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From caterpillar to butterfly: a window for looking into students' ideas about life cycle and life forms of insects

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Research paper

From caterpillar to butterfly: a window for looking into students' ideas about life cycle and life forms of insects

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The purpose of this study was a qualitative analysis of high school students' ideas about life cycle and life forms of the butterfly. For this purpose, open-ended questions and drawing methods were applied to 194 high school students from the ninth to eleventh grades and 14 to 16 years of age in Erzurum, Turkey. Students' drawings were categorised using a five-level coding framework and the frequencies of drawn external organs (elements) were calculated; open-ended responses were also evaluated and interpreted. The results indicated that many students have a wide range of misconceptions. These misconceptions could be attributed to results of the students' naive experiences and/or insufficient emphasis of the Turkish primary and secondary biology curriculum on the phenomenon of metamorphosis. Some students were able to identify the morphological structure of a butterfly and caterpillar, but had difficulty classifying them and describing how the transformation from a caterpillar to a butterfly works and what this process is. Students used different concepts to define the phenomenon of metamorphosis such as evolution, growing up, development, mutation or adaptation.

Keywords: biology education; caterpillar and butterfly; drawing method; metamorphosis; misconceptions

Introduction

The process of metamorphosis is a very important biological phenomenon in the life cycle of many insect species (invertebrates) and amphibians (vertebrates). Typically, complete metamorphosis of insects (Figure 1) consists of four stages: egg, caterpillar, pupa (chrysalis), and adult butterfly. The caterpillar hatches from the egg and moves using three pairs of true legs (like all insects) and five further pairs of 'prolegs'. A caterpillar has a hairy cuticle protecting it from its probable predators. As a rule, a caterpillar's cuticle is thin and flexible, although it may carry a protective armature of closely set hairs, or strong sharp spines (Carpenter 2005). After the caterpillar hatches from the egg it will start consuming the host plant. In the chrysalis stage the caterpillar has made its final moult into a pupa and in about 1–2 weeks an adult butterfly emerges from the pupa (Ballard n.d.). Consequently, metamorphosis separates the physiological processes of growth (larva), transformation (pupa) and reproduction (adult), and provides a reduction in competition among the stages of development by differentiating the ecological niche and living habitat (Shepardson 1997).

This wonderful biological process should be comprehended well to provide meaningful learning about several biological phenomena and conceptions such as reproduction, biodiversity, classification of animals, ecological balance and evolution. Despite the importance of the conceptual understanding of the insect life cycle, the process of metamorphosis is only explained in the sixth-grade science and technology curriculum in Turkey (see Table 1) and in the following grades (high school) the phenomenon of metamorphosis is not mentioned at all (Presidency of

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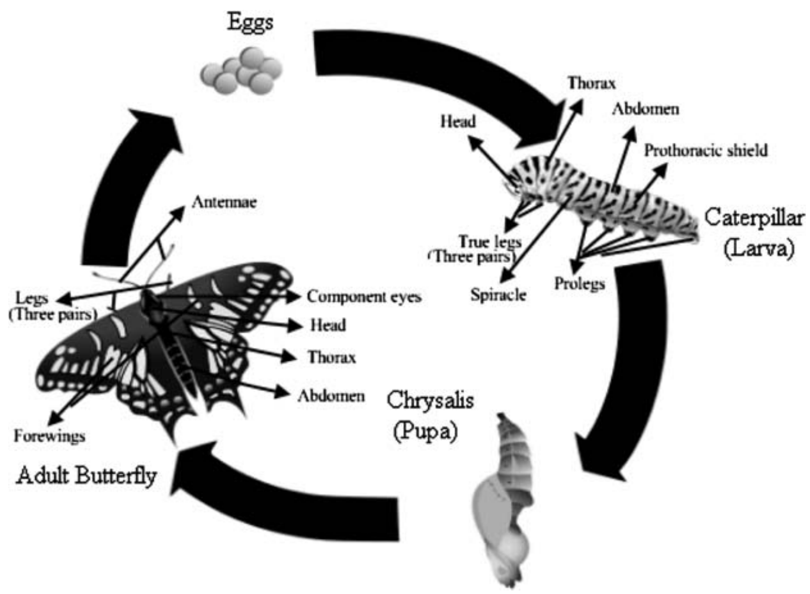


Figure 1. A diagram of complete metamorphosis and external body parts of a caterpillar and an adult butterfly (adapted from Bugboy52.40. (2009)).

Table 1. The contents of elementary and secondary biology curriculum in Turkey

Elementary grades (from 4 to 8)	Secondary grades (from 9 to 12)
Let's solve the riddle of human body	Cell, organism and metabolism
Let's explore the world of living things	Classification of living things and biodiversity
Reproduction, growth and development in living things	Ecology
	Energy transformations in living things
Organ systems in human body	Cell divisions and reproduction
Cell divisions and heredity	Botanic
Energy relations of living things	Zoology and human
	Evolution
Human and environment	

Training Committee [PTC] 2005, 2006, 2011). As a result, students have various naive ideas about this process attained from informal sources (*ie* direct observation, peers, TV, magazines). Many studies have shown that naive ideas and conceptions of the students about scientific phenomena were generally different from scientific ones (Cimer 2007). Additionally, researchers have recognised the persistence of these non-scientific conceptions even after conventional teaching, and also the potential impacts of these ideas on subsequent learning (Beeth 1993; Cinici and Demir 2013; Cinici, Sozbilir, and Demir 2011; Prokop et al. 2009b). These erroneous ideas generated by children are also regarded as naive beliefs (Caramazza, McCloskey, and Green 1980), alternative conceptions (Arnaudin and Mintzes 1985), children science (Gilbert, Osborne, and Fenshman 1982) or misconceptions (Fisher 1985).

According to Mintzes (2003), one of the characteristics of misconceptions is that they are found in males and females of all ages, abilities, socioeconomic status and cultures; another is that they are often resistant to lecture-based teaching strategies; and the others are as follows. They interact with knowledge presented by teachers and result in unintended learning outcomes; they are similar to ideas of previous generations of natural philosophers; they are products of direct observation, everyday language, the mass media and peer culture. Moreover, as asserted by Driver, Guesne, and Tiberghien (1985), students' misconceptions influence their learning in various ways, including the observations they make, their explanations of observations, and the strategies they use to scaffold new ideas and understandings. Hipkins et al. (2002) suggested that eliciting the existing ideas, values and beliefs which students bring to the classroom may facilitate meaningful learning of them. Consequently, owing to the critical role of students' existing ideas in the conceptualisation of new knowledge, the researchers have focused on attempts to elicit and evaluate these ideas (Leach and Scott 2003; Rebich and Gautier 2005). Under these circumstances, in the present study we focused on two specific questions: what are the high school students' ideas about the life cycle and life forms of butterfly, and what are the reasons for these ideas?

Background on children's ideas about the insect life cycle

In spite of the significance of the phenomenon of metamorphosis in biology education, few studies were attained through literature review and all of them were carried out at preschool or/and elementary grades. Some of these studies aimed to investigate the effects of various active teaching approaches on the understanding of insects and their life cycles (Fay 2000; Samarapungavan, Mantzicopoulos, and Patrick 2008; Shepardson 1996, 1997) while the others focused on the children's present ideas or understandings (Barrow 2002; Bartoszeck, Rocha da Silva, and Tunnicliffe 2011; Shepardson 2002).

Shepardson (2002) explored elementary graders' ideas about insects from kindergarten to fifth grade through the use of three different tasks: draw and explain, interview about instances, and children's formation of a general rule for what makes an organism an insect. He found that the students' ideas about insects reflect understandings based on physical characteristics of size and shape, arthropod characteristics, insect characteristics, human–insect interactions, means of locomotion, life habits and feeding habits of insects. Barrow (2002) aimed to determine elementary graders' understanding about insect characteristics, their life cycles, environmental conditions, and their impacts on humans. According to the results, students focus on the harmful effects of insects for humans rather than their beneficial effects. In addition, their knowledge about the life cycles of the insects has been found dramatically insufficient. Barrow (2002) also found several misconceptions about insects. For example, pupils drew an internal skeleton for an insect and most of them knew only the adult phase of an insect's life cycle. In a similar way, Shepardson (1996) reported that most children viewed the life cycle of butterflies as three stages: caterpillar, cocoon, and adult. The children did not consider the egg stage in the life cycle of butterflies. Therefore, they held an incomplete understanding about the process of metamorphosis. Bartoszeck, Rocha da Silva and Tunnicliffe (2011) concluded that insects generally raise curiosity of young children (ages 4–6) and therefore they notice insects in their everyday lives and gain knowledge about insects' external structure and habitats. Similarly, Strommen (1995) found that first grade pupils mostly identified insects with habitat characteristics.

Writings and drawings

A vast body of study reports many methods and activities to reveal students' in-depth thinking and ideas about scientific conceptions and phenomena that are generally related to students' either talking or writing about science (Reiss and Tunnicliffe 2001). Many researchers who suggested various phases about the drawing development of children were inspired by the work of Luquet (cited by Bartoszeck, Rocha da Silva and Tunnicliffe 2011), who proposed the following five age stages: scribbling (ages 2–3); fortuitous realism (ages 3–4); failed realism (ages 4–5); intellectual realism (ages 5–8); and finally visual realism (seen in drawings of children at ages 8–12; in this stage, children try to draw the object from a certain perspective realistically).

Recently, students' drawings have also gained popularity in educational research to elicit students' or teachers' core ideas and mental models about scientific conceptions or phenomena (Bahar et al. 2008; Cardak 2009; Ozden 2009; Patrick and Tunnicliffe 2010; Prokop and Fančovičova 2006; Prokop, Fančovičova and Tunnicliffe 2009a; Prokop, Prokop, and Tunnicliffe 2007a, 2007b; Prokop et al. 2009b; Reiss and Tunnicliffe 2001; Zoldosova and Prokop 2007). Drawings have been considered as both an effective and simple research instrument which enables easy comparisons of students' beliefs and ideas (Bahar et al. 2008). The drawing method has also been evaluated as an alternative channel for children having difficulty expressing their in-depth knowledge verbally (Rennie and Jarvis 1995). Biology educators, therefore, can use drawings to probe students' understanding about scientific conceptions or phenomena (Dikmenli 2010). On the other hand, the drawing method has some limitations besides its advantages. According to White and Gunstone (2000), although using drawings to reveal understanding is a useful approach, as it is an open technique and limited by the drawing ability of students, it is difficult to score drawing reliably. Strommen (1995) found that the drawing method is an insufficient and wrong way if any other additional methods are not used. For these reasons, various additional methods along with drawings such as open-ended questions (Kose 2008; Prokop, Prokop and Tunnicliffe 2007b; Prokop et al. 2009b); interviews (Cardak 2009; Dikmenli 2010; Zoldosova and Prokop 2007) and questionnaires (Prokop and Fančovičova 2006) were used in many studies. For example, Prokop and Fančovičova (2006) proposed that using the method of drawing in combination with written responses or interviews would provide more reliable information about understanding about scientific phenomena. Kose (2008) investigated university students' misconceptions concerning photosynthesis and respiration in plants. As a result, he stated that the drawing method, in conjunction with interviews, has been used successfully to diagnose students' conceptual understandings and misconceptions. As concluded from the literary review, students' drawings may be difficult to evaluate and may also be insufficient to probe and interpret their core ideas. That is, students' spontaneous drawings can be used as a proper method to determine their misconceptions to some extent but not enough. In this study findings elicited from students' spontaneous drawings have been supported with open-ended questions. That is, we took courage from the studies mentioned above to employ students' free-response writings and drawings as data gathering techniques. The study of Bartoszeck, Rocha da Silva and Tunnicliffe (2011), who explored preschool children's (ages 4–6 years) understanding about insects by analysing their drawings resembles the current study in terms of data gathering and analysis procedure. However, the main difference between the two studies is the ages of the participants. Bartoszeck, Rocha da Silva and Tunnicliffe (2011) claimed that the observations of children in daily lives are very important beyond formal teaching to gain knowledge. Moreover, children's knowledge they bring from earlier years indicate coherence. In this respect, the present study will provide a chance to test this common claim.

Purpose of study and research questions

The brief review mentioned above showed that there are numerous studies about ideas on students' biological concepts from kindergarten to university; however, any research dealing with adolescent students' ideas about the phenomenon of metamorphosis has not been reached. Moreover, previous studies have used mainly written and/or oral explanations to diagnose preschool or elementary graders' ideas about the life cycle and life forms of insects and thereby the main purpose of this study was a qualitative analysis of high school students' ideas about the process of metamorphosis and the external organs of a caterpillar and a butterfly (see figure 1) through their drawings and writings. The specific questions of the study were as follows.

1. What are the high school students' ideas about the life cycle and life forms of a butterfly?
2. What are the reasons for these ideas?

The responses to these two questions could provide direct implications and recommendations to curriculum developments and teaching practice.

Methods

Participants

High school students drawn from the ninth, tenth and eleventh grades (aged 14–16 years) participated in the study. The study was conducted during the first semester of the 2010–11 academic year, among an urban public Anatolian high school students in Erzurum, one of the eastern provinces of Turkey. Anatolian high schools in Turkey accept students who displayed a high level of achievement in the centralised exam at the eighth grade. Therefore, the general academic achievements of the students are similar to each other and their socioeconomic status is mostly moderate.

The participants consisted of 194 students (81 ninth graders, 71 tenth graders and 42 eleventh graders); 110 were male (56.7%) and 84 were female (43.3%). However, the study was not focused on gender differences. All of them take biology as a school subject. Unfortunately, the new compulsory biology curriculum in Turkey does not touch on the content of the metamorphosis process in any grade of high school (PTC, 2011). So, except for the sixth grade, participants had received no previous formal instruction on this biological phenomenon. Moreover, in comparison with the children living in rural areas, these students living in an urban area have a limited chance to encounter and examine closely a caterpillar or a butterfly in their daily lives. On the other hand, they have many opportunities to see a caterpillar or a butterfly in the text books or media as animated or unanimated images. However, as stated by Bartoszeck, Rocha da Silva and Tunnicliffe (2011), these images spread by the media are not always portrayed with scientific accuracy. With regard to formal teaching, the following activities about the phenomenon of metamorphosis are included in the sixth grade science and technology teaching programme: a suitable living environment (habitat) for caterpillars is set up using a box, stretch film and mulberry leaves. A few local caterpillars are placed in the box. Later, the students observe the caterpillars' stages of development and draw them. The students seek the phenomenon of metamorphosis from visual and written sources. They have also modelled the stages of metamorphosis using plasticine (PTC, 2011), although when I asked the students whether they made these types of active teaching practices, none of them remembered whether they had prepared a caterpillar habitat and/or models.

Research instruments and procedure

Free-response data were collected through written responses coupled with student-generated drawings to reveal their ideas. The data collection process was conducted in two lessons. During the first lesson (45 min), students were given the necessary information about drawings and sample activities. In this session, some students said that they could not draw, so at that time we told them not to get anxious because we are mainly interested in what they thought about tasks, no matter how well they could draw. By these exercises, we struggled to eliminate the probable anxiety of the students about drawing tasks. In the data-obtaining stage (second session), each student was given a sheet of paper with open-ended questions and sufficient space for drawing tasks. Given this approach, we used the following free-response questions.

1. Is the caterpillar a vertebrate or invertebrate? Why?
2. Is the butterfly a vertebrate or invertebrate? Why?

3. Is there any relation between a caterpillar and a butterfly, and, if so, how?
4. Are they the same species or not?

Finally, students were asked to draw a caterpillar first and then a butterfly, and display the external organs (elements) of them with arrows.

By means of the drawing task, the students' ideas about the life forms of the butterfly were investigated, not the ability to draw it, so the precision in shape was ignored. It was a struggle to provide a scoring scale which gave minimum credit to the artistic quality of the drawing (Reiss et al. 2002). Students generate the drawings based on their prior experiences and present ideas. According to the stages proposed by Luquet, the participants who were 14–16 years old exceeded the highest phase (fifth phase) in drawing development. The details of the students' drawings were evaluated. The absolute frequencies of the drawn external organs were determined to set categories of drawn elements. The drawings of the students were also analysed using a five-point rubric (Table 2) which was developed through the related literature (Bahar et al. 2008; Kose 2008; Dikmenli 2010). The rubric describes a framework for visual analysis of the students' drawings. In order to maintain an objective approach when scoring students' drawings, two scorers who are academics in the science education department scored independently and decided whether the drawings met the criteria for a caterpillar and a butterfly. If the scorers did not agree, they discussed non-consensual drawings until they reached a shared decision. Drawings which were considered not to represent a caterpillar or a butterfly were categorised into the second level. Sample drawings given in Figure 4 can be clearly seen to not be accurate enough to represent a caterpillar or a butterfly. As for third-level drawings (Figures 5 and 6), although some external organs were drawn properly, the existence of some misconceptions (Table 5) facilitated their categorisation in the third level. Moreover, the scorers concurred with a basic criterion in the determination of fourth- and fifth-level drawings. According to the criterion, drawings which were visually proper and did not have any misconceptions were categorised in the fourth level if they had three proper organs, while the drawings with four or more proper organs were put into the fifth level.

The relationships between the scores of the two independent scorers were examined using Pearson's correlation coefficient. The results of the analyses showed highly significant correlations ($p < .001$) both for caterpillar (0.85) and butterfly (0.87). Additionally, the reliability coefficients were also calculated for caterpillar (Cronbach's alpha = 0.93) and butterfly (Cronbach's alpha = 0.91), of which values exceeded critical value 0.7 (Prokop, Prokop and Tunnicliffe 2007b). Consequently, the accuracy of the scoring system was confirmed by the high values of the reliability and Pearson's correlation coefficients.

Results

Students' drawings

The data obtained from drawings and writings were used to analyse different dimensions of students' views. Students' drawings were analysed through a five-point rubric (Table 2) and are presented in Figures 2 and 3. These figures provide an overview

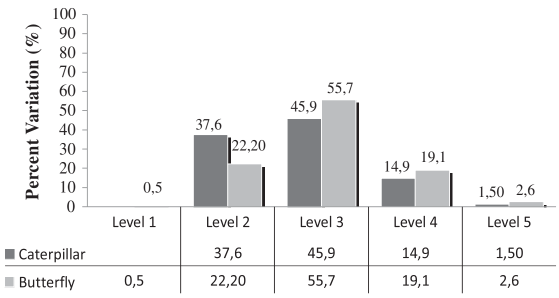


Figure 2. The comparison of the levels of students' drawings of the caterpillar and butterfly.

Table 2. A five-level categorization rubric used for scoring the students' drawings

Levels	Description of conception
Level 1: No drawing	Students said, 'I don't know', or no response was given to the statement
Level 2: Non-representational drawings	Drawings included only 1 or 2 identifiable external organs (elements) of a caterpillar or a butterfly (see Figures 1 and 2) evaluated in level-two category. Silhouettes of drawings not representing a caterpillar or a butterfly were also added into this category
Level 3: Drawings with misconceptions	These types of drawings showed some degree of understandings of a caterpillar or a butterfly but also demonstrated misconception(s)
Level 4: Partial drawings	The drawings in this category demonstrated partial understanding of the conceptions. Includes the drawings of caterpillar/butterfly with 3 proper external organs (elements)
Level 5: Comprehensive representation drawings	Drawings in this category were the most competent and realistic drawings of the caterpillar/butterfly's external structure. Drawings showing sound understanding and contained four or more proper external organs of a caterpillar/butterfly evaluated at this level

of the levels of students' drawings. As can be seen from Figure 2, the drawings with misconceptions (see Figures 5 and 6) have the highest percentage values both for a caterpillar (45.9%) and a butterfly (55.7%). However, comprehensive representational drawings (Figure 8) have the lowest percentage value of the drawings both for a caterpillar (1.5%) and a butterfly (2.6%).

Of the students, 19.1% produced partial drawings (Figure 7) for a butterfly and 14.9% for a caterpillar; in addition, students' non-representational drawings (Figure 4) were calculated as 37.6% for a caterpillar and 22.2% for a butterfly.

Further detailed investigation of the drawings was executed to create set categories of the drawn elements and counted percentages of appearance (Tables 3 and 4). Table 4 shows the elements related to the external organs of the butterfly used by the students in their drawings. Wings (99.48%) are the most frequently drawn element for the butterfly and antennae (75.25%) were also used in more than half of the butterfly drawings. On the other hand, as can be seen in Table 3, the most characteristic external organ of the caterpillar is the head (59.27%) and the second is the eyes (42.78%).

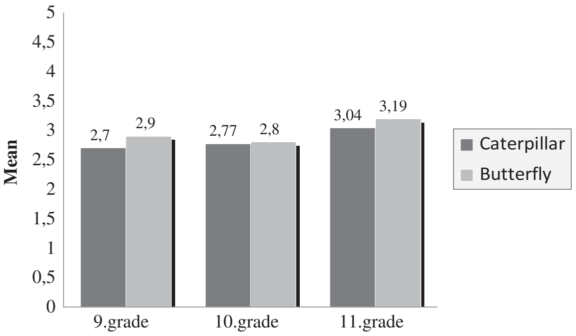


Figure 3. Relationship between mean scores of the students' caterpillar and butterfly drawings.

The findings presented in Tables 3 and 4 indicated that body segments (42.26%) and legs (34.53%) were used more in the caterpillar drawings compared with the butterfly drawings (13.40% and 11.85%, respectively). Furthermore, some students (12.88%) used hairy cuticle in their caterpillar drawings, but none of the students used this element in the butterfly drawings.

Misconceptions

In this section, students' misconceptions about the caterpillar and the butterfly obtained from their drawings and responses to open-ended questions are presented and evaluated. In Table 5, the frequencies and percentages of some widespread misconceptions elicited from drawings are presented.

The free responses of the students demonstrated that, although a limited number of students (n = 7) stated that there is no relation between a caterpillar and a butterfly, most of the students are aware of the relation between them. Moreover, many students (19.07%; n = 37) stated that a caterpillar forms a chrysalis (pupa) around itself. However, when they were asked to define this transformational phenomenon, they used various conceptions such as growing up (26.29%; n = 51), metamorphosis (14.95%; n = 29) or evolution (14.95%; n = 29). In addition, a few students also used conceptions of mutation and adaptation to define the phenomenon of metamorphosis (see Table 6). Moreover, none of them considered eggs as a phase of complete metamorphosis.

The comparative results showed that a variety of misconceptions elicited from open responses were

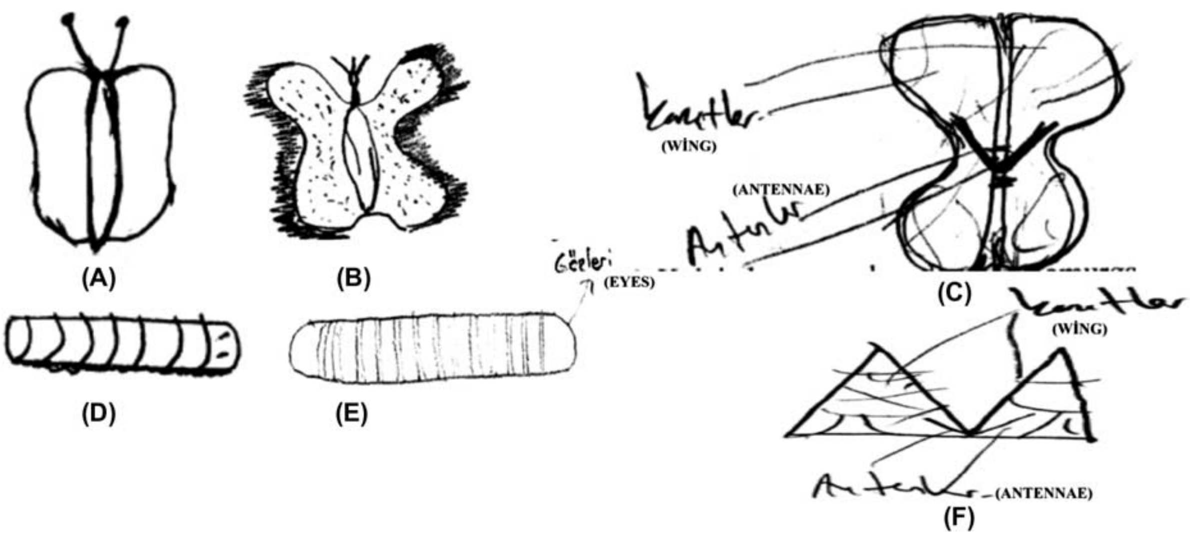


Figure 4. Six non-representational drawings (level 2).*
Note: *Drawings considered not to represent a caterpillar or a butterfly were categorised in this level.

consistent with the drawings. For example, many students classified the butterfly as vertebrates both in their free responses (39%; n = 75) and drawings (as seen in Figure 5C,D). They asserted some worthwhile reasons for thinking in this way: 'A butterfly must have a skeleton consisting of bone or cartilage to be able to fly' (n = 38); 'An animal having wings must classify in vertebrates'. In a different example, a ninth-grade male student's (S1) statement 'I found caterpillars when I was digging the ground with my friends' and many students' drawings (see Figure 6D) have also proven that there is a harmony between open responses and drawings.

The students have many misconceptions related to the classification as well as the life cycle and the life forms of the butterfly (Table 6). According to the open responses about the caterpillar, most of the students stated correctly that caterpillar is an invertebrate animal (80%; n = 157). However, when their reasons for thinking in this way were examined,

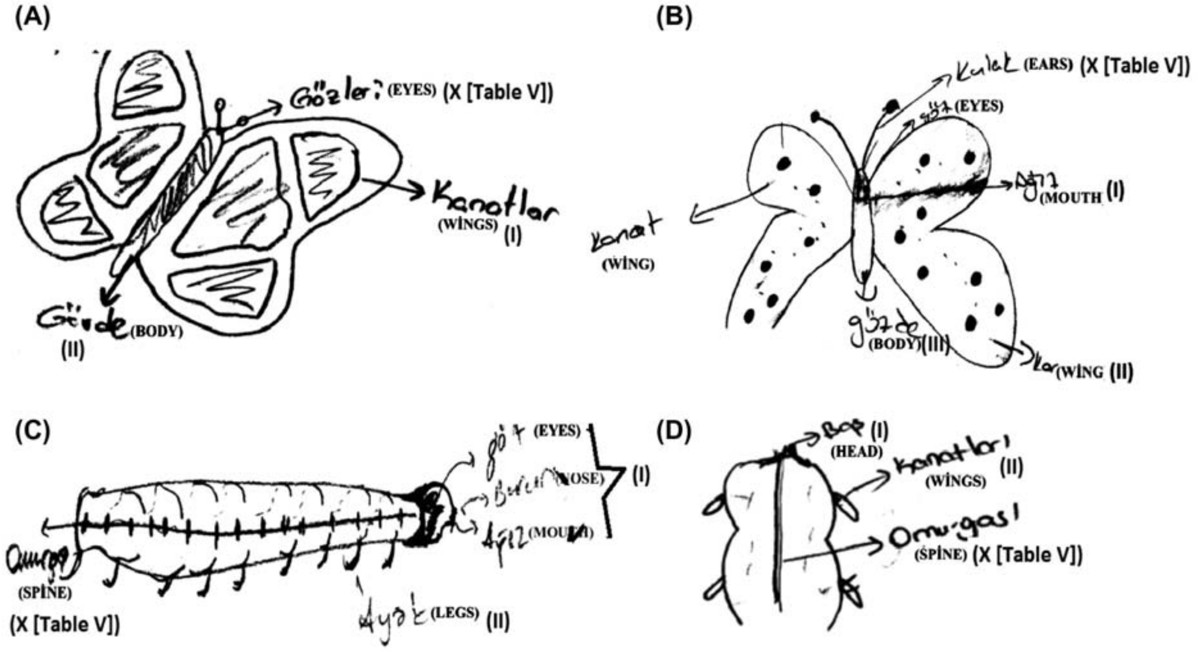
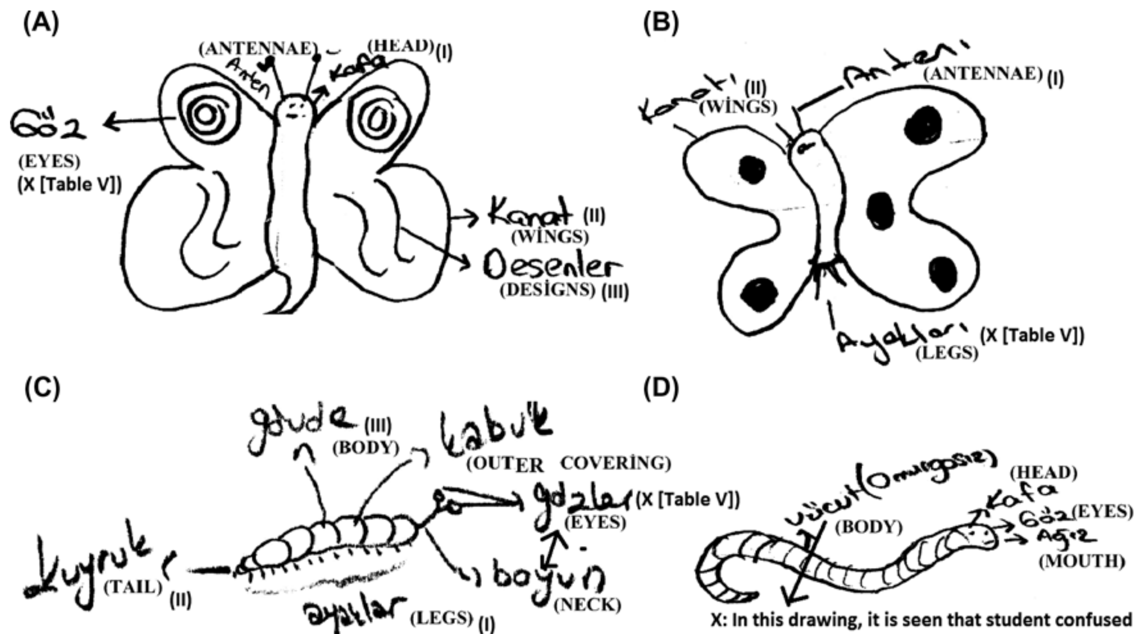


Figure 5. Four drawings with misconceptions (level 3).*
Note: *Although there were some properly drawn organs in the drawings (I–II–III) in this level, existence of clear misconceptions (X) were taken into consideration.



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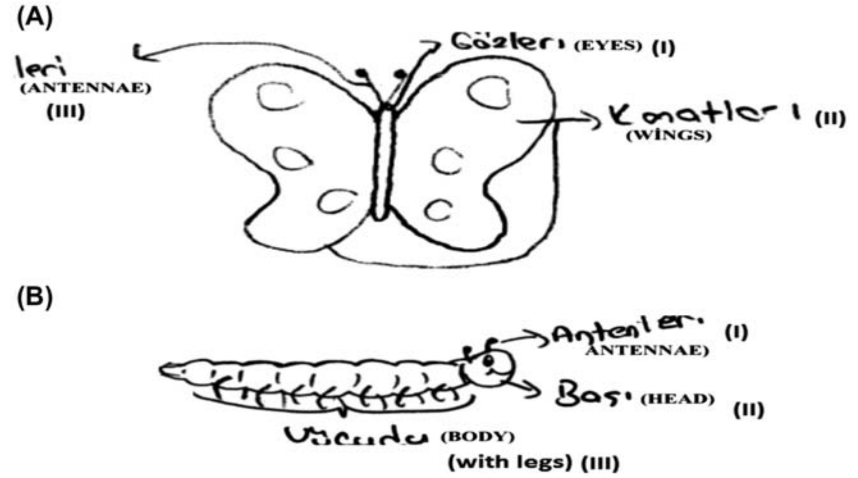

Figure 7. Two partial drawings (level 4).*
Note: *For a drawing to be categorised in this level, it had to be realistic, have three organs drawn properly and have no misconceptions.

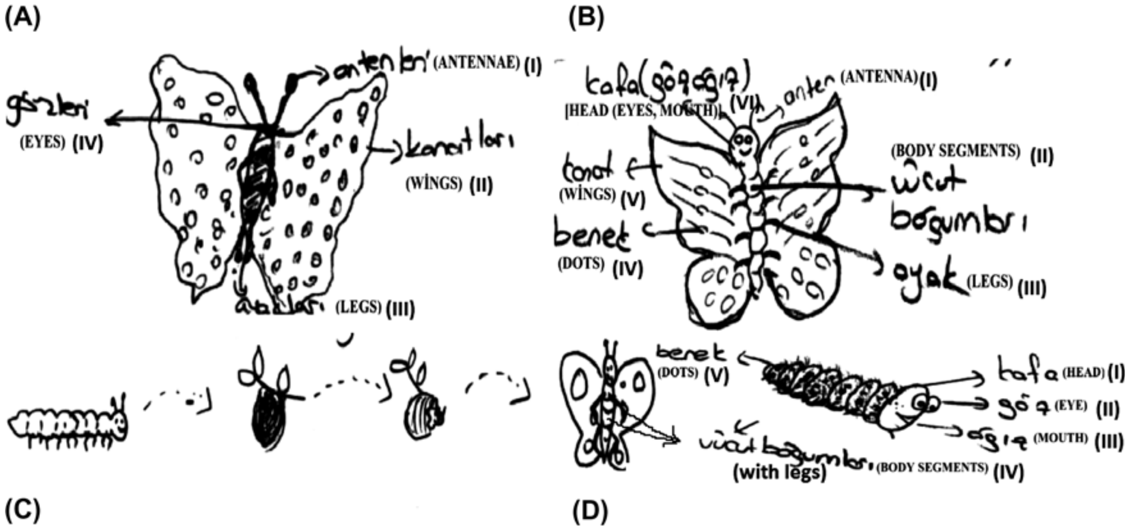

Figure 8. Four examples of comprehensive representation drawings (level 5).*
Note: *For a drawing to be categorised in this level, it had to be realistic, have four or more organs drawn properly and have no misconceptions.

some interesting misconceptions appeared: 'Since a caterpillar crawls to move, it is classified in invertebrates' (21%; $n = 40$); 'Since caterpillars have a very flexible and pliable body structure, they are classified in invertebrates' (32%; $n = 62$).

On the other hand, many students (51.03%; $n = 99$) who have stated correctly that a butterfly is an invertebrate animal asserted some logical inferences for this: 'Caterpillar turns into a butterfly. Because of the fact that caterpillar is an invertebrate, butterfly is also an invertebrate'; 'Since butterfly is an arthropod, it is an invertebrate'; or 'Since butterfly is an insect, it is an invertebrate'.

Discussion

The students readily wrote and drew their understandings related to the life cycle and life forms of a butterfly. When the percentage scores of the drawings' levels are taken into consideration (Figure 2), it should be seen that approximately half of the students have misconceptions concerning the external organs of a caterpillar or a butterfly. These results imply that high school students have several misconceptions as well as inadequate knowledge and experiences in terms of the life cycle and life forms of a butterfly. The fact that the majority of the participants live an urban area and, except for during the sixth grade, the process of metamorphosis is not mentioned in the Turkish biology curriculum from elementary grades to high school grades supports this implication. Tunnicliffe and Reiss (1999) have concluded that the core knowledge about animals is more influenced by informal information from home and direct observations. Additionally, they found that books, school, or mass media seemed to be relatively less-important sources of knowledge about animals for the children.

The findings presented in Tables 3 and 4 imply that students might not have enough opportunity for close observation of the butterfly because it flies. For this reason, a lower number of the students considered more particular organs (*ie* body segments, legs and hairy cuticle) of the butterfly when they were compared with drawings of the caterpillar. Therefore, these students could not consider the butterfly's morphological similarities with the caterpillar. These findings may be one reason why some students classified the caterpillar and butterfly as different species.

On the other hand, the findings about the students' responses to open questions indicated that many students also have a wide range of misconceptions, as seen in Table 6. Moreover, some of these misconceptions about the process of metamorphosis are fairly interesting: 'Butterfly is in the caterpillar. So, it impels and presses exoskeleton of the caterpillar and goes out'; 'Caterpillar is a baby and turns into butterfly when it grows up like the humans becoming adults'. This last misconception has reflected the students' anthropomorphic reasoning identified by Leach et al. (1992). They elicited anthropomorphic reasoning about insects which reflect the incorporation of human attributes (*eg* 'the caterpillar forms a cocoon because it needs a home'). The misconception seen in Figure 6B, 'The butterfly has got one pair of legs', could also be evaluated as a result of an anthropomorphic reasoning approach. Moreover, none of the students considered eggs as a phase of complete metamorphosis like the elementary graders sampled by the studies of Barrow (2002) and Shepardson (1996).

The results elicited from comparative findings between students' drawings and writings showed that there is a harmony between open responses and drawings. For example, from both of the responses (drawings [Figure 6D] and writings [Table 6(10)]), we deduced that students confused the caterpillars with earthworms. This faulty idea of the high school students was also elicited many elementary graders (Shepardson 1997). Leach et al. (1992) noted that upper elementary graders tended to classify organisms based upon structural features. Similarly, Chen and Ku (1998) found that children's animal classification was based mainly on their visual experiences. Students 'make analogies' (Prokop et al. 2009b) and frequently use typical invertebrate crawling to explain unfamiliar organisms like the caterpillar. So, drawing a caterpillar like an earthworm is a result of making analogies between them. On the other hand, although the students mostly and correctly classified the caterpillar and butterfly in invertebrates, many students thought that caterpillar and butterfly are different species (45%; n = 86). While some of these students did not state any reason, some of them

Table 3. Most frequent elements for caterpillar drawn by students

Grade		Elements							
		Segments	Head	Eyes	Mouth	Antennas	Tail	Legs	Hair
9	*N*	30	41	36	21	15	9	28	7
	%	37.03	50.61	44.44	25.92	18.51	11.11	34.57	8.64
10	*N*	34	45	30	19	21	5	20	14
	%	47.88	63.38	42.25	26.76	29.57	7.04	28.16	19.71
11	*N*	18	29	17	9	9	7	19	4
	%	42.85	69.04	40.47	21.42	21.43	16.66	45.23	9.52
Σ	*N*	82	115	83	49	45	21	67	25
	%	42.26	59.27	42.78	25.25	23.19	10.82	34.53	12.88

Table 4. Most frequent elements for butterfly drawn by students

Grade		Elements						
		Segments	Head	Eyes	Mouth	Antennas	Wings	Legs
9	*N*	4	31	22	4	60	80	9
	%	4.93	38.37	27.16	4.93	74.07	98.76	11.11
10	*N*	17	37	25	12	52	71	7
	%	23.94	52.11	35.21	16.90	73.24	100	9.85
11	*N*	5	18	9	4	34	42	7
	%	11.90	42.85	21.42	9.52	80.95	100	16.66
Σ	*N*	26	86	56	20	146	193	23
	%	13.40	44.33	28.86	10.31	75.25	99.48	11.85

(16.49%; n = 32) asserted that 'caterpillar is classified in reptile, whereas butterfly could fly' (5.15%; n = 10) or stated that 'caterpillar is an invertebrate, whereas butterfly is a vertebrate'. Various misconceptions were also elicited from the students who thought that caterpillar and butterfly are different species (Table 6). Some misconceptions related to students' core ideas about vertebrate and invertebrate concepts were also provided through the open responses: 'invertebrates must have very flexible and pliable body' or 'having wings and legs are peculiar to vertebrates'.

If all these misconceptions are considered, it was asserted that when students differentiate between vertebrate and invertebrate, they took the animals' external views, habitats, movement types and the functional similarities of their organs into consideration. Braund (1998) found that according to children, vertebrates typically have great and strong bodies with obvious heads and limbs while invertebrates are seen as shapeless, legless animals that crawl. A very strong idea held by the children at all ages is that any animal that coils or flexes cannot possess a backbone. The backbone was also regarded as a wide, straight structure by the children. In a recent

Table 5. Students' misconceptions obtained in the drawings

Misconceptions	9th grade		10th grade		11th grade		Σ	
	N	%	*N*	%	*N*	%	*N*	%
1. The eyes of a butterfly/caterpillar are at the top of the antennae (Figures 5A, 6C)	11	13.58	5	7	2	4.76	18	9.27
2. One pair of prolongation at the top of the head is ears of a butterfly (Figure 5B)	6	7.40	12	16.90	6	14.28	24	12.37
3. The butterfly has got one pair of legs (Figure 6B)	8	9.87	6	8.45	5	11.90	19	9.79
4. A butterfly or a caterpillar has a spine on its back (Figure 5C,D)	3	3.70	4	5.63	2	4.76	9	4.64
5. The eyes of a butterfly are on its wings (Figure 6A)	1	1.23	2	2.81	1	2.38	4	2.06

Table 6. Misconceptions elicited from the students' free-response writings

Misconceptions about classification of animals

1. A caterpillar is classified as a reptile, whereas a butterfly could fly.
2. A butterfly must have a skeleton consisting of bones or cartilage to be able to fly.
3. A caterpillar changes into a new species after the metamorphosis process.
4. A caterpillar is an invertebrate animal. However, when it changes into a butterfly, it becomes a vertebrate animal.
5. Because the spine limits the capability of locomotion, the caterpillar is an invertebrate animal.
6. Invertebrates must have a very flexible and pliable body.
7. Before the butterfly went out from its cocoon, its legs had been formed. An animal having legs is classified in vertebrates.
8. An animal having wings must classify in vertebrates.
9. As a caterpillar crawls to move, it is classified in invertebrates.
10. I found caterpillars when I was digging the ground with my friends.
11. As the caterpillar has a very flexible and pliable body structure, it is classified in invertebrates.

Misconceptions about the phenomenon of metamorphosis

1. A caterpillar undergoes a dramatic **mutation** and mutates a butterfly.
2. Transformation from caterpillar to butterfly is **evolution**.
3. Phenomenon of metamorphosis occurs as a result of **adaptation**.
4. Caterpillar is a baby and turns into a butterfly when it **grows up** like the humans becoming adults.
5. Butterfly is in the caterpillar. So, it impels and presses exoskeleton of a caterpillar and goes out.

study, Yen, Yao, and Mintzes (2007) determined that movement and viability are the most common attributes to define animals. They also stated that many students had difficulty in making the distinction between vertebrates and invertebrates; and students used external morphology, habitat, and type of movement to distinguish between common vertebrates and invertebrates like in the present study.

Conclusions and implications

In this study, analyses of the students' written responses and drawings show that they have many misconceptions about both the life cycle and the life forms of a butterfly. The similarities between the early school age children's misconceptions about metamorphosis sampled by previous studies and those of the students in puberty determined by the present study could be considered proof of the durability and universal character of misconceptions (Mintzes 2003).

To some extent, these misconceptions could be attributed to the results of the students' naïve experiences and insufficient interactions with these animals, and may also be attributed to a lack of time spent on the process of metamorphosis during formal instructional settings in elementary and secondary grades. The students who did not gain true scientific understanding used various conceptions such as evolution, mutation or adaptation to define metamorphosis. This result supports the view that non-scientific understanding in any topic also causes faulty understanding and interpretation of various other topics (see Yen, Yao, and Mintzes 2007). Another important result of the study is that students' basic understanding about biological conceptions and natural phenomena is influenced more by informal experiences. For this reason, curriculum developers must sufficiently place the process of metamorphosis in the instructional programmes of elementary and secondary grades. When this result is also evaluated with regard to instructional practice, it is suggested that teachers struggle to develop meaningful learning environments. Students should be involved in a variety of hands-on activities exploring the life cycle and life forms of animals (insects and amphibians). In these activities, it is essential that students go outside and explore the area to observe various types of insects. Students could also bring some insects into the laboratory for closer observation. Moreover, teachers should encourage and guide students to make collections of insects or to establish a living environment for them in the laboratory. Providing students with opportunities to investigate and observe insects in their habitats or laboratories enhances their limited and naive ideas about structural or functional attributes of the insects. In this way, the level of making analogies to unfamiliar animals which was determined as a problem in this study could also be lessened.

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