, 'Human and Environment'. The learning goals of this topic are for students to be aware of biodiversity and its importance, to give examples of endangered and extinct species in Turkey and worldwide, to present methods to stop BL, and to gain an appreciation for plants and animals. In the Grade 8 science curriculum, the topics 'Adaptation and Evolution' and 'The Energy Relations in Ecosystems' are offered. In the former, the contributions of adaptations to biodiversity and the reasons for different adaptations are the focus, whereas in the latter, students are taught to understand the relations between producers and

consumers in terms of energy and food, to explain matter cycles and to grasp the importance of recycling and renewable energies. In the Grade 9 biology curriculum, there are two topics related to BL. These are 'Classification of Species and Biodiversity' and 'Conscious Persons and Environmental Protection'. The first topic aims to teach students to explain the importance of biodiversity, to be aware of the reasons of why Turkey is a rich country in terms of biodiversity and to learn about the personal and social actions that can help to conserve this biodiversity. In the second topic, the harmful effects of humans on the environment and the reasons for and solutions to environmental pollution are emphasised. In the Grade 10 biology curriculum, the topic 'The Ecology of Ecosystems' is presented. Its goal is for students to learn relevant terms, such as habitat, population, community and ecosystem, and to make connections among these terms, to understand the matter cycle and energy flow and to understand the relations between ecosystems and sustainability.

The characteristics of the sample city are also important for the present study. Kırşehir is a small city relative to many other cities in Turkey, with a population of about 100,000 (in the centre). The economy is primarily based on agriculture. The adults who live in the centre (who probably include most of the parents of the school students in our sample) still have strong ties to their villages in rural parts of Kırşehir, and they usually visit these villages periodically to conduct agricultural activities. In addition, even though the city does not include any large green areas, there are many rivers, dumps, lakes, wetlands and valleys hosting a variety of organisms that are very close to the city centre. Therefore, school students in the sample have opportunities to be in close contact with nature.

## Questionnaire Design

In the existing literature regarding BL, researchers have used either semi-structured interviews (e.g. Palmer, 1997) or closed-form questionnaires (e.g. Eurobarometer, 2007). In the present study, we believed that a questionnaire with open-ended questions would provide us with a deeper understanding of the underlying reasons for responses than we would obtain using closed questions and give the opportunity to better generalize our results relative to interview research (Creswell, 2008). In selecting the open-ended questions, the first author and two other science educators who study environmental education held three meetings in which they discussed the main aim of the research, the possible questions to ask, and the pertinence of these questions to the research purposes. The layout of the questionnaire was another focus of these meetings. Upon attaining 100 % consistency among these experts, the questionnaire was finalised.

The final form of the questionnaire included six open-ended questions preceded by a cover sheet asking for personal details such as Grade and gender. In addition, following each open-ended question, a blank space was left for the students to write down their responses. We also stressed that they could use extra blank pages to continue their responses. The open-ended questions used in the present study are as follows:

1. Please define the term 'biodiversity' in your own words. Please explain your definition as thoroughly as possible.
2. What do you think about the reasons for biodiversity loss? Please list your reasons and explain them as thoroughly as possible.
3. What do you think about the results of biodiversity loss? Please list the results you predict and explain them as thoroughly as possible.
4. What do you think about solutions to biodiversity loss? Please list your solutions and explain them as thoroughly as possible.

5. Please give as many examples of extinct and endangered species on the Earth (apart from Turkey) as you can and write down the reasons for extinction or the endangered status for each species.
6. Please give as many examples of extinct and endangered species in Turkey as you can and write down the reasons for extinction or the endangered status for each species.

In the present study, we focus on the first four questions. A subsequent paper (Kilinc, Eroğlu, Demiral, Kartal & Yeşiltaş, unpublished data) will analyse the responses given for the last two questions.

## Administration of Questionnaire

Questionnaires were completed during normal classroom lessons in the presence of the usual teachers and one of the researchers. The questionnaires were completed individually under 'examination conditions', although no time limit was imposed. In addition, students were assured that their responses would be anonymous.

## Analysis of the Data

After collection of the completed compositions, the responses were typed into Microsoft Excel and then printed out. The transcripts of these responses were used for two-staged content analysis by the authors using 'mind maps'. In the first stage, apart from the first author, each author (one of four other authors) selected one grade and performed content analysis on the students' transcripts in this grade. Upon finishing this process, the first author performed content analysis on all of the data. In this way, each grade's compositions were analysed by two experts. In addition, the raters are male science educators who study environmental education for some time.

In the content analysis, we adopted Creswell's approach (Creswell, 2008), with some slight differences. The preliminary exploratory analysis, coding process and thematic analysis were the main stages in this approach. In the preliminary exploratory analysis, we read the data twice to obtain a general sense of the data. After that, we wrote down some notes (such as short phrases, concepts and ideas) and thought about the organisation of the data using these notes. In the second stage, we employed a coding process. Here, we identified a code word or phrase that accurately described the meaning of each text segment. After that, we began to construct mind maps using these code words. We grouped similar codes and looked for redundant codes. The main purpose here was to reduce the total number of codes to 25 to 30. We then revisited the data to see whether new codes emerged. We also noted some specific excerpts from the transcripts that support the codes. Furthermore, we decided to discard the codes representing less than 1 % of the total codes. Lastly, we reduced the list of codes to 10-to-20 themes. These themes comprised similar codes aggregated together to form a major idea in the database. In our thematic analysis, we revisited the data and sought to find interrelating themes that were used by individual students in responding to different questions. The first two stages of content analysis were used in analysing the descriptions of biodiversity and the reasons for, results of and solutions to BL. The third stage was used to elicit the conceptual patterns characterising the reasons, results, and solutions.

To reach a final decision about the themes included in responses to each question, we calculated the inter-rater reliability coefficients following the coding process. In the first stage, the authors worked together to discuss the principal themes that they had identified. Upon achieving consistency in terms of the main themes, they began to examine the number

of participants that they had jointly nominated under each theme. Inter-rater reliability coefficients were used to represent the percentages describing the overlap between two raters' classifications of the participants. For the first question (descriptions of biodiversity), the inter-rater reliability coefficients across the grades (from 7 to 10) were 71.0, 66.2, 66.8 and 73.0, respectively. For the second question probing the reasons for BL, these scores across the grades (from 7 to 10) were 69.1, 74.4, 66.0 and 77.0, respectively. For the third question about the results of BL, these figures across the grades (from 7 to 10) were 63.1, 66.8, 61.9 and 66.6, respectively. For the fourth question regarding the solutions to BL, these values (from 7 to 10) were 65.2, 63.7, 76.5 and 71.2, respectively. We then discussed each theme until 100 % consistency among all raters was achieved. We consider these high inter-rater reliability coefficients and discussions to attain 100 % consistency to be strengths of this research in terms of reliability (Fraenkel & Wallen, 2003).

We use codes and abbreviations to indicate the students whose responses are excerpted. The code P23-7th, for example, means that the excerpt belongs to the 23rd participant in Grade 7.

## Results

### Definitions of Biodiversity

As seen in Table 1, participants commonly preferred the definition 'biodiversity is the *diversity of living organisms*'. A large portion of this group provided this definition without any explanation. Some also broke the term down and said that biodiversity should be the diversity of living organisms if the word 'bio' implied 'living organism'. A few participants, in addition to their definition, also classified the organisms as animals, humans, plants and bacteria. Still fewer participants tried to explain the reasons for this diversity by arguing that all living organisms have different roles in the ecosystem and that different living organisms have different genetic codes. In addition, some emphasised the danger of BL and the importance of acting immediately to stop this mounting threat.

*Species diversity* was the second most common definition provided by the participants. Participants used the terms 'species' and 'living organism' interchangeably, perhaps because they have similar meanings in Turkish. In addition, some participants understood the term 'biodiversity' in terms of *the number of species* in a certain area, and they stressed that as the number of the species increased, the biodiversity would rise. Like these participants, others stressed that biodiversity is the *total number of species on earth*.

The definition *disparities of living organisms* was used by some participants. They explained that organisms have disparities stemming from their physical appearance, genetic codes, territories, foods and ecological roles. Also, some stressed that all living organisms possess unique benchmarks. Furthermore, *diversity within a species* was another definition supplied by participants. Some stressed that crossing over is an important process in creating this diversity. Also, some argued that internal diversity was necessary to adapt to new environments.

*The science of classifying species* was an incorrect definition that was provided by some participants. The following excerpts display this misunderstanding:

- It is a scientific field investigating different species and their lives. (P44-9th)
- [It is] a science that classifies the living organisms into taxa such as species, family and class. There are many species, but in order to investigate them we should divide them into groups. (P49-8th)

**Table 1** The definitions of biodiversity and the distribution of these definitions according to gender and grades

| | 7th (f) | | 8th (f) | | 9th (f) | | 10th (f) | | Total (f) | | Total (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Total | F | Total | F | Total | F | Total | F | Total | |
| Diversity of living organisms | 13 | 29 | 13 | 38 | 12 | 20 | 14 | 34 | 52 | 121 | 41.58 |
| Species diversity | 9 | 14 | 3 | 9 | 11 | 18 | 9 | 11 | 32 | 52 | 17.87 |
| The number of species | 2 | 4 | 0 | 2 | 5 | 7 | 8 | 10 | 15 | 23 | 7.90 |
| Total number of species | 0 | 0 | 0 | 3 | 4 | 5 | 4 | 5 | 8 | 13 | 4.47 |
| Disparities of living organisms | 0 | 0 | 0 | 0 | 4 | 9 | 1 | 4 | 5 | 13 | 4.47 |
| Diversity within a species | 1 | 1 | 1 | 7 | 3 | 3 | 1 | 1 | 6 | 12 | 4.12 |
| The science classifying species | 2 | 5 | 0 | 0 | 1 | 3 | 0 | 4 | 3 | 12 | 4.12 |
| Biological diversity | 3 | 6 | 1 | 2 | 1 | 1 | 0 | 0 | 5 | 9 | 3.09 |
| Genetic diversity | 0 | 2 | 3 | 3 | 1 | 2 | 1 | 1 | 5 | 8 | 2.75 |
| Diversity in vital processes | 1 | 2 | 0 | 1 | 0 | 1 | 2 | 3 | 3 | 7 | 2.40 |
| Diversity in ecosystems | 1 | 1 | 3 | 3 | 0 | 0 | 0 | 1 | 4 | 5 | 1.72 |
| I have never heard about biodiversity | 3 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 1.37 |
| A species | 3 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 4 | 1.37 |
| Diversity of animals | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 1 | 2 | 4 | 1.37 |
| Distinct populations | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 1.37 |
| Total (f) | 40 | 74 | 26 | 72 | 42 | 69 | 40 | 76 | 148 | 291 | – |

Some participants have written more than a definition. Therefore, the numbers represent the number of conceptions, not the number of participants

*F* female

In the case of *biological diversity*, like *diversity of living organisms*, participants benefited from the dissection of the term and the meaning of the word 'bio'. Another definition was *genetic diversity*. These participants mostly stressed that different species have different genetic codes, and some emphasised that living organisms have different sets of chromosomes and DNA.

In addition, a few participants used the definition *diversity in vital processes*. They mostly stressed that species developed strong adaptations to survive because of natural selection. In addition, some pointed out that there were many differences among species in terms of growth, development, reproduction and nutrition. The following two excerpts demonstrate how participants used this definition:

- The diversity enhances the adaptation capability of any species. For instance, the foxes living in deserts are different from the ones living in the Arctic. (P14-10th)
- Some vital processes vary among living organisms. These are reproduction, secretion, development, nutrition etc. (P50-7th)

Also, some participants pointed out that biodiversity was the *diversity of ecosystems*. According to them, species on Earth are distributed to different habitats that have unique features. They gave some examples of such habitats, such as deserts and forests. Moreover, a few participants articulated that they had *never heard about biodiversity*. These participants reported that they had not encountered this term in formal (textbooks, school) or informal

(newspaper, TV, journals) environments. Therefore, these participants merely attempted to guess the term's exact meaning.

A misunderstanding raised in the study concerned the definition of *a species*. Some participants believed that biodiversity was a species and they only used singular terms in their definitions. The following excerpt exemplifies this situation:

- Biodiversity is a species. It can be a plant species or an animal species. It is a conception that is decreasing these days. (P14, 9th)

Another misunderstanding was defining biodiversity only as *diversity of animals*. Although it is possible that these participants considered only animals to be living organisms, we did not have the opportunity to understand the reasons for this misconception because these participants' responses were very short. Furthermore, some participants responded that *distinct populations* constitute the biodiversity in an area.

## Reasons, Results and Solutions

### *Reasons for BL*

As seen in Table 2, *environmental pollution* was the most popular reason for BL given by participants. Even though some other reasons were given that can be included under environmental pollution, such as radioactivity and chemicals, we aggregated the statements including the term 'pollution' together as *environmental pollution*. Participants giving this explanation usually referred to human carelessness and the increased population growth. Littering, greenhouse gases, which come from fossil resources, exhaust smoke, factory waste and unrecyclable plastics were given as examples of the sources of pollution. Moreover, some participants focused on the direct influences of environmental pollution, such as poisoning some animals with harmful wastes and the decrease in the availability of healthy foods, whereas others concentrated on indirect effects such as habitat destruction and the decrease in reproduction rates.

*Global warming* was the second most common reason given by participants. They particularly associated the physical results of global warming, such as climate change, increase in the temperature and ice caps melting, with BL. They believed that these changes would result in adaptation problems and the eventual extinction of some living organisms. Some responded that the polar ice caps' melting caused the extinction of polar bears because it restricted their habitats. In addition, a few participants stressed that the drought caused by global warming was another reason for BL. Interestingly, we also found that some students misunderstood the connections between global warming and BL. Their misconception was to confuse the reasons for global warming with those of ozone depletion. The following excerpts exemplify this situation:

- ….global warming diminishes biodiversity. We should not use deodorants because they deplete the ozone layer and in turn cause global warming. (P6, 10th)
- Some materials used by humans (deodorants, sprays, etc.) pollute the ozone layer and lead to global warming that is the reason of biodiversity loss. (P41, 10th)

The participants stressed that *over-hunting* was another crucial reason for BL. For delineating the term 'hunting', respondents used different adjectives, such as 'uncontrolled', 'illegal', 'banned' and 'wrong'. Some stressed that over-hunting of a species would result in corruption

**Table 2** The reasons for BL and the distribution of these reasons according to gender and grades

| | 7th (f) | | 8th (f) | | 9th (f) | | 10th (f) | | Total (f) | | Total (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Total | F | Total | F | Total | F | Total | F | Total | |
| Environmental pollution | 23 | 42 | 6 | 24 | 20 | 31 | 14 | 26 | 63 | 123 | 21.39 |
| Global warming | 11 | 19 | 8 | 24 | 20 | 28 | 18 | 32 | 57 | 103 | 17.91 |
| Over-hunting | 17 | 31 | 2 | 13 | 13 | 25 | 10 | 19 | 42 | 88 | 15.30 |
| Carelessness | 11 | 16 | 5 | 8 | 4 | 12 | 6 | 6 | 26 | 42 | 7.30 |
| Chemicals | 3 | 6 | 1 | 1 | 4 | 8 | 7 | 17 | 15 | 32 | 5.57 |
| Habitat destruction | 5 | 12 | 0 | 2 | 5 | 6 | 6 | 12 | 16 | 32 | 5.57 |
| Deforestation | 6 | 7 | 1 | 6 | 10 | 13 | 3 | 5 | 20 | 31 | 5.39 |
| Corruption of the natural balance | 1 | 2 | 3 | 6 | 3 | 4 | 4 | 9 | 11 | 21 | 3.65 |
| Apathy of humans | 4 | 9 | 2 | 6 | 1 | 1 | 2 | 2 | 9 | 18 | 3.13 |
| Industrialisation | 1 | 2 | 2 | 6 | 4 | 6 | 2 | 3 | 9 | 17 | 2.96 |
| Distorted urbanisation | 3 | 3 | 2 | 8 | 3 | 3 | 0 | 0 | 8 | 14 | 2.43 |
| Drought | 3 | 3 | 1 | 9 | 0 | 1 | 0 | 0 | 4 | 13 | 2.26 |
| Ozone depletion | 0 | 2 | 0 | 1 | 2 | 3 | 1 | 3 | 3 | 9 | 1.57 |
| Famine | 0 | 0 | 1 | 1 | 2 | 6 | 0 | 2 | 3 | 9 | 1.57 |
| Selfishness of humans | 3 | 3 | 0 | 1 | 3 | 3 | 0 | 1 | 6 | 8 | 1.39 |
| Disasters | 0 | 5 | 0 | 0 | 1 | 1 | 2 | 2 | 3 | 8 | 1.39 |
| Radioactivity | 0 | 0 | 0 | 0 | 2 | 3 | 4 | 4 | 6 | 7 | 1.22 |
| Total (f) | 91 | 162 | 34 | 116 | 97 | 154 | 79 | 143 | 301 | 575 | – |

Some participants have written more than a reason. Therefore, the numbers represent the number of conceptions, not the number of participants

*F* female

of the food chain. Also, some participants explained that hunting must be done in the appropriate season. They argued that some hunters hunt animals during their reproduction periods. In addition, a few participants discussed hunting endangered species and argued that some hunters purposefully choose these organisms because it is hard to find them.

*Carelessness* was another cause mentioned by the participants. They particularly used this term in the sense that people behaved or made decisions without knowing the possible results of these acts or decisions. The students considered carelessness to be the reason for such consequences as environmental pollution, habitat destruction, over-watering, over-consumption of natural resources, littering, deforestation and over-hunting. In other words, they considered the fundamental factor causing BL to be human carelessness. Also, we noticed that these participants began their arguments by mentioning human carelessness and then focused on its results, such as environmental pollution, and finalised the arguments with BL. The following excerpt exemplifies this thinking pattern:

- The main reason for biodiversity loss is careless behaviours of humans in some areas. We can give examples of this: over-hunting, deforestation, pesticides, etc. All these lead to biodiversity loss. (P9-10th)

In addition, many participants in this group stressed that people do not have enough information about the environment, ecological processes and ecosystems. Some also pointed out shortcomings in education as a cause.

*Chemicals* were given as a reason for BL by some participants. They wrote that chemicals destroyed habitats and leaked into the food of living organisms. In this group, some students also placed emphasis on pesticides. They argued that these chemicals lead species living in the soil to diminish. Also, some respondents pointed out that pest control by planes caused biological magnification in the ecosystem. The statements of a participant espousing this view are as follows:

- …again careless pest control! For instance, they utilise planes to spread the chemicals on the fields. Even though the main idea is getting the pests under control, they also destroy some useful organisms that are of importance to the food chain. (P55, 10th)

When it comes to *habitat destruction*, participants stated that environmental pollution destroyed the balance of nature and in turn restricted the habitats. Also, this situation caused alterations in the life conditions of the habitat, such as decreases in food abundance and changes in microclimates. To the participants in this group, these changes trigger natural selection, and the species that cannot adapt to new environments become extinct. In the case of *deforestation*, participants said that humans clear forests by logging or burning to use the cleared land for roads and new settlements. They also argued that the removal of trees without sufficient reforestation resulted in habitat destruction and in turn BL.

The participants also stressed that *corruption of the balance of nature* could cause BL. The terms 'chain', 'biological balance', 'ecological balance' and 'natural system' are frequently used by these participants, meaning that they believe there is a balance among living organisms in nature. Their responses usually stressed that humans create environmental pollution that has led to corruption of the balance of nature, resulting in BL. The following two excerpts exemplify these responses:

- All living organisms around us are in a cycle. There are connections among them. If a piece of the chain breaks, the whole ecosystem can face the dangers. Usually humans play great roles in the extinction of species. Due to the reasons such as habitat destruction and over-exploitation, some species are likely to become extinct. (P4, 10th)
- Corruption of balance of nature! The reason for this is human beings. Thanks to this corruption, global warming happened. Radioactivity and chemicals have a range of harmful influences on both humans and living organisms. The exhaust smoke, factory wastes and various sprays cause corruption of the ecological balance. Because this situation destroys the habitats of living organisms, some species become extinct. (P13, 10th)

Regarding *apathy of humans*, the participants criticised some people who are not willing to take steps to protect endangered species, and they mentioned that these people did not care about BL or consider future generations. In the case of *industrialisation*, as expected, participants generally associated this conception with environmental pollution and factories. Also, a few participants stressed that industrialisation was the desire of humans to master nature. However, we could not investigate the direct relations between industrialisation and BL because the participants in this group did not address this thought in depth.

*Distorted urbanisation* was another reason stressed by the participants. They mentioned that people employ deforestation to make room for new settlements, and artificial constructions replace the green areas that are the habitats of many animals. With respect to *drought*, participants stressed that the drought and desertification resulting from global warming have led to adaptation problems for the local species. The Seyfe Lake, which was a habitat for many bird species and dried up a few times in the past, was a popular example.

In the case of *ozone depletion*, participants explained that people deplete the ozone layer by using deodorants and sprays and this depletion causes much more harmful direct sun radiation to reach living organisms, which causes their extinction. Also, some stressed that the ultraviolet light coming from the ozone hole has destroyed habitats. In the case of *famine*, participants mentioned that because of corruptions in food chains, organisms could not find enough food and thus became extinct. Other participants explained famine as a result of habitat destruction.

*Selfishness of humans* was another negative anthropocentric construct that was given as a reason for BL. Participants mentioned that some people behave as if they are alone in this universe. Also, these participants usually pointed out that some people kill animals merely to meet their ego or satisfaction needs. Luxury items such as leather belts and fur coats were the examples of this behaviour. In addition, some described people who harm biodiversity as lacking empathy. The following two excerpts indicate the participants' reactions to selfish people:

- Biodiversity loss! The reasons for this case are the desire to satisfy cruel emotions of cruel persons and the pursuit of the emotions that are necessary to lead a luxurious life. (P22, 10th)
- Global warming and selfishness! We only think about ourselves. However, there are many other organisms living in nature. Also, humans got used to the 'easy life'. Our consumption exceeded the production. (P7, 9th)

In regards to *disasters*, some participants stressed that there were natural causes of BL, such as disasters, in addition to anthropocentric reasons. Earthquakes and floods were the popular examples. Participants particularly stated that disasters lead directly to mass deaths and in turn extinctions. *Radioactivity* from radioactive waves, harmful rays, infrared rays, X-rays and gamma rays was another reason mentioned by the participants. Some respondents stressed that these resources destroy habitats, whereas some thought that they directly affect the organisms and gradually made them go extinct.

*Results of BL*

As seen in Table 3, the *corruption of the balance of nature* was the result most commonly mentioned by the participants. The terms 'chain', 'system' and 'balance' were used many times in the responses. They frequently used the term 'chain' metaphorically and compared the ecosystem to a chain and the living organisms to the links of the chain. Taking a closer look at responses, the corruption of the food chain, food pyramid, matter cycle and collaboration among organisms were the main issues the students discussed. Of these issues, corruption of the food chain was the most popular argument. Participants stressed that there were strong connections among the species that were linked in a prey–predator relation. The reasoning here was, 'if one of the members of a food chain becomes extinct, this will result in the other members' extinction in the near future'. Also, we noticed that bees were a popular organism to exemplify the problems in the food chain. Furthermore, the participants argued that the main reason for the corruption of the food chain was humans' intervention in the chain. The following excerpts display the relations between intervention and BL:

- The biodiversity loss has harmful effects on all of the living organisms and nature. For instance, scientists have done research: They killed the wolves and then the number of deer increased. All the deer started to eat the trees, and this has diminished the flora in

**Table 3** The results of BL and the distribution of these results according to gender and grades

| | 7th (f) | | 8th (f) | | 9th (f) | | 10th (f) | | Total (f) | | Total (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Total | F | Total | F | Total | F | Total | F | Total | |
| Corruption of the balance of nature | 28 | 53 | 11 | 30 | 34 | 52 | 25 | 52 | 98 | 187 | 45.06 |
| Health problems and human extinction | 8 | 20 | 9 | 26 | 5 | 15 | 7 | 18 | 29 | 79 | 19.03 |
| Extinction of other species | 6 | 17 | 7 | 11 | 15 | 15 | 6 | 10 | 34 | 53 | 12.77 |
| Famine | 8 | 13 | 3 | 5 | 0 | 2 | 0 | 1 | 11 | 21 | 5.06 |
| None of the living organisms can survive on Earth | 0 | 3 | 1 | 3 | 3 | 5 | 1 | 4 | 5 | 15 | 3.61 |
| Harmful effects on the ecosystems | 1 | 4 | 1 | 4 | 3 | 3 | 0 | 0 | 5 | 11 | 2.65 |
| Decrease in the amount of oxygen | 2 | 2 | 1 | 6 | 0 | 1 | 1 | 1 | 4 | 10 | 2.41 |
| Drought | 1 | 3 | 2 | 4 | 0 | 0 | 1 | 1 | 4 | 8 | 1.93 |
| Environmental pollution | 2 | 2 | 1 | 2 | 1 | 3 | 1 | 1 | 5 | 8 | 1.93 |
| Natural selection | 0 | 3 | 1 | 2 | 1 | 1 | 0 | 1 | 2 | 7 | 1.69 |
| Aesthetic anxieties | 1 | 4 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 6 | 1.45 |
| Global warming | 2 | 2 | 0 | 0 | 1 | 2 | 1 | 1 | 4 | 5 | 1.20 |
| Social problems | 2 | 3 | 0 | 0 | 1 | 2 | 0 | 0 | 3 | 5 | 1.20 |
| Total (f) | 61 | 129 | 37 | 93 | 64 | 102 | 43 | 91 | 205 | 415 | – |

Some participants have written more than a result. Therefore, the numbers represent the number of conceptions, not the number of participants

*F* female

that place. When they decreased the number of deer, the number of trees increased. In the end, the scientists decided not to touch the ecological balance. There is a system and balance in nature. (P39, 7th)

- Due to biodiversity loss, the ecological balance would be destroyed. The chickens, for example, were killed due to swine flu. However, this situation led to the population of ticks exploding, and we then witnessed the corruption of ecological balance. I think everything is connected to each other. (P77, 9th)

Also, some students pointed out that there is collaboration among living organisms and that each species has unique responsibilities. They stated that BL would cause the corruption of this collaboration. The following two excerpts exemplify this reasoning:

- There is a cycle in nature. Every living organism has unique responsibilities, and they could not be realised unless the ones who have responsibilities are available. The balance of nature is corrupted. Also, this implies the end of the world. (P38, 7th)
- There is a balance and a system on the earth and every living organism has a place in this system. The extinction of the species means the corruption of this balance. That is, biodiversity loss affects all of the organisms in a negative way. For instance, unless a bee existed, honey could not be available; unless a tree existed, oxygen could not be produced; unless yeast existed, we could not make fermentation. (P42, 7th)

In addition, some participants stressed that one of the consequences of BL was the corruption of the matter cycle. They considered that BL would result in problems in matter

cycles such as carbon, nitrogen and phosphorus because every organism has some duties in maintaining these cycles. They also pointed out that every organism, even humans, would become extinct upon their corruption.

In the case of *health problems and human extinction*, we noticed that the participants in this group revealed many concerns about the future of humans following BL. They stressed that BL would lead to harmful effects on humans: people could not meet their vital needs, pandemic cases would spread out, the life span would shorten, birth defects would occur, many people would die and humans would become extinct. The most common idea was that humans would be harmed by BL because their vital needs could not be met. Famine or a decrease in the number of food sources were popular examples. They particularly pointed out that humans are the highest link of the food chain, so any problem in the chain would harm humans' future. In addition, some mentioned that humans would not benefit from nature as before. In terms of utilising nature, some also argued that people use natural resources to resolve their health problems. These participants focused mainly on the benefits of plants in producing drugs. To them, any problem in this process would result in increasing pandemic diseases and in turn many deaths. The following excerpt exemplifies these responses:

- Humans benefit from animals, plants and most of the other living organisms in daily life. If BL happens, we will struggle in meeting some of our needs. We utilise the living organisms around us in different sectors accompanied by health. If BL happens, human life would be in danger! (P4-10th)

Some participants stressed that BL would result in the *extinction of other species*. We generally saw this result in the beginnings of the responses. In other words, students began their responses with this result and then explained some other results. We therefore could not investigate the relations among BL and extinction of species. However, some participants were aware of the interrelations among living organisms and the fact that BL would result in new losses in other species groups.

In the case of *famine*, although a few participants mentioned this result for humans, the participants usually mentioned this result for all living organisms. They stressed either the organisms would not find enough food or they would not be able to find any food at all. Participants frequently associated this result with problems in the food chain. In addition, some participants said *none of the living organisms can survive on the Earth*. They explained that living organisms in the future will not be able to survive on Earth because of the decrease in the amount of natural resources. They used the phrase 'the end of the world' many times in their responses. The following excerpt includes the main ideas of these participants:

- There can be rather bad consequences. Maybe there would not be a planet called Earth after 200 or 300 years. We would disappear, who knows! God's decision! (P30, 9th)

Regarding *harmful effects on ecosystems*, the participants stated that BL would result in corruption of the balance of nature and in turn destroy more ecosystems. Also, they particularly pointed out that problems in the ecosystems would be indicators of a general extinction. In addition, the participants pointed out that there would be *decreases in the amount of oxygen*. The main argument here was that the decrease in the number of plants (especially trees) would cause the photosynthesis rate to diminish, and this would automatically result in decreases in the amount of oxygen in the atmosphere. Some students also stressed that humans would not be able to breathe as well. When it comes to *drought*, the

main argument was the decrease in the number of plants. Participants stressed that this decrease would lead to global warming and, in turn, drought.

Regarding *environmental pollution*, the participants did not give clear responses, so we could not investigate the reasons underlining this theme. They merely said that BL would result in environmental pollution. However, one participant stated that new harmful species would evolve, so the use of pesticides or drugs to kill these organisms would increase, and this would pollute the environment. Another result was *natural selection*. The participants stressed that BL would lead to new environments and in turn new kinds of natural selection. Some predicted that new harmful species would appear as a result of natural selection. Also, some said that there would be great migrations if species could not adapt to changes in their habitats.

*Aesthetic anxieties* were another result of BL. The participants gave several arguments relevant to this point: future generations would never see the species, the love of nature would decrease, natural beauty would diminish and people would not care about nature anymore. With respect to *global warming*, although these participants confused the results and reasons of BL, one participant challenged our argument. He mentioned that BL implied a decrease in the number of plants on earth, and this would result in global warming.

In the case of *social problems*, the participants stressed that poverty would increase and the gap between the poorest and richest people would expand. Also, a few stressed that there would be new wars for food resources and water. Only one participant pointed out that there would be many unemployed persons after BL, but we could not investigate the relation between these two dimensions because her composition was too short.

### *Solutions to BL*

As seen in Table 4, *stopping over-hunting* was the most popular solution to BL identified by the participants. Some stressed that all hunting activities should be banned, whereas some believed in the need to restrict hunting. In addition, many participants believed that if hunting is necessary, hunters should be educated and should hunt during periods other than species' reproduction periods. With respect to *raising awareness*, the participants underscored the importance of education in curing BL. The participants suggested two types of education. Some recommended giving conservation education during formal education (in school) starting at the kindergarten level, whereas others argued that informal education (seminars, campaigns and TV programs) for adults would be successful. Regarding the content of this education, the importance of biodiversity for humans, possible results of BL, becoming a conscious consumer, ameliorating environmental pollution, reducing global warming and conscientious hunting were suggested. The following excerpt includes some of a participant's suggestions:

- People should be educated about this topic. Unless we interfere with this process, not only other living organisms such as plants and animals but also we (humans) will be harmed. The results of BL ought to be told to humans in an outstanding way! (P7, 9th)

The participants suggested that teachers, representatives of environmental groups and citizens themselves should offer this education. In the latter case, a few persons said that there would be a domino effect if people were willing to share their knowledge with one another. The following excerpt gives one of the responses of these participants:

- We can educate humans. You educate me, I three persons, those three other three…In this way, the number of educated people would increase, and all of the public would be trained.

**Table 4** The solutions to BL and the distribution of these solutions according to gender and grades

| | 7th (f) | | 8th (f) | | 9th (f) | | 10th (f) | | Total (f) | | Total (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Total | F | Total | F | Total | F | Total | F | Total | |
| Stopping over-hunting | 9 | 18 | 2 | 9 | 14 | 24 | 8 | 21 | 33 | 72 | 15.62 |
| Raising awareness | 9 | 20 | 8 | 14 | 15 | 18 | 8 | 17 | 40 | 69 | 14.97 |
| Conservation activities for species | 6 | 23 | 2 | 11 | 8 | 19 | 7 | 14 | 23 | 67 | 14.53 |
| Reducing environmental pollution | 12 | 19 | 4 | 8 | 9 | 13 | 4 | 7 | 29 | 47 | 10.19 |
| Ending global warming | 3 | 6 | 4 | 6 | 1 | 3 | 8 | 15 | 16 | 30 | 6.50 |
| Planting trees | 4 | 6 | 6 | 14 | 2 | 4 | 3 | 5 | 15 | 29 | 6.29 |
| Environmental friendly industrialisation | 4 | 8 | 4 | 8 | 2 | 6 | 1 | 5 | 11 | 27 | 5.86 |
| Paying attention when using natural resources | 2 | 7 | 0 | 2 | 3 | 8 | 3 | 8 | 8 | 25 | 5.42 |
| Decreasing chemicals | 4 | 8 | 1 | 1 | 5 | 8 | 3 | 8 | 13 | 25 | 5.42 |
| Political actions | 2 | 5 | 0 | 4 | 3 | 6 | 2 | 2 | 7 | 17 | 3.69 |
| Care for nature | 5 | 7 | 0 | 2 | 1 | 1 | 1 | 3 | 7 | 13 | 2.82 |
| Waste management | 1 | 1 | 1 | 3 | 1 | 5 | 1 | 1 | 4 | 10 | 2.17 |
| Supporting environmental groups | 0 | 1 | 0 | 4 | 1 | 1 | 2 | 3 | 3 | 9 | 1.95 |
| Ending ozone depletion | 1 | 3 | 0 | 0 | 1 | 1 | 2 | 2 | 4 | 6 | 1.30 |
| Using renewable energies | 0 | 0 | 2 | 3 | 0 | 1 | 1 | 1 | 3 | 5 | 1.08 |
| Using technology | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 5 | 1.08 |
| Too late to do something | 0 | 2 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 5 | 1.08 |
| Total (f) | 62 | 135 | 34 | 93 | 66 | 119 | 54 | 114 | 216 | 461 | – |

Some participants have written more than a solution. Therefore, the numbers represent the number of conceptions, not the number of participants

*F* female

Regarding *conservation activities for the species*, participants suggested two types of conservation: conservation in a specific environment planned for the species and conservation in the natural habitat of the species. In the former case, participants considered that people need to create some (artificial) areas, such as animal shelters, reproduction camps and farms, where endangered species can live and reproduce. In the latter case, the participants stressed that people need to protect natural habitats or extend the habitats for conserving the species. They also suggested making some habitats into wildlife parks. The following excerpt includes a local activity as an example:

- We can protect the natural conditions of the species. For instance, people conserve sea turtles in Turkey by protecting their reproduction areas. (P56, 9th)

Although there are other solutions related to environmental pollution on the list, we particularly noted the presence of the theme of *reducing environmental pollution* because these participants mostly stressed that there was a need to keep the environment clean and to reduce environmental pollution without any explanation of how to do so. Some pointed out the types of pollution, such as air, water and soil pollution, in their compositions. In the case of *ending global warming*, some personal actions were mentioned, such as planting trees, using public transportation instead of driving a car, and not using polluting resources such as wood and coal.

Participants were also aware that these actions would reduce greenhouse gasses, especially carbon dioxide, a crucial contributor to global warming. On the other hand, a misconception in this area was apparent. Even though chlorofluorocarbons (CFCs) from sprays and aerosol deodorants are included on the list of causes of global warming, a few participants made an incorrect association. They believed that people need to reduce spray usage because CFCs destroy the ozone layer and in turn lead to global warming.

*Planting trees* was another solution suggested by participants. Planting trees was considered a necessary step to stop BL because forests provide habitats for a range of species. Also, some respondents mentioned that we need to prevent deforestation. Regarding *environmentally friendly industrialisation*, participants commonly suggested using a filter system for the chimneys of factories. In addition, some believed that factories ought to be built in unpopulated areas. In addition, a few participants stressed that people could reduce industrialisation to prohibit BL.

In the case of *paying attention when using natural resources*, participants pointed out that people need to stop the over-consumption of the natural resources, particularly water resources. In addition, a few participants said that people need to find other resources to use that would not affect endangered species. In regards to *decreasing chemicals*, participants said that people need to be careful in both producing and consuming chemicals. They stressed that decreases in the consumption of cosmetic products, detergents, shampoos and pesticides are necessary. They also suggested that people should use some organic products.

In terms of *political actions*, passing new laws that create animal shelters and ban the over-exploitation of animals, punishing people who do not obey the laws pertaining to conservation of species, informing world leaders about the impending problem of BL and taking global precautions were the political actions mentioned by the participants. A few participants also highlighted the importance of building an international institution to employ and follow these actions. In the case of *care for nature*, the participants said that people ought to give much importance to nature, animals, the environment and ecosystems. Some said that people need to appreciate nature and respect the life of living organisms. The love of nature and caring about environmental problems were important arguments in the compositions. In addition, one participant said that people need to build empathy for endangered species.

With respect to *waste management*, participants placed an emphasis on recycling activities. They stressed that people need to sort wastes such as plastic, paper and batteries. In addition, one participant thought that if people used recyclable paper, there would be no need to cut down trees. In addition, a few participants suggested using easily biodegradable plastics in packaging. Some participants also mentioned the importance of minimising waste. In the case of *supporting environmental groups*, donating to these groups, joining environmental clubs and starting new groups were the actions mentioned by the participants. In addition, two participants named an NGO that focuses on conserving some local bird species.

All participants who mentioned *ending ozone layer depletion* stressed that people should take precautions to end this depletion, although they did not describe these precautions. Some participants wrote that *using renewable energies* instead of fossil fuels would be useful in ending BL. They gave some examples, such as using natural gas (even though it is not a renewable energy) instead of coal and using sun energy instead of wood. However, we could not see the relations between this theme and ending BL because the responses were too short. We concluded that students might associate this theme with reducing environmental pollution or ending global warming.

In the case of *using technology*, participants said that people could use technology to end BL. Cloning endangered species, reproducing endangered species in laboratory environments and tracking endangered species with special equipment were the examples given. In

addition, some participants said that it was *too late to do anything*. They believed that as technology progresses, there will be many problems such as desertification and global warming that cause BL. The following excerpts exemplify these participants' perceptions:

- We cannot do anything anymore, I think. However, some people try to do some things. They try to conserve endangered species, but I wonder how effective they are. They only rescue them from becoming extinct, but the species do not reach huge populations like before. (P27, 10th)
- The end of the world is coming. As technology progresses, living organisms' lives are endangered. I think we cannot stop the biodiversity loss anymore. That is, as human beings make progress in technology, due to the problems such as global warming, the species will gradually become extinct. (P28, 10th)

Reasons, Results and Solutions: Conceptual Patterns

Upon investigating the students' conceptions regarding reasons, results and solutions in a detailed way, we noticed some general conceptual patterns on the level of individual student that were used by many participants in responding to the questions. As can be seen in Table 5, participants used 11 conceptual patterns in understanding BL: balance of nature, global warming, environmental pollution, hunting, human factors, forest, modernisation, ozone depletion, chemical use, indirect conservation and helplessness.

## Discussion

In this study, we aimed to characterise school students' conceptions about BL by asking direct questions about the definition of biodiversity and about the reasons for, results of and solutions to BL. Considering the results of the present study, we can say that students have a range of conceptions that are not grounded by strong scientific understandings. They usually used their informal reasoning and language repertoires with weak reasoning modes in responding the questions about BL. The informal learning contexts, such as the media, which are pedagogically unplanned environments, are likely to be influential in this result. The students in our sample, for example, were aware of the lost bee populations, culling birds due to swine flu and the problems in Seyfe Lake in the sample city of Kırşehir without further reasoning. In addition, looking at almost equal frequencies of each conception and reasonings underlying these conceptions across the grades, we can say that instructional interventions did not lead to a reasonable conceptual progress. This negative conclusion may stem from five main challenges about BL. We borrow three challenges to learning about biodiversity and its conservation from Menzel and Bögeholz (2009). According to those authors, the first challenge is the semantic structure of the term 'biodiversity'. It is usually understood as the variety of species, whereas the term also refers to ecosystems and genetic diversity. The second challenge is the nature of the knowledge underlining BL. This knowledge covers complex ethical, economic, social and political issues, whereas the term mostly directs the focus to ecological dimensions. The third challenge for learners is the difficulty of understanding the global dimension of the problem. This problem is especially pressing in biodiversity hotspots, where a large portion of the biota has already been destroyed. We added two more challenges to the list provided by Menzel and Bögeholz (2009): the curriculum and the teachers. Regarding the curriculum, for example, academic biology presently focuses primarily on physiology, molecular biology and genetics, and these developments in biology affect the structure of the curriculum. Therefore, teachers might not be able, or even willing, to teach about biodiversity due to the popularity of other

**Table 5** Conceptual patterns used by the participants regarding reasons for, results of and solutions to BL

| Conceptual patterns | Reasons | Results | Solutions |
|---|---|---|---|
| Global warming | Global warming | Global warming | Ending global warming |
| | | Drought | Using renewable energies |
| Environmental pollution | Environmental pollution | Environmental pollution | Reducing environmental pollution |
| | | | Waste management |
| Hunting | Over-hunting | | Stopping over-hunting |
| Human factors | Carelessness | Health problems and human extinction | Raising awareness |
| | Apathy | Social problems | Paying attention when using natural resources |
| | Selfishness | Aesthetic anxieties | Care for nature |
| Balance of nature | Habitat destruction | Corruption of the natural balance | Conservation activities for the species |
| | | Extinction of other species | |
| | Corruption of the natural balance | Famine | |
| | | Harmful effects on ecosystems | |
| | | Natural selection | |
| Forest | Deforestation | Drought | Planting trees |
| | | Decrease in the amount of oxygen | |
| Modernisation | Industrialisation | | Environmentally friendly industrialisation |
| | Distorted urbanisation | | |
| | | | Using technology |
| Ozone depletion | Ozone depletion | | Ending ozone depletion |
| Chemical use | Chemicals | | Decreasing chemicals |
| Indirect conservation | | | Political actions |
| | | | Supporting environmental groups |
| Helplessness | | | Too late to do something |

topics (Lindemann-Matthies & Bose, 2008). The actual teachers who are responsible for disseminating knowledge about BL to their students may constitute another challenge. Studies indicate that student teachers and in-service teachers have naive conceptions regarding BL and thus have low levels of self-efficacy in teaching this topic (Uzun, Özsoy & Keleş, 2010; Kurumlu, 2008).

Looking from positive side, we believe that students' conceptions about BL that we revealed in the present study have a potential to be starting points for a stronger science curricula that is contextualized in students' own conceptions. We, therefore, decided to discuss students' conceptions in a detailed way and suggest curricular and practical implications in following sections.

## Definitions

Students exhibited a range of conceptions of the definition of biodiversity. Most of the participants (63 %) described biodiversity by using species diversity-driven terms such as

diversity of living organisms, species diversity and disparities of living organisms. That is, they considered diversity in the individual sense, whereas genetic diversity (3 %) and ecosystem diversity (2 %), which are important parts of global biodiversity, were mentioned by only a small portion of the participants. Similar results were reported in other research (Dervişoğlu, 2007; Eurobarometer, 2007; Kostova & Atasoy, 2008; Menzel & Bögeholz, 2009; Uzun, Özsoy & Keleş, 2010). Biodiversity was defined in the Convention on Biological Diversity, signed by 154 nations at the Rio summit, as the variability among living organisms from all sources, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which these are a part; this includes diversity within species, between species and of ecosystems (UNEP, 1993). That is, the term comprises three facets: habitat diversity, species richness and genetic information within species (Kassas, 2002). In addition, the science curricula and the course textbooks targeting the students in the sample described biodiversity in the same way. However, in view of the species-based definitions in the present study, we can conclude that school students were likely to dissect the term 'biodiversity' in their definitions. Because the term 'bio' implies 'living thing', they were likely to consider biodiversity to be the diversity of living things or of species. Similar reasoning has also been observed in other studies (Hunter & Brehm, 2003). Because this semantic structure of the term 'biodiversity' fails to include its more complex meaning (Menzel & Bögeholz, 2009; Novacek, 2008), the terminology used in textbooks or by teachers in real classrooms can be changed slightly. Lessons about biodiversity can make use of synonyms such as 'biological richness' or 'Gen-Ecosystem-Species (GES) diversity' so that students are able to associate the term with other concepts (diversity of ecosystem, genetic diversity, diversity within a species) that are less intuitive due to the restricted meaning of the term 'bio'. Another implication may be that more time should be devoted to learning about aspects of biodiversity apart from species diversity.

In addition, though their prevalence in the sample was relatively low, a few misunderstandings regarding the definition of biodiversity were apparent. A minority of the sample (4 %), for example, confused 'biodiversity' with 'taxonomy'. Similar results were also found in Menzel and Bögeholz's (2009) study. A possible explanation for this situation may be the placement of the topic of biodiversity in the curricula. In Grade 9, for example, a lesson titled 'The Classification of Living Organisms and Biodiversity' is included in the curriculum. In this lesson, some general information about taxa and taxonomy techniques is given, and then the importance of biodiversity and possible conservation strategies are discussed. This combination of topics might be responsible for this misunderstanding. For this reason, an embedded curriculum in which information about biodiversity is related to different topics, such as sustainable development, taxonomy, ecosystems, environmental pollution and evolution, seems promising. The definition *animal diversity* was another misunderstanding in the study. The reason for this misunderstanding may be the fact that some children associate living organisms only with animals due to their attractive and animate nature. In removing this misunderstanding, some teaching materials covering other groups of organisms such as bacteria, fungus and plants can be developed. Indicating another misunderstanding, a few participants (1 %) used the definition *a species*. In addition, a similar portion (1 %) articulated that they had *never heard about biodiversity.* These participants reported that they had not encountered this term in formal (textbooks, school) or informal (newspaper, TV, magazines) environments. The knowledge gaps were especially apparent for younger students (Grades 7 and 8), perhaps because they had not yet developed a strong understanding of biodiversity due to their relatively low exposure to this issue in formal and informal environments.

Conceptual Patterns about Reasons, Results and Solutions

The conceptual patterns were used by the participants in the present study were balance of nature, global warming, environmental pollution, hunting, human factors, forest, modernisation, ozone depletion, chemical use, indirect conservation and helplessness.

'Balance of nature' was the most popular conceptual pattern used by the participants. As reasons for BL, habitat destruction and corruption of the natural balance were stressed. As results of BL, corruption of the natural balance, harmful effects on ecosystems, natural selection, extinction of other species and famine were mentioned. As solutions to BL, conservation activities for endangered species were mentioned. Participants generally wrote that there is a balance in nature and any intervention by humans, such as environmental pollution, results in the corruption of this balance, causing BL. Indeed, the balance of nature metaphor is of great importance for understanding ecology (Ladle & Gillson, 2009; Zimmerman & Cuddington, 2007). Zimmerman and Cuddington (2007), for example, conclude that college students believe that the balance of nature is descriptive of real ecological systems. In addition, some participants in the present study concentrated on habitats and ecosystems. Some of these stressed that habitat destruction is one of the causes of BL, whereas others said that BL would cause harmful effects on ecosystems. In addition, protecting natural habitats (conservation activities for species) was one of the top solutions to BL. Even though the awareness of habitat destruction and problems in ecosystems does not seem high, these results are encouraging because there has been an increasing appreciation among experts that conservation can be more effective if it is focused on the balance of nature and preserving the habitats of organisms (Ashworth et al., 1995; Grace & Ratclifee, 2002). On the other hand, even though most of the participants seemed to be aware of the balance of nature, it should be noted that they used this metaphor without further reasoning. Zimmerman and Cuddington (2007) reported that many students believed that balance is inherent to nature rather than the result of some specific causal mechanisms. Also, they concluded that students might have equated the balance of nature to the mathematical concept of equilibrium, which is often covered in the introduction to predator–prey models. We noticed a similar situation in the present study. Therefore, for effective teaching, this conceptual pattern should be supported by purposeful interventions targeting the causal relations. In this process, 'Reveal the underlying CAusal Structure' (ReCAST) activities can be used. These activities are designed to reveal underlying causal structures and the nature of causality. Research indicates that students who participate in these activities exhibit a deeper understanding of connectedness within ecosystems and have fewer difficulties in understanding ecological concepts and balance of nature (Basca, Grotzer, Donis & Shaw, 2000; Grotzer & Basca, 2003).

Participants considered 'global warming' as both a reason and a result of BL and proposed ending global warming as a solution to BL. As a reason, participants thought that some physical consequences of global warming, such as drought and ice caps melting, would result in adaptation problems leading to BL. The awareness of physical consequences of global warming is a very common finding in other studies with school students (Jeffries, Stanisttreet & Boyes, 2001; Kilinc, Stanisstreet & Boyes, 2008; Kostova & Atasoy, 2008) and adults (Bostrom, Morgan, Fischhoff & Read, 1994; Leiserowitz, 2003). Kilinc et al., (2008), for example, stressed that Turkish school students were aware of the physical results of global warming but not the biological consequences. However, in a subsequent study, when asked directly which organisms would be most vulnerable to global warming, the school students associated these physical results with biological extinction of species such as polar bears and wildflowers as well as ecosystems such as coral reefs (Eroğlu et al., 2010). Some other studies have reported that people easily associate global warming with the extinction of species (Eurobarometer, 2009; Kostova & Atasoy, 2008; Leiserowitz, 2003). Because only one participant said that the

decrease in the number of forests on earth would cause global warming, we conclude that faulty logic is the reason why participants considered global warming to be a result of BL. There is a general conflation of environmental problems in the minds of students due to faulty logic (Francis, Boyes, Qualter & Stanisstreet, 1993). They sometimes confuse the causes and results of problems, as in the case of global warming in the present study. As a solution, some participants were aware of the personal actions they could take to reduce global warming. They listed many actions, such as using renewable energy, taking public transportation instead of driving a car and planting trees.

In addition, some participants in the present study exhibited a common misconception regarding a conflation of global warming and ozone depletion. They wrote that the main reason for global warming is the hole in ozone layer caused by sprays and aerosol deodorants. They also pointed out that a decrease in the usage of these items would close the ozone layer and in turn reduce global warming. In the existing literature, there appears to be a general conflation of thinking about global warming and ozone layer depletion. The dominant model for this conflation, as in the present study, is likely to be that the ozone hole allows more heat or ultraviolet rays to reach Earth's surface and causes global warming (Bostrom et al., 1994; Boyes & Stanisstreet, 1997; Jeffries, Stanisstreet & Boyes, 2001). Surprisingly, these misconceptions also affected the connections between global warming and BL in students' minds. Even though a few students made incorrect connections between global warming and BL, we conclude that the topic of global warming is a strong candidate for teaching students about BL because of the popularity of this issue in the media (Novacek, 2008) and because students easily associate it with BL. Thus, in the classroom, the science of global warming and its effects on organisms and ecosystems may be discussed via some real examples such as coral reefs and polar bears (Eroğlu et al., 2010).

In the case of 'environmental pollution', we see that some participants used this conceptual pattern for all questions about BL in the questionnaire. Even though global warming, ozone depletion and chemicals are examples of environmental problems, students who used the 'environmental pollution' theme usually did not give the details of their reasoning. These students gave some concrete reasons for BL, such as littering, factory waste and exhaust smoke. They did not give clear responses about results of BL, perhaps because of the faulty logic mentioned above. The reasoning here may be that because BL is a bad outcome, this would lead to other bad outcomes such as environmental pollution. These students also did not specify possible actions to reduce environmental pollution, although some focused on waste management. Thus, apart from well-known environmental pollution types such as global warming, ozone depletion, chemicals and radiation, some students also used 'environmental pollution' as a weak conceptual pattern to understand BL. These students should receive extra attention to close the knowledge gaps in their minds. The possible reasons for environmental pollution, direct and indirect effects of these reasons on biodiversity and ways to reduce pollution can be understood by focusing on different types of environmental pollution so that students can develop a strong understanding of the relations between pollution and BL.

'Hunting' is another conceptual pattern used by the participants. Over-hunting was one of the top reasons given for BL, whereas stopping over-hunting was the most popular solution to BL. The research show that most of the children associate the extinction concept with hunting or culling concepts, so they approach the issue of conservation in terms of stopping hunting activities (Ashworth et al., 1995; Grace, 2009; Hunter & Brehm, 2003; Mankin, Warner & Anderson, 1999; Stanisstreet, Spofford & William, 1993). Similarly, the students in the present study understood BL as the death of individual organisms, perhaps because they have personal experiences thanks to media or direct observations. In educational settings, the emphasis may be placed more on habitat destruction, which is the main factor

affecting BL, than on over-hunting. Direct comparisons between the effects of over-hunting and habitat destruction, for example, can be made via peer group discussions (Grace, 2009; Kals & Ittner, 2003).

In the 'human factors' theme, reasons for, results of and solutions to BL that are directly related to humans were given. As reasons for BL, some undesirable features of humans, such as carelessness, apathy and selfishness, were emphasised. According to participants, the knowledge gaps in carelessness, a failure to think about future generations in apathy about nature as well as materialistic and selfish values in selfishness were influential factors. Similar results were observed in another Turkish study: Erdoğan and others (2008) revealed that school students were more concerned about individuals' selfish attitudes and behaviours for engaging in protecting species and regions. As results of BL, participants mentioned direct effects of BL on human populations. These are health problems and human extinction, social problems and aesthetic anxieties. First, students seemed to be well informed about the fact that people meet their vital needs, such as food and medicines, by using organisms. Second, unemployment, poverty and new wars were predicted. Finally, the decrease in natural beauty and a concern that future generations would never be able to see current species were revealed. As solutions to BL, students mentioned raising awareness, caring for nature and careful usage of natural resources. Thus, some of the students were aware that humans cause BL, BL would affects humans and humans need to do something to end BL. This 'zig-zag' understanding is of great importance for understanding BL and conservation of species. In addition, we know that when a risk is perceived personally, the intention to act to remove it increases (Dervişoğlu, 2007; Sjöberg, 2000a, 2000b; Sjöberg & Torrel, 1993). Thus, in conservation education, the effects of BL on humans, such as the aesthetic, utilitarian (food and health) (Kellert, 1985) and intergenerational aspects (Hunter & Brehm, 2003; Palmer, 1997), can particularly be emphasised since they are likely to work as value-based motivational factors for a better conceptual change. Curriculum designers and teachers should be aware that this anthropocentric reasoning (human factors) may also be a danger for educational interventions. Students who focus on utilitarian aspects may miss the interconnections among other organisms. To avoid this problem, the value of living things in nature can be taught in the context of the harmony among all living things, together with their benefits to human beings (Yörek et al., 2008).

Regarding the 'forest' theme, to the participants, deforestation was a reason for BL and, as expected, planting trees was proposed as a solution to BL. In addition, students believed that there would be droughts and decreases in the amount of oxygen available due to the lack of trees. The research demonstrates that students generally consider forests as the habitat of many organisms (Gebhard, Nevers & Billmann-Mahecha, 2003; Grace & Ratcliffe, 2002; Snaddon, Turner & Fostner, 2008). Therefore, educational interventions targeting conservation of species can also focus on this theme because students easily make connections between green areas and biodiversity. In the theme of 'modernisation', on the other hand, students proposed industrialisation and distorted urbanisation as the reasons for BL, whereas environmentally friendly industrialisation and modern technology were the proposed solutions. Reasons such as industrialisation and distorted urbanisation are influenced by the negative image of modernisation's effects on nature (Menzel & Bögeholz, 2009). A lack of space for natural habitats and living organisms and subsequent environmental pollution may make students concerned about BL. In addition, in the case of using technology, some students proposed that endangered species could be cloned using biotechnological techniques.

A similar outcome was also observed in some other studies (Dawson, 2007; Lamanaouskas & Petkeviciene, 2008; Uşak, Erdogan, Prokop & Özel, 2009). Even though the acceptance of cloning can be increased by purposefully focusing on saving endangered species, students should not think that all endangered species could be rescued by the technology. Again, the emphasis should be placed on the main causes of BL, such as habitat destruction, and related possible solutions.

In the 'ozone depletion' theme, the participants believed that the ultraviolet light coming through the ozone layer hole destroys habitats and that direct ultraviolet rays lead species to become extinct. They also proposed ending ozone layer depletion as a method of ending BL. However, they did not describe how to fix the ozone layer. We can argue that students made some simple connections between ozone layer depletion and BL; however, the awareness of personal actions to end this depletion and, in turn, BL is very low. Conservation education can also include direct actions to reverse ozone layer depletion and the influences of these actions on the efforts to end BL. In the 'chemical use' theme, participants reported that pesticides, detergents, cosmetic products and shampoos leach into species' food sources, where they undergo biological magnification, and also destroy natural habitats. Therefore, for ending BL, these students said that people need to decrease their usage of these chemicals and replace them with organic products. Even though the number of students who used this conceptual pattern was low relative to many other patterns, some students were willing to make some changes in their lives. In addition, though their actions to decrease their chemical consumption seem to be limited by the prevalence of organic products in the Turkish market, an education program directing students to decrease the chemicals they use can be efficient because some students have pre-existing conceptions about this issue.

With respect to the 'indirect conservation' theme, participants proposed some political actions, such as making new laws, punishments for people who do not comply with the laws and informing world leaders about BL. In addition, supporting environmental groups by joining and/or donating to them was suggested by a few participants. However, these indirect actions that are highly related to politics did not attract many participants' attention. Turkish students do not give much importance to political actions, perhaps because their trust in politicians is very low relative to their trust in people in other human services professions. Also, some recent decisions by the Turkish government, such as establishing new hydrothermal plants and clearing coastlines for new roads and tourist destinations, might be responsible for the negative image of political actions. Another reason may be the lack of space to discuss these actions in textbooks. On the other hand, joining environmental groups, in particular NGOs, and donating to them are relatively new concepts for many people in Turkey. Even though modern Turkey has witnessed some strong reactions to the participation of NGOs in the fight against environmental pollution, these reactions were restricted to the local areas in which immediate effects of environmental pollution existed. We propose that the political actions targeting ending BL can be included in textbooks and discussed in real classroom environments. Also, the opportunity to establish some clubs in the schools as preliminary versions of NGOs may be influential.

The final theme was 'helplessness'. These participants mainly thought that it is too late to do anything to end BL. They said that as technology progresses, people will not be able to stop the extinction of the species. Even though the number of participants who gave this response is rather low, these students require close attention. Discussion environments eliciting students' ideas may be helpful for these students. Through these discussions, students who exhibit learned helplessness would have the opportunity to see that there are many types of possible solutions and that people can do something to stop BL.

## Limitations and Future Perspectives

Like all scientific research, the present study possesses some limitations. In a methodological sense, because we used open-ended questions with a large number of students, sometimes it was not possible to understand the underlying reasons for the responses. In these cases, we tried to make some comments using existing literature. However, we accept that this situation restricts the generalisability of the results. Semi-structured interviews with school students based on the present results can be suggested. Furthermore, in the case of generalisability, we consider that a quantitative study with a questionnaire in which the items are based on the conceptions of school students identified in the present study seems very attractive.

The sample used in this research may constitute another limitation. Turkish school students who live in a small city, where they may have opportunities to contact nature, might tend to develop stronger cognitive frameworks relative to their counterparts in metropolitan cities. A similar study targeting the school students in bigger cities such as Istanbul would give the opportunity to compare the present results with other cases and show whether these preconceptions are common in Turkey. Another research agenda may be cross-country comparisons. As we mentioned before, Turkey is a developing country and also has a rich biodiversity. In addition, we are aware that the 'hotspot' areas in terms of biodiversity are frequently located in developing countries. This direct contact with biodiversity might make understanding the topic easy in these countries relative to the developed countries (for further discussion, see Inglehart & Wenzel 2005). Comparisons among developed and developing countries in which the conceptions of school students about BL are investigated, are likely to be vital both to determining the prevalence of these conceptions and to designing stronger science curricula.

We presented some conceptual patterns students used in understanding BL in the present study. Due to space limitations, we could not discuss these patterns further. Individual studies focusing on each theme would provide us with a deeper insight regarding the interrelations among the patterns and the contributions of each pattern to the understanding of BL. Also, during our analysis, we noticed that the topic is very suitable for reasoning research in educational inquiry. Even though the main aim of this research was not to elicit the reasoning modes or compare the conceptions with a reasoning model, we saw that students made use of many reasoning modes, such as causal (e.g. Perkins & Grotzer, 2005), moral (e.g. Kals & Ittner, 2003), anthropomorphic (e.g. Bloom, 2001), teleological (e.g. LNCSSP, 1992) and value-based (e.g. Grace & Ratcliffe, 2002) reasoning. In the case of BL, follow-up research on reasoning modes and their relations with the conceptions we found seems to be intriguing. In addition, we disaggregated the data by gender in each table, although our aim was not to include a discussion of gender differences in the data in the present paper. We believe that other research focusing on gender differences would be valuable because the distribution of certain conceptions by gender signals certain causal relationships between gender and the understanding of BL. Moreover, the effect of gender in the tables may yield ideas that can be used by science teachers to plan courses about BL.

Finally, we await the answers to many questions about the educational settings in teaching BL: what are teachers' and student teachers' conceptions of BL? To what extent are these conceptions similar to or different from the conceptions of school students? How do these conceptions develop across different Grades? What teaching techniques can be developed based on the preconceptions identified in the present study? What differences would different teaching methods (for example, free-choice learning settings, inquiry methods, case studies for decision making and critical thinking activities) make in teaching about BL? All of these questions need further research.

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