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Turkish high school students' ideas about invertebrates: General characteristics and classification

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Identifying alternative conceptions is a vital part of teaching and learning in science because it provides information about students' ideas to both themselves and their teachers. In this context, the purpose of the current study is twofold. The first aim is to examine high school students' alternative conceptions about general characteristics and classification of invertebrates. The second aim is to elicit high school students' ability to classify invertebrates. A total of 127 grade 10 and 129 grade 11 students (aged 15-17 years) from four Turkish Anatolian high schools participated in the study. Data were collected using the Animal Classification Test (ACT) and through interviews. A wide range of alternative conceptions emerged and the origin of these alternative conceptions are discussed. Furthermore, the results indicated that although the students could correctly recognize the difference between vertebrates and invertebrates (Phyla), they had failed to recognize the corresponding sub-categories (Classes). As a consequence, it was asserted that when the students classified the animals, they took into consideration only the animals' external views, habitats, nutrition and movement types and similarities in the functions of their organs. Thus the students used analogical approaches based on empirical classification criteria.

Keywords: alternative conceptions, animal classification, biology education, invertebrates

Introduction

Extensive evidence in the literature has repeated the need for science educators to understand their students' pre-instructional understanding of scientific concepts, processes and phenomena which generally differ from accepted scientific views as a prerequisite to improve teaching and learning in science (Cinici, Sözbilir, & Demir, 2011; Cinici, & Demir, 2013; Liew & Treagust, 1998; Odom, 1995). These conceptions generated by students have been called children science (Gilbert, Osborne, & Fenshman, 1982), alternative conceptions (Arnaudin & Mintzes, 1985) or misconceptions (Fisher, 1985) and have a considerable effect on subsequent learning (Beeth, 1993).

In this study, high school students' ideas about the general characteristics of invertebrates and their classification were examined. Throughout the text, alternative conceptions have been defined as students' non-scientific conceptions. Awareness of the critical role of alternative conceptions in the acquisition of new knowledge naturally leads researchers to identify and evaluate the learners' relevant knowledge and ideas prior to instruction (Leach & Scott, 2003; Rebich & Gautier, 2005). Research studies on alternative conceptions suggest that these conceptions have many important characteristics. According to Mintzes (2003), alternative conceptions are found in males and females of all ages, abilities, socioeconomic status and cultures; they are often resistant to conventional teacher-centered teaching strategies; they interact with knowledge presented by teachers and result in unintended learning outcomes; they resemble the ideas of previous generations of natural philosophers; they are products of direct observation, everyday language, peer culture and visual/written media.

Alternative Conceptions about Animals and Animal Classification

There is a considerable body of literature concerning students' alternative conceptions about animals and animal classification. These studies have pointed out that students from a wide range of grades or socio-cultural environments display many alternative conceptions (Braund, 1991; Chen & Ku, 1998; Cinici, 2011; Cinici, 2013; Kubiatko & Prokop, 2007; Prokop, Kubiatko & Fančovičová, 2007; Trowbridge & Mintzes, 1988; Yen, Yao, & Chiu, 2004; Yen, Yao, & Mintzes, 2007). For example, Braund (1991) stated that according to children, animals having a hard shell made an animal a "vertebrate", and having no appendages made them an "invertebrate". In a subsequent study, Braund (1998) found that according to the children aged from 7 to 15, typically vertebrates have great and strong bodies with obvious heads and limbs whilst invertebrates are seen as shapeless, legless animals that crawl. According to the children any animal which coils or flexes cannot possess a backbone and the backbone is also a wide and straight structure. Yen et al. (2007) implemented a study on Taiwanese students and found that for most students, the concept of animal refers to vertebrates, especially to common mammals and birds. Movement and viability were the most common attributes of animals. Many students had difficulty in making the distinction between vertebrates and invertebrates. Moreover, Trowbridge and Mintzes (1988) suggested that students have a highly restricted view on the concept of animal, applying the label almost exclusively to vertebrates, especially to common mammals.

Kubiatko and Prokop, (2007) showed that many children incorrectly thought that dinosaurs were closely related to mammoths and whales rather than birds and the majority of them incorrectly thought that the penguin was a mammal. In a recent study, Patrick and Tunnicliffe (2011) have investigated 4-10 year old children's knowledge about plants and animals by conducting structured interviews with 72 UK and 36 US children. They concluded that vertebrates were cited more often than invertebrates and the most named scientific category was mammals. In addition, Prokop, Prokop and Tunnicliffe (2007a) found that many children possessed scientifically correct knowledge about the anatomy of animals but misclassified invertebrates as vertebrates by drawing bones inside their bodies. In a study similar to the present one, Kattmann (2001) found that children experienced difficulties in biological classification and he also concluded that children's animal classification criteria could be attributed to four large areas of life: water animals (aquatic animals, swimming), air animals (air living animals, flying animals), ground animals (creepers, crawling animals), land animals (land living animals, running animals, four legs, game, and domestic animals).

The Importance of Animal Classification in Biology and Environmental Education

Systematics and taxonomy are seen as the corner-stones of biological sciences dedicated to studying biodiversity, naming and classifying living things (Keogh, 1995). Randler (2008) stated that students need to know how living things are classified to better understand their bio-diversity. Moreover, a vast body of literature reaches the consensus that true and meaningful learning of the classification or bio-diversity of animals is very important for providing true understanding of many biology contents. For example, Lin and Hu (2003) concluded that alternative conceptions about basic biota (plants, animals, and microorganisms) may contribute to larger conceptual difficulties in the context of food chains, photosynthesis, and cellular respiration. Similarly, Trowbridge and Mintzes (1988) suggested that alternative conceptions about classification may negatively impact learning of higher-order concepts such as ecology and evolution. Yen et al. (2007) stated that the binomial classification system organizes and structures scientific reasoning across a wide range of biological disciplines from evolution and ecology to anatomy and physiology. Adeniyi (1985) concluded that conceptual difficulties concerning biodiversity significantly undermine the acquisition of broader, explanatory biological concepts. Consequently, alternative conceptions about animals and animal classification can cause a lack of understanding or misunderstanding of a wide range of biological concepts and phenomena during formal instructional settings.

Students' knowledge about living things may also influence their attitudes towards them. Improving positive attitudes toward animals is one of the essential goals of biology and environmental education curricula. Prokop et al. (2011) carried out a cross-cultural research focused on Slovakian and Turkish students' fear, disgust and perceived danger regarding various invertebrates. The mean rating scores of fear, disgust and perceived danger of invertebrates showed that Turkish students' mean scores were significantly higher than Slovakian students' scores in all three dimensions. The children were also unable to identify invertebrates. Indeed, educational researchers commonly claim that students' knowledge in science influence their attitudes, learning outcomes, science course selections and future career choices (Nieswandt, 2005; Prokop, Prokop, & Tunicliffe, 2007b). For example, Wagler (2010) found that if a novice elementary teacher had a positive attitude toward a specific animal she/he was likely to include that animal from their future science curriculum. In a subsequent study Wagler and Wagler (2012) found that the external morphology of an insect is an important component negatively affecting preservice elementary teachers' attitudes toward insects and beliefs concerning the likelihood of incorporating insects into future science education settings. Prokop et al. (2007b) examined grades 1-9 students' views on their future intended careers. Future careers in biology-related disciplines received relatively little attention in comparison with other jobs. Namely, very few students were interested in professions in biology. When these results were evaluated, it may be asserted that there are multidimensional correlations between individual knowledge, attitude and behavior. In this regard, it should not be forgotten that the students of today should be thought of as tomorrow's environmental policy-makers having a right to voice their opinions about environmental matters (Keogh, 1995). So, it could be suggested that biological educators should enable their students to have an appreciation of bio-diversity and how its preservation is important for our future.

Purpose of Study and Research Questions

As asserted above students' scientifically true understanding of animals and animal classification are very important to facilitate meaningful learning of many biological topics and concepts and to promote positive attitudes towards the environment and animals. Furthermore, the review has revealed that the students' level of knowledge about vertebrates is more comprehensive than that about invertebrates and also their attitudes or perceptions towards invertebrates are more negative than to vertebrates. So, lower levels of students' cognitive and affective attainment related to invertebrates have provided the impetus to embark on this study. Furthermore, the lack of educational research in the Turkish context about the issue has encouraged me in this study. Finally, the current empirical knowledge of science educators is concerned mostly about vertebrates with limited knowledge about children's abilities to identify invertebrates (Prokop et al., 2011). The purpose of this study is therefore, to examine high school students' alternative conceptions about the general characteristics of invertebrates and their classification. The specific questions of the study are as follows:

1) What attributes do high school students focus on about the general characteristics of invertebrates?
2) What are the students' basic criteria about classification of animals that result in scientifically acceptable or alternative conceptions?

The responses provided by students to these two questions could provide important implications and recommendations for further research for and teaching practice.

Methodology

Participants

A total of 257 participants (15–17 years old) consisting of 127 grade 10 and 129 grade 11 students randomly selected from four different public Anatolian high schools in the center of Erzurum, Turkey participated in this study. Anatolian high schools in Turkey accept students who have performed at a high level of achievement in centralized examinations at 8th grade. The formal knowledge about the classification of animals that all these students possessed was about the same. Biological classification is first introduced from early elementary grades and is reinforced in the upper grades (high-school), specifically in the new 9th grade compulsory curriculum in Turkey. The participants in this study that was conducted in the 2010-2011 academic year, however, had received no previous formal instruction on animal classification.

Data Collection Instruments and Procedure

In the current study interviews and a written test (*ACT*) with open-ended and multiple-choice questions was used to identify students' alternative conceptions. The *ACT* developed by the researcher consisted of three open-ended questions eight multiple-choice items involving drawings or photographs of eight invertebrates (Cinici, 2011).

The open-ended questions were administered to probe students' understanding of the general characteristics of animals (*What are the general characteristics of animals*?) and the general characteristics of invertebrates (*What is your opinion of invertebrate animals? What are their characteristics*?). Drawings or photographs of invertebrates (octopus, jellyfish, snail, caterpillar, leech, butterfly, sea star and crab) were also included in the *ACT* to provide basic information to the students in answering the multiple-choice items. The multiple-choice items required students to determine and mark the classes and phyla of these animals. In identifying the invertebrates in the *ACT*, the views of an expert in the field of zoology and two experts in biology education as well as information form the related literature was sought (Chen & Ku, 1998; Yen et al., 2004; Yen et al., 2007). Furthermore, the previous teaching experience~~s~~ of the author who was a biology teacher in an Anatolian high school contributed to the selection of the animals. The aim was to select appropriate animals that were difficult to classify. Experts' views were used to establish the validity of the *ACT*. The test was revised to accommodate the comments and suggestions of the experts. The first draft of the test consisting of 19 items (the first 3 questions were open ended and the following 16 questions were multiple-choice~~s~~) was pilot-tested with 52 grade 9 students in an Anatolian high school. After that, some questions which were difficult for the students to understand were revised. At the end of this process the final version of the *ACT* was administered to 127 grade 10 and 129 grade 11 students in four different public Anatolian high schools. The data obtained from the students' responses were binomially coded as correct (score 1) or incorrect (score 0) and analysed with the total possible maximum score being 8 for the multiple-choice items about the classification of invertebrates. Finally, the reliability of the ACT was computed and its' Cronbach's alpha coefficient was found to be 0.69. This value showed that the test was sufficiently reliable (Salvucci et al. 1997). Semi-structured interviews were conducted individually with ten students at each educational level (with 20 students in total) to probe the students' mental models. According to Duit (2004) "mental models" are built to interpret the construction of students' representations of scientific phenomena, processes and concepts. The students who participated in interviews were selected from among volunteers on the basis of their performance in the *ACT* (from low to high scores).

Analyses

The open-ended responses were gathered and categorized in terms of their similarities and presented in Table 1. The responses from the students about the invertebrate animals in the interviews were also transcribed and some excerpts of the ensuing dialogue that provided important clues about the students' understanding are presented in the following section. For multiple-choice answers, frequency (f) and percentage (%) analyses were performed. These findings are presented in Table 2 in Appendix and in eight figures (Figures 1 to 8). In addition to descriptive statistics, paired samples t-test analysis was also used to compare the mean scores of *Classes* with the mean scores of *Phyla,* both of which were categories of invertebrates in the multiple-choice items.

Results

Students' ideas about general characteristics of invertebrates

The critical characteristics used by the students to define invertebrates were categorized into three groups: Structural anatomy, External morphology and Movement type. These categorical responses are summarized in Table 1. In the interviews, the researcher asked the students some questions ascertain their ideas about defining the characteristics of invertebrate animals, for example:

> Interviewer: "In your opinion, is a snake a vertebrate or invertebrate?"
> Student 3 (grade 10): "Since a snake has no bones, it is an invertebrate animal (internal skeleton)."
> Interviewer: "Why do you think that a snake does not have an internal skeleton?"
> Student 3 (grade 10): "A snake crawls on the ground and it is very flexible and pliable too. If it had an internal skeleton, it would not have been able to do pliable movements."
> Interviewer: "What are the general characteristics of reptiles?"
> Student 3 (grade 10): "They are invertebrate animals and crawl on the ground."
> Interviewer: "What does the term "invertebrate animal" mean?"
> Student 5 (grade 10): "It is an animal which does not have internal skeleton."

The findings gathered from the interviews indicated that according to the students, invertebrates don't have an internal skeleton consisting of bones, crawl on the ground and they are very flexible and pliable animals.

Table 1. The most commonly used characteristics of invertebrate animals by students

Systematic group	General Traits	Ideas of the Students
Invertebrates	Structural anatomy	They do not have backbone and their body structures are soft.
	External morphology	They have flexible, amorphous bodies and small-sized bodies compared to vertebrates.
	Movement type	They also crawl on the ground and move more slowly and are flexible compared to vertebrates.

Students' understanding about classification of animals

Students' responses to the multiple-choice items in the *ACT* were used to reveal what they actually knew about classification of invertebrates into taxa (*phyla* and *classes*). These data were analyzed using paired samples t-test analysis and presented together with descriptive statistics. Table 2 shows the frequencies (f) of responses for each subordinate group concept and eight figures (Figures 1 to 8) also provide the percentage (%) of responses related to each taxon (*phyla* or *classes).*

The comparison between the students' responses to *Classes* and *Phyla* indicated a statistically significant difference. The students' mean scores about *Phyla* were higher than that of the *Classes* ($\overline{X}_{phyla}=6.38$, $SD=1.22$; $\overline{X}_{classes}=3.41$, $SD=1.64$; $t_{(255)} = -29.56$; $p < 0.001$). This result indicated that the students' success in separating the animals into two main groups (*phyla)* as vertebrates and invertebrates is significantly higher than their success in separating ~~of~~ these two main groups into sub-groups (*classes*).

In the octopus question, most of the students correctly classified it under invertebrates ($f/\%_{(10.\ grade)} = 115/90$; $f/\%_{(11.\ grade)} = 118/91$) and under mollusks ($f/\%_{(10.\ grade)} = 74/58$; $f/\%_{(11.\ grade)} = 71/55$). However, some students incorrectly labeled the octopus as a fish (Pisces) ($f/\%_{(10.\ grade)} = 22/17$; $f/\%_{(11.\ grade)} = 30/23$). In the interviews, the researcher asked them, "Why is the octopus a fish (Pisces)?" Most of the students explained that the octopus is a fish because it lives in the water and breathes with its gills.

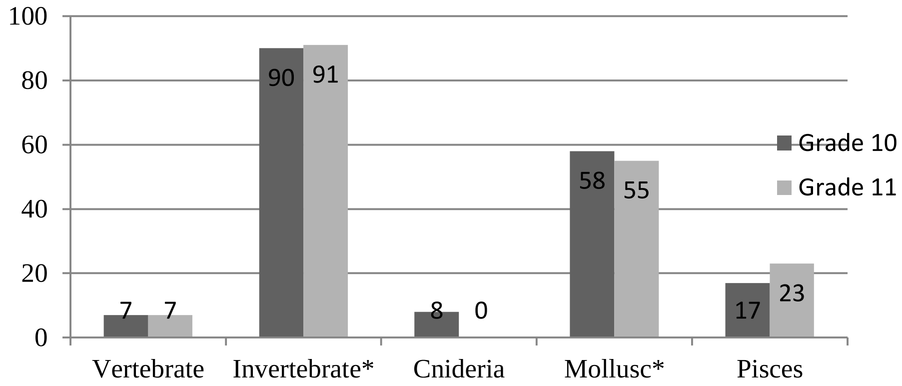

Figure 1. The percentages (%) of the responses relevant to classification of the octopus

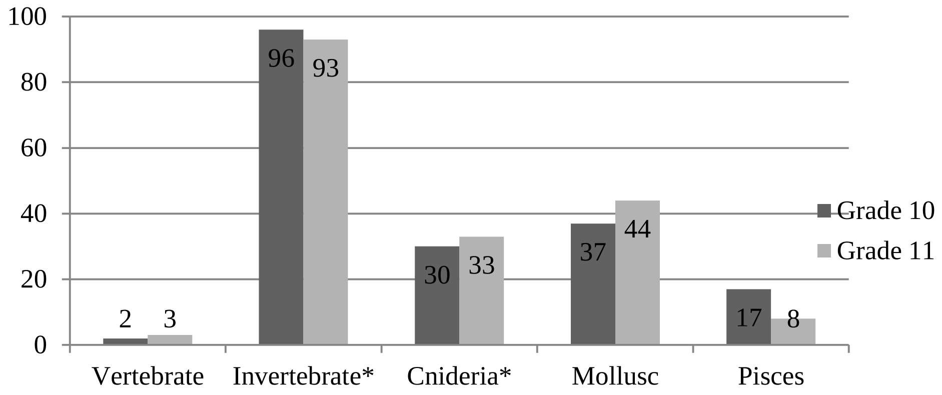

Figure 2. The percentages (%) of the responses relevant to classification of the jellyfish

When the students' responses to the jellyfish question was examined in Table 2 and Figure 2, it could be shown that while most of the students correctly classified the jellyfish under invertebrates (*Phylum*) (f/%$_{(\text{ grade } 10)}$ = 122/96; f/%$_{(\text{ grade } 11)}$ = 120/93), many students also misclassified it under mollusks (*Classis*) (f/%$_{(\text{grade } 10)}$ = 47/37; f/%$_{(\text{grade } 11)}$ = 120/57) or fish (f/%$_{(\text{grade } 10)}$ = 21/17; f/%$_{(\text{grade } 11)}$ = 10/8). The findings that were provided from interviews gave some indication about why students used such alternative notions:

Interviewer: "Why is a jellyfish classified under mollusks?"
Student 3 (grade 11): "They do not have bones and their bodies are very soft and pliable."
Student 2 (grade 10): "Since a jellyfish does not have a skeleton, it is classified under mollusks."
Interviewer: "Why is a jellyfish classified as fish (Pisces)?"
Student 4 (grade 11): "Since a jellyfish lives in the sea and breathes with its gills, it is a species of fish."

The students' responses to classification of a snail (see Table 2 and Figure 3) showed that though most of the students correctly classified the snail under invertebrates (f/%$_{(\text{grade } 10)}$ = 108/85; f/%$_{(\text{grade } 11)}$ = 114/89), a small number of the students correctly classified the snail under mollusks (f/%$_{(\text{grade } 10)}$ = 40/32; f/%$_{(\text{grade } 11)}$ = 63/49). Moreover, the snail was misclassified by many students under annelids (f/%$_{(10.\text{ grade})}$ = 17/13; f/% $_{(\text{grade } 11)}$ = 20/15) or reptile (f/%$_{(\text{grade } 10)}$ = 22/17; f/%$_{(\text{grade } 11)}$ = 22/17).

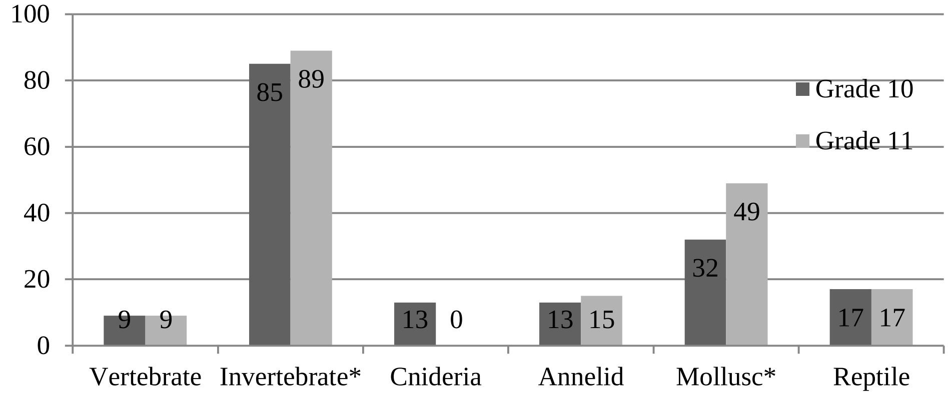

Figure 3. The percentages (%) of the responses relevant to classification of the snail

The interviews provided some evidence about why students held such alternative notions:

Interviewer: "Why is a snail classified under invertebrates?"
Student 3 (grade 11): "A snail is an invertebrate animal because it crawls on the ground, does not have legs, moves more slowly and its body structure is very soft."
Interviewer: "Why is a snail classified under annelids?"
Student 4 (grade 11): "They have moist skin and they live in soil like earthworms."
Student 6 (grade 11): "Their external morphology and movement are similar to worms."
Student 7 (grade 10): "Their appearance and body structures are similar to worms and they crawl on the ground like worms."
Interviewer: "Why is a snail classified under reptiles?"
Student 8 (grade 11): "They crawl on the ground thanks to a slick secretion secreted from their skin."
Student 1 (grade 10): "I saw them on a tree when we were on the picnic. They did not have legs and they moved very slowly."

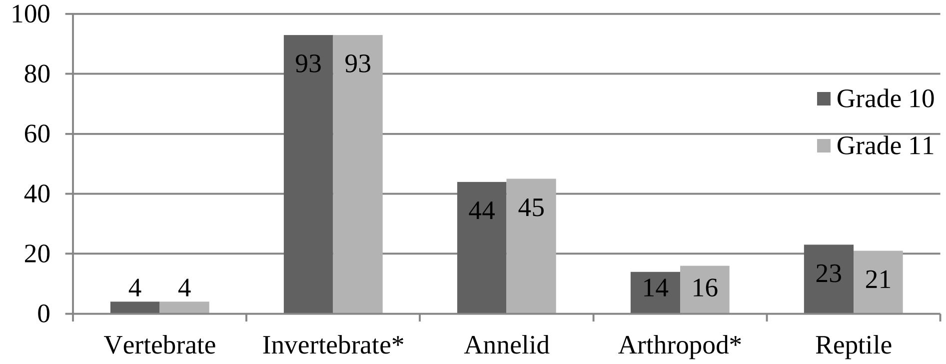

Figure 4. The percentages (%) of the responses relevant to classification of the caterpillar

Though most of the students knew that the caterpillar, pupa, and adult are all stages in the life cycle of a butterfly, when the students' responses to the caterpillar and the butterfly questions were examined (see Table 2 and Figure 4 & 5), it was seen that the students were forced to understand the classification of this animal in the same species and metamorphosis process. In the interviews, the researcher asked them some questions to elicit their understanding:

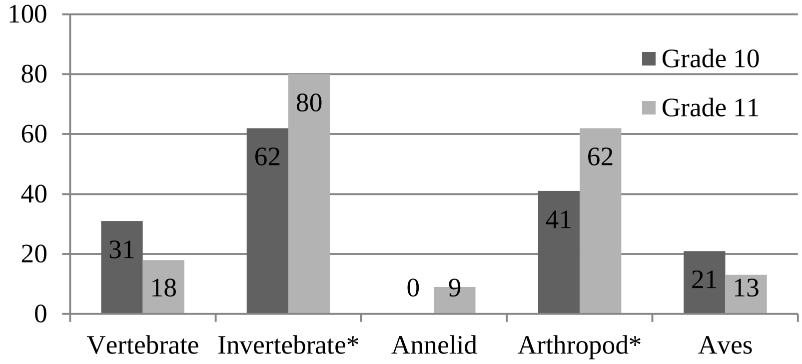

Figure 5. The percentages (%) of the responses relevant to classification of the butterfly

Interviewer: "Are a caterpillar and a butterfly in the same or different species?"
Student 10 (grade 10): "The caterpillar enters the pupal stage and it transforms into butterfly. They are different species because they have different habitats, movement type and appearance."
Student 8 (grade 10): "A caterpillar crawls on the ground, whereas a butterfly flies. For this reason they are different species."
Interviewer: "Is there any relationship between a caterpillar and a butterfly?"
Student 3 (grade 10): "They can be classified in the same species. The caterpillar is a baby. It grows up and becomes an adult butterfly."
Student 2 (grade 11): "Because of the fact that the butterfly is classified under arthropods and the caterpillar is transformed into a butterfly via an evolutionary mechanism, the caterpillar is also classified as an arthropod."
Student 3 (grade 11): "The butterfly is formed as a result of evolution of the caterpillar."
Interviewer: "Why is a butterfly classified under reptiles?"
Student 9 (grade 10): "The caterpillar is a reptile and since the butterfly is transformed from the caterpillar, the butterfly is a reptile too."
Interviewer: "Why is a caterpillar classified under reptiles?"
Student 9 (grade 10): "A caterpillar crawls on the ground and does not have legs like reptiles."
Interviewer: "Why is a caterpillar classified under annelids?"
Student 5 (grade 11): "They are invertebrate and they crawl on the ground like worms."
Student 3 (grade 11): "They crawl on the ground and do not have legs like worms."
Interviewer: "Why is a butterfly classified as bird?"
Student 2 (grade 10): "Because of the fact that the butterfly has wings and it flies like birds, it is a bird."

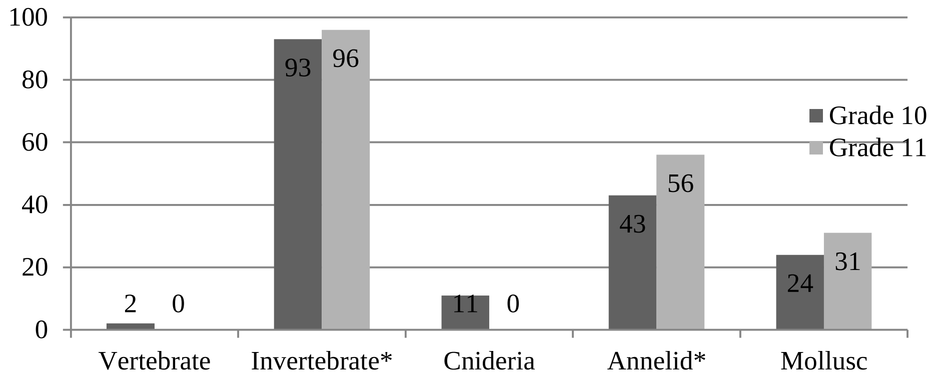

Figure 6. The percentages (%) of the responses relevant to classification of the leech

The findings gathered from the students' responses to the leech question (see Table 2 and Figure 6) showed that while most of the students correctly classified the leech as invertebrate (*Phylum*) (f/%$_{(grade\ 10)}$ = 118/93; f/%$_{(grade\ 11)}$ = 122/96), a small number of students classified it under annelids (*Classis*) (f/%$_{(grade\ 10)}$ = 54/43; f/%$_{(grade\ 11)}$ = 72/56) correctly. In addition, some students also misclassified the leech under mollusks (f/%$_{(grade\ 10)}$ = 31/24; f/%$_{(grade\ 11)}$ = 40/31). In the interviews, the researcher asked them, "Why is the leech classified under mollusks?" Most of them explained that since their body structures are very soft and pliable, they are classified under mollusks."

When the responses about the classification of the sea star were scrutinized (see Table 2 and Figure 7), although most of the students correctly classified the sea star under invertebrates (*Phylum*) (f/%$_{(grade\ 10)}$ = 114/89; f/%$_{(grade\ 11)}$ = 116/90), a small number of students correctly classified it under echinoderms (*Classis*) (f/%$_{(grade\ 10)}$ = 45/35; f/%$_{(grade\ 11)}$ = 63/49). Moreover, the sea star was misclassified by some of the students under mollusks (f/%$_{(grade\ 10)}$ = 22/17; f/%$_{(grade\ 11)}$ = 19/15) or sponge (f/%$_{(grade\ 10)}$ = 28/22; f/%$_{(grade\ 11)}$ = 26/20). In the interviews, the researcher asked them, "Why is the sea star classified under sponge?" Most of them explained that its body appearance is soft and pliable, and it do not stir or act like sponges."

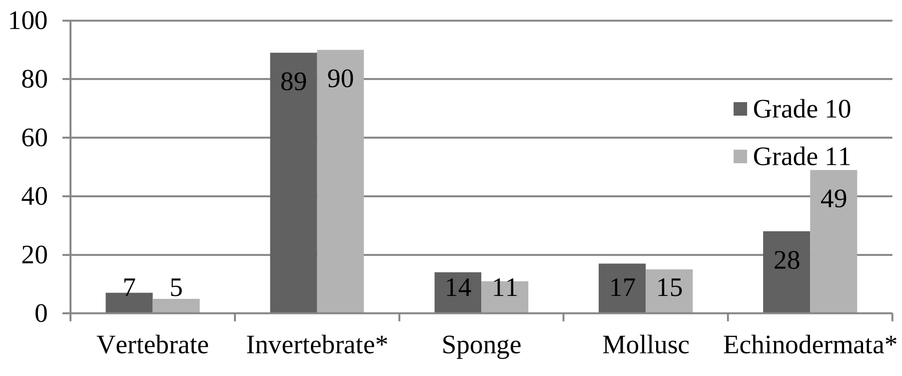

Figure 7. The percentages (%) of the responses relevant to classification of the sea star

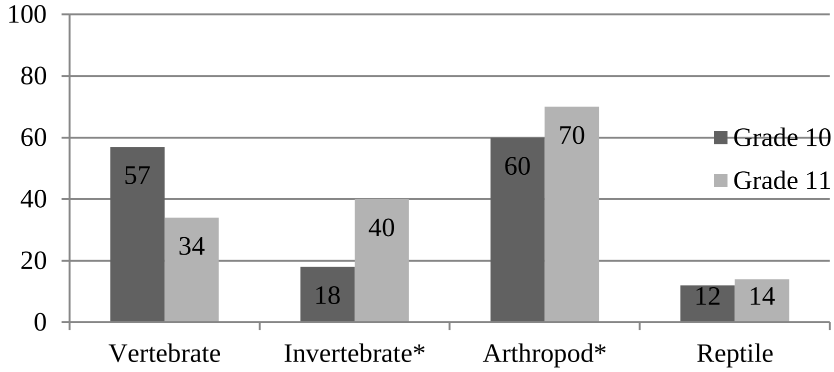

Figure 8. The percentages (%) of the responses relevant to classification of the crab.

The findings from students' answers to the question of classification of a crab (see Table 2 and Figure 8) showed that while most of the students correctly classified the crab as arthropod (f/%$_{(grade\ 10)}$ = 75/60; f/%$_{(grade\ 11)}$ = 90/70), many students misclassified it under vertebrates (f/%$_{(grade\ 10)}$ = 47/37; f/%$_{(grade\ 11)}$ = 120/57). Moreover, some students incorrectly classified the crab as a reptile. The researcher interviewed some of the students who misclassified the crab as a vertebrate or reptile and obtained the following responses:

> Interviewer: "Why is a crab classified under vertebrates?"
> Student 9 (grade 10): "They have a hard shell and they are seen to be strong like vertebrates."
> Interviewer: "Why is a crab is classified under reptiles?"
> Student 3 (grade 10): "The crab crawls on the ground and does not have legs like reptiles."

Discussion

In this study, three related task sets (open-ended questions, multiple-choice items and individual interviews) were used to document alternative conceptions about classification of invertebrates that are held by a sample of 256 high school students. The results showed that high school students display a wide range of alternative conceptions. These alternative conceptions were compared with the results of similar studies that were carried out in different countries. The results of the comparison provided some evidence about some alternative conceptions being specific to a particular country while others were internationally held characteristics. Furthermore, the origins of these alternative conceptions are mentioned.

The results of the study showed that from the students' point of view, a crab is a vertebrate because it has a hard shell and strong appearance; since an octopus lives in the sea, it is a fish; a jellyfish is classified under mollusks because it does not have any bones and its body is very soft and a snake is an invertebrate animal because it crawls on the ground and is also very flexible and pliable. So, because of their external morphology, habitat and movement type identifying some animals could be difficult for the students. Similarly, Kattmann (2001) found that although habitat and movement patterns are very important data for the children when classifying an animal, they have difficulty identifying some animals truthfully in the light of these data.

Yen et al. (2004) proposed that alternative conceptions about animal classification seem to correlate with students' perceptions of certain external morphological features of organisms, especially segmentation, body covering and appendages. For example, Kubiatko and Prokop, (2007) concluded that the majority of the children incorrectly thought that the penguin was a mammal and Braund (1998) found that for children any animal that coils or flexes cannot possess a backbone. Consequently, the present study and similar studies mentioned above suggest that when the students classified the animals, they took into consideration the animals' external morphologies, habitats, nutrition and movement types and function similarities of their organs. As stated in a study by Cinici (2011), students used analogical approaches based on Aristotle's classification criteria (Kiziroglu, 2008). This result supports the view stressed by (Mintzes, 2003): Alternative conceptions resemble the ideas of previous generations of philosophers. Children's elementary criteria of classification asserted above also have an influence on their views (Kattman, 2001).

In this study, invertebrates were described mostly with soft, flexible, amorphous bodies and smallsized bodies compared to vertebrates by the students as in the study by Kattmann (2001). Most of the participants in this study also explained their ideas about invertebrates such as they crawl on the ground, do not have legs, move more slowly and are pliable compared to vertebrates. These results are similar to some extent to those of previous studies. For example, Braund (1991) found that according to the children, having a hard shell made an animal "vertebrate"; having no appendages made one "invertebrate". In another study, Braund (1998) also found that typically vertebrates are regarded as large animals with obvious heads and limbs whilst invertebrates are seen as shapeless, legless animals that crawl. Similarly, many students, in this study, misclassified the snail and the caterpillar under reptiles based on some non-scientific ideas such as "they crawl on the ground and do not have legs". Moreover, most of these students classified the reptiles under invertebrates, so according to them snakes are classified under invertebrates too. Braund (1998) and Yen et al. (2004) stated that visual absence of limbs in the snakes and their movement similar to worms probably is why snakes are frequently misclassified as invertebrates. On the other hand, Prokop et al. (2007a) found that although the children have scientifically acceptable knowledge about the anatomy of animals, they have driven bones inside the bodies of the invertebrate animals.

The results derived from the responses to multiple-choice items also suggest that although the students could correctly differentiate between vertebrates and invertebrates (*Phyla*), they did not successfully to classify them into sub-categories (*Classes*). For example, although all invertebrates, except for the crab, in the *ACT* were correctly classified as invertebrate by most of the students, their success in classification of these animals into sub-categories was lower. Braund (1991) has argued that the narrowness of children's conceptions of animals extended towards their understanding about sub-classes of animals. Another finding about misclassification of sub-categories deduced from the *ACT* and the interviews is that most of the students correctly classified the caterpillar and butterfly under invertebrates, even though many students were not aware that the butterfly larvae (caterpillar) and adult butterfly are classified under the same species. Furthermore, the findings from the interviews showed that some of the students recognized the transformation from caterpillar to butterfly as evolution. These findings about the caterpillar, butterfly and phenomenon of metamorphosis are in line with a more recent study that focused on high school students' ideas about the life-cycle and life forms of insects (Cinici, 2013). This finding exposed that high school students having problems about animal classification may also have problems about the concept of evolution, or vice versa. This result also supports the findings of Yen, et. al. (2007) who concluded that binomial classification scaffolds scientific reasoning across several sub-disciplines such as evolution, ecology, anatomy and physiology. Trowbridge and Mintzes (1988) also suggested that alternative conceptions about classification negatively impacted learning of higher-order concepts such as ecology and evolution.

When the results of the study were evaluated, it could be stated that the students have two basic handicaps in classifying animals. The first is the students' poor conceptual prototypes and the second is faulty generalizations of concepts. Most of the students classified common (prototypical) representatives of an animal species more correctly than lesser-known representatives of it. This assertion supports the results by Trowbridge and Mintzes (1988). When students were for the class of an animal, they tended to think about their own prototype. For example, most of the students correctly classified a jellyfish and a leech under invertebrates because they have a mental representation (a prototype) of an invertebrate animal that they described as having a soft, flexible, amorphous body. On the other hand, most of the students incorrectly classified a crab under vertebrates because according to the students a crab has a hard shell and it appears to be strong. So, this body structure fit the students' prototype for vertebrates, even though it does not fit the students' conceptual prototype for invertebrates. These results showed that the students' criteria for classifying animals were based essentially on poor and naïve sensory experiences that resembled the prototypes in their minds. For example, small and soft or pliable animals that crawl on the ground are invertebrates; a butterfly is a bird because it flies in the sky and a crab has a hard shell and it is seen to be strong so, it could be a vertebrate animal.

The generalization is essentially a main cognitive process in the development of conceptions. However, responses of the students to the open-ended questions and interviews reflected the students' narrow views or lack of experience about phenomena or conceptions. This lack of experience may be a reason for the students' over-generalized or under-generalized application of their understanding. For example, the interviewer asked the students: "Why is a snail classified under reptiles?" And a tenth grade student said that "I saw them on a tree when we were on the picnic. It looked as if it did not have legs and moved more slowly." In another example of over-generalization, students who misclassified a caterpillar as annelid stated that "It crawls on the ground and moves more slowly like a worm."

The findings of the present study and related literature (Kubiatko & Prokop, 2007; Prokop et al., 2011; Trowbridge & Mintzes, 1988; Yen et al. 2007) cited above have strongly asserted that the concept of animal to many students refers to vertebrates, especially to common mammals and so their understanding about vertebrates is more comprehensive than about invertebrates. Recently, the literature has also voiced that attitudes or perceptions towards invertebrates are more negative than for vertebrates (Gerdes, Uhl & Alpers, 2009; Prokop et al., 2011; Wagler & Wagler 2012). Consequently the students' cognitive and affective levels about invertebrates are less than that for vertebrates.

Conclusions and Implications

The present study investigated how invertebrate animals are classified into taxonomic categories (*Phyla* and *Classes*) by high school students and has documented the frequencies of scientifically-acceptable classifications and misclassifications held by the students involved. Evidence has also been gathered and presented as to why the students held alternative conceptions about classification that were displayed in their responses to open- ended questions and interviews. According to the results, it can be asserted that when students classified the animals, they took into consideration the animals' external morphologies, habitats, nutrition and movement types and function similarities of their organs.

The students had difficulty in classifying animals because of their poor conceptual prototypes for animals and faulty generalizations. As a consequence, students' non-scientific ideas and inappropriate criteria about classification were evaluated as a particular reason for misclassification of invertebrates and also faulty interpretation of important biological concepts or phenomena like evolution and metamorphosis.

The current study has several implications for formal or informal biology education and future research. In the present study, it was stressed that students have less knowledge and poor attitudes about invertebrates compared to vertebrates. If further research is focused on ontological, epistemological and socio-cultural nature of students' ideas about invertebrates, it could provide very valuable contributions to the related literature.

It can also be suggested that educational researchers need to identify and determine the causes and origins of the students' non-scientific ideas to develop meaningful learning environments and so to address the alternative conceptions. This study only focused on some special species of invertebrates. So, more extensive specimens might be used in further research. Furthermore, we need studies focused on effects of students' socio-economic status and cultural beliefs or prejudices on understanding of biodiversity, classification of animals, vertebrates or invertebrates and attitudes to vertebrate or invertebrate animals.

In the study, most of the students classified common "prototypical" representatives of an animal class more correctly than lesser-known representatives. So, instruction on animal classification should be focused on the development of scientifically true mental models of concept prototypes. Teachers should provide opportunities such as interactions with models, pictures and real examples of a wide variety of animals to expand the scope of students' information about animals and animal classification. These opportunities will enable the students to overcome faulty generalizations and support them in developing more scientifically acceptable conceptual prototypes of animals.

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Appendix

Table 2. The frequencies of the students' responses relevant to classification of invertebrates (N=256)

Animals	Grade	N	Sponge	Cnidarians	Annelids	Mollusks	Arthropods	Echinoderms	Pisces	Am-phibi-ans	Reptile	Aves	Vertebrate	Invertebrate*
1. Octopus	10	127	-	10		74*	-	-	22	-	-	-	9	115
	11	129	-	-	-	71*	-	-	30	-	-	-	9	118
2. Jellyfish	10	127	-	38*	-	47	-	-	21	-	-	-	3	122
	11	129	-	43*	-	57	-	-	10	-	-	-	4	120
3. Snail	10	127	-	17	17	40*	-	-	-	-	22	-	12	108
	11	129	-	-	20	63*	-	-	-	-	22	-	12	114
4.Caterpillar	10	127	-	-	56	-	17*	-	-	-	30	-	5	119
	11	129	-	-	59	-	20*	-	-	-	27	-	5	120
5. Butterfly	10	127	-	-	-	-	52*	-	-	-	-	27	40	79
	11	129	-	-	12	-	80*	-	-	-	-	17	23	104
6. Leech	10	127	-	14	54*	31	-	-	-	-	-	-	3	118
	11	129	-	-	72*	40	-	-	-	-	-	-	-	122
7. Sea star	10	127	28	-	-	22	-	45*		-	-	-	9	114
	11	129	26	-	-	19	-	63*	-	-	-	-	6	116
8. Crab	10	127	-	-	-	-	75*	-	-	-	15	-	93	29
	11	129	-	-	-	-	90*	-	-	-	19	-	57	67