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Investigation of Anthropomorphic Discourses in Biology Textbooks

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Abstract

Although anthropomorphic language is known to be widely used in popular science textbooks and in classroom settings by both teachers and students to describe scientific concepts, little is known about how often and for which biology concepts it is used in high school biology textbooks. Since the issue of using anthropomorphic discourses in the language of science is controversial, it is important to analyze such discourses in biology textbooks. This study aimed to analyse the anthropomorphic discourses used in high school biology textbooks. In this study, anthropomorphic discourses used in high school biology textbooks were examined using the document analysis method. The process of analyzing sentences containing anthropomorphism was carried out in five stages: the naming stage; the elimination and separation stage; the compilation and category development stage; the validity and reliability stage; and the stage of digitizing the qualitative data. It was determined that a total of 1074 anthropomorphic discourses were used in relation to 177 biological concepts in the 4 biology textbooks examined. The anthropomorphic discourses in the books were classified into 19 categories. The findings showed that anthropomorphic discourses are used very frequently in high school biology textbooks and most of them are embedded in the language and consist of stereotyped terms and idioms.

Keywords: Anthropomorphic Discourses, Biology, Textbooks

INTRODUCTION

The word "metaphor", which comes from the Greek metaphora, is formed by the combination of the words meta: beyond and phrein: to convey, and it means "to transfer from one place to another". According to the cognitive linguistic approach, metaphor is not only the quality of words but also of concepts. The function of metaphor is to reason and to provide a better understanding of certain concepts. Therefore, metaphor is common both in everyday language and in thought and action (Lakoff & Johnson, 1980).

A special type of metaphor approach in teaching is anthropomorphism. This term derives from the Greek terms "anthropos" meaning "human" and "morphos" meaning "shape". Anthropomorphism is the attribution of human physical and mental characteristics to non-human entities, such as objects, animals or machines (Barnhart, 2000, p. 39). Anthropomorphism refers to a discourse that allows an understanding of something in terms of the properties of something else. According to Lakoff and Johnson (1980), such a metaphor allows us to make sense of phenomena in the world with terms that we can understand on the basis of our own motivations, goals, actions and characteristics. Anthropomorphism attributes both physical and mental human characteristics, such as emotion, motivation and reasoning to other living beings and inanimate objects (Kallery & Psillos, 2004). For example: "Butterflies love flower nectar". Some researchers argue that the emphasis on anthropomorphism stems from a human-centred perspective (Shepardson, 2005).

The use of anthropomorphic discourses in science teaching has been a controversial issue in the literature. Some researchers think that encouraging the use of anthropomorphic ideas is problematic because continued use can lead to misconceptions (Tamir & Zohar, 1991) and, in some cases, to emotional problems (Kallery & Psillos, 2004). Anthropomorphisms, when properly constructed, can be considered as a part of a teachers' effective pedagogical content descriptions (Treagust & Harrison, 2000). However, a possible failure of anthropomorphism to meet the implied meanings may constitute an obstacle to learning (Taber & Watts, 1996). As Taber (1995) states, if a person who uses a metaphor does not know the nature of the metaphor or is not aware of the metaphor, the metaphor may lead that person to false thoughts that s/he is not aware of. There are also some reports of students' anthropomorphic misconceptions. For example, the pattern of thinking

"Adaptations take place in line with the needs of organisms" is a misconception about evolution (Tshuma & Sanders, 2015). Therein lies the idea that non-human organisms have a human-like reasoning and the ability to make a prediction aimed at avoiding possible negative future consequences. This leads to the idea that adaptation is voluntary rather than for real scientific reasons. Such cognitive interpretations may also be problematic, as they are associated with systemic misunderstandings that cover wide areas (Betz et al., 2019). Correcting misinterpretations is an important aspect of addressing misunderstandings about science and is critical in developing students' science literacy (Taber, 2008). Some studies, however, indicate the definite existence of relationships between such fictional forms of thinking and biological misconceptions, including teleological thinking (Kampourakis, 2014; Nehm & Ridgway, 2011), essentialist thinking (Shtulman & Schulz, 2008), and anthropic thinking (Byrne, Grace & Hanley, 2009; Coley & Tanner, 2012; Moore et al., 2002; Shtulman, 2006).

Despite the potential dangers mentioned above, there is substantial evidence that the use of anthropomorphism in science is a common practice at all levels of education. For example, it is seen that teachers in primary education use anthropomorphic discourses towards target objects, especially in the fields of both physics and biology. However, it is suggested that such discourses should be used carefully (Kallery & Psillos, 2004). Because if there is a lack of knowledge about the concept of biology targeted by anthropomorphic discourse, this may lead to illogical and unrelated personification. As a result, wrong inferences can be produced by students. Thus, anthropomorphism can be valuable for explaining scientific concepts, provided it is carefully arranged to avoid potential dangers and disadvantages (Duit, 1991; Kallery & Psillos, 2004). Treagust and Harrison (2000) argue that anthropomorphism can be used as a valuable pedagogical tool that provides familiar explanations for students. Utilizing anthropomorphisms in lessons can help "humanize" the science curriculum and make science more accessible to children by increasing their empathy with scientific subjects (Zohar & Ginossar, 1998). Indeed, the use of anthropomorphic ideas can encourage learning. Moreover, anthropomorphisms are an integral part of human life and it does not seem possible to avoid them completely (Kattmann, 2008; Zohar & Ginossar, 1998). According to Kattmann (2008), we cannot learn at all without

anthropomorphic concepts. Anthropomorphic thinking and speech is an inevitable part of human understanding of nature and can support learning under certain conditions. That is why anthropomorphisms should be used rather than excluded. In addition, teachers may deliberately use teleological and anthropomorphic metaphors to increase motivation and reduce complexity and the number of technical terms (Treagust & Harrison, 2000). However, this is considered legitimate if teachers and students are aware of the rules implied in scientific norms (Lemke, 1990, p. 134; Taber & Watts, 1996).

Tamir and Zohar (1991) examined the extent to which high school and university students were able to distinguish between factual and anthropomorphic expression. Interviewing 28 high school students, the researchers asked, "Do you think plants or animals really want or strive for something?" They found that while 30% of the students believed that this was the case in plants, 62% believed that this was true only for animals. Only a quarter of the students made a clear distinction between anthropomorphic and factual statements.

Zohar and Ginossar (1998) wrote a reminder article on removing the taboo on teleology and anthropomorphism in biology teaching. According to the researchers, children encounter unlimited teleological and anthropomorphic formulations in popular science books and movies. There is no consensus on the universal rejection of teleological explanations and formulations by educators and biologists. It does not matter whether high school students accept them for anthropomorphic or teleological reasoning. Using a textbook that contains teleological or anthropomorphic formulations does not imply that biology students will use such formulations more often in the future. Students' thoughts on their own learning processes confirm that anthropomorphic formulations improve their understanding and empathy. The data show that most students do not see anything wrong with the inclusion of anthropomorphic formulations in science textbooks and that anthropomorphic and teleological language in biology textbooks improves their understanding of the subject.

Kallery and Psillos (2004) stated that there is considerable evidence that the use of anthropomorphism and animism in science teaching is a common practice at all levels of education, but not much is known about teachers' views on whether anthropomorphic and animistic

discourses should be used in science. Researchers investigated teachers' opinions on this topic. The results of the study showed that the use of animism and anthropomorphism by preschool teachers can cause cognitive and emotional problems, especially in young children. The results also revealed that despite their reservations, teachers had to use animism and anthropomorphism both consciously and unconsciously due to the weak content and pedagogical content knowledge in science education.

According to a longitudinal study by Hellden (2005) on biology students aged nine to fifteen, anthropomorphic reasoning plays an important role in conceptual development and the fact that students resort to anthropomorphic ideas does not prevent learning.

Barman, Stein, McNair and Barman (2006) stated that elementary school students attributed anthropomorphic characteristics to plants such as breathing, drinking and eating to explain the needs of plants. When students interpret an organism's properties and functions from their own experience, they often attribute human traits or anthropomorphic explanations to organisms. For example, students often believe that plants need to eat, breathe and drink water in a similar way to humans. Therefore, they fall into a contradiction when they hear that plants make their own food. Here, the teacher's role is critical in helping students go beyond their current understanding. The teacher should help students understand that plants differ from humans in form and function.

Byrne, Grace and Hanley (2009) investigated the anthropomorphic and anthropocentric ideas that 414 students aged 7, 11 and 14 had about microorganisms, and whether these ideas influenced their understanding. Anthropomorphic ideas about microorganisms were evident in the responses from all age groups. Anthropomorphic ideas seemed to help children explain their understanding of some aspects of microorganisms. However, the imbalance in the children's anthropocentric views on microorganisms seemed to prevent them from thinking about other aspects of microorganisms. For example, students overlooked the importance of the role of microorganisms in biotechnological applications or in the decomposition and cycling of substance. According to the results of the study, focusing on the dangers that microorganisms are thought to pose to human health creates a hostile view towards microorganisms, which may hinder learning in the future.

According to Tshuma and Sanders (2015), textbooks are widely used by students and teachers and serve as a vital

educational tool for them, especially in times of curriculum change. In this process, biology textbooks are considered to be correct in terms of scientific content. In South Africa, these researchers examined whether life sciences textbooks have a potential impact on misconceptions about evolution by natural selection. In the study, non-scientific statements about evolution were found in all six books prepared for grades 10 to 12. Some of these statements pointed to obvious misunderstandings and some of them implicit misunderstandings. Examples of these are ideas such as the evolution of organisms in line with needs and the survival of the fittest. These are unscientific ideas rather than simple mistakes. In addition, these expressions describe extensive language-related problems. Because they are often not noticed and secretly undermine the learning of correct scientific ideas about evolution. The "evolution on demand" framework seems to be influenced by anthropomorphic and teleological thinking.

Effective teaching in biology classrooms depends on the communication strategies used by textbook writers and teachers. A biology lesson, by its nature, includes abstract concepts at microscopic and sub-microscopic level. In a situation where the students lack sufficient terminology, it is a particularly important problem as to how to make them grasp a new and abstract concept. In such cases, it becomes difficult to establish the common bonds necessary for communication among individuals, communication weakens and a mental confusion begins. In order not to fall into such a confusion, the writer or teacher, who is the source of communication, often resorts to metaphoric or figurative language. The use of figurative language may further increase in teaching practices of complex biological phenomena. Although it is known that anthropomorphic language is widely used to describe scientific concepts, both in popular science textbooks and in classroom settings by teachers and students, little is known about how often and for which biology concepts it is used in high school biology textbooks. Since the issue of using anthropomorphic discourses in the language of science is controversial, such discourses should be analysed in biology textbooks.

Constructivist epistemology argues that it is important to reveal what students already know and understand about scientific concepts, because prior knowledge influences subsequent learning. If good learning outcomes are aimed, previous ideas should not be ignored, because these ideas can form

the basis of conceptual restructuring so that meaningful learning can take place. From this point of view, anthropomorphic explanations in biology textbooks affect students' conceptual framework and effective learning. Therefore, it is necessary to analyse and filter the anthropomorphic explanations in the textbooks.

In this study, the use of anthropomorphic language, which is a controversial subject in science teaching and learning, in biology textbooks was examined. It was revealed how the biological expressions in the books are presented to the reader in this way. We believe that an idea can be developed on this subject by examining the biology textbooks.

The main purpose of this study is to analyse the anthropomorphic discourses used in high school biology textbooks.

METHOD

In this qualitative study, document analysis was carried out. The document analysis method is defined as the collection, review, examination and analysis of documents as the primary data source in study data (O'Leary, 2004). Document analysis includes the analysis of written materials containing information about the case or cases that are to be investigated (Yıldırım & Şimşek, 2016, p. 189). Biology textbooks were used as data source in this study.

A gradual process was followed in the content analysis of the documents: (1) Selecting a sample from the data subject to analysis: The biology textbooks planned to be analyzed in the study have a wide variety of examples for many grade levels. In this case, it is very difficult to analyze the document data as a whole. Therefore, a sample was selected from this data set. In the sample selection, it was decided to include common biology textbooks taught in high schools in Turkey. The textbooks were prepared as a continuation of each other, based on the high school curriculum. These books were distributed free of charge to all students by the government. (2) Developing categories: In this study, anthropomorphic discourses in biology textbooks were identified through directed content analysis. Categories were created from the identified anthropomorphic discourses. This stage was explained in detail in the data analysis section. (3) Determining the unit of analysis: Depending on the purpose of this study, the unit of analysis was chosen as the sentence. (4) Digitization: The data obtained from the analysis of biology textbooks were digitized and presented.

Examined Biology Textbooks

In the 2022-2023 academic years, four biology textbooks were published for high school students by the Turkish Ministry of National Education. Therefore, in this study, four biology textbooks for 9th, 10th, 11th and 12th grades prepared in line with the biology curriculum were analysed. These textbooks were used in high schools all over Turkey with the approval of the Ministry of National Education. No comparison was made between the books examined in this study because the subjects in these books were progressing as a continuation of each other.

Book A: Kabaoğlu, B., Aktaş, E., Demiray, F., Bozbey, F., Baştan, M., & Yılmaz Kaçar, M. (2018). Fen lisesi biyoloji 9 ders kitabı [High School Biology Textbook, Grade 9]. Milli Eğitim Bakanlığı.

Book B: Aktaş, E. & Demiray, F. (2018). Fen lisesi biyoloji 10 ders kitabı [High School Biology Textbook, Grade 10]. Milli Eğitim Bakanlığı.

Book C: Demirbilek, E., Kolotoğlu, S., & Akan, Ş. (2018). Fen Lisesi Biyoloji 11 Ders Kitabı. [High School Biology Textbook, Grade 11]. Milli Eğitim Bakanlığı.

Book D: Şahintürk, A. P., Oğuzman, H., Çakır, M. N., Vurdem, N., & Uzandaç, Z. (2018). Fen Lisesi Biyoloji 12 Ders Kitabı [High School Biology Textbook, Grade 12]. Milli Eğitim Bakanlığı.

The chapter titles of the books are as follows:

Book A: Biology as Life Science, Cell, Living World.

Book B: Cell Divisions and Reproduction, Basic Principles of Heredity, Ecosystem Ecology and Current Environmental Issues.

Book C: Human Physiology, Community and Population Ecology.

Book D: From Gene to Protein, Energy Conversions in Living Things, Plant Biology, Living Things and Environment.

Data Analysis

No a priori codes were created for analysis, so coding proceeded from the perspective of grounded theory (Glaser & Strauss, 1967). Grounded theory is a qualitative methodology based on inductive logic. Each book was carefully read in its entirety by all three researchers, paying attention to both text and visuals. Researchers independently took notes on the anthropomorphic discourses they encountered in the books. A total of 1218 sentences initially assumed to contain anthropomorphism were identified in the four biology textbooks examined. However, only 1074 sentences were evaluated in this study because they actually contained anthropomorphism. The remaining 144

sentences were excluded from the scope of the study. The reasons for why 144 sentences were excluded from the scope of the study are given in detail in "Stage 2" below. The process of analysing and interpreting sentences containing anthropomorphism was carried out in the following stages: (1) naming stage; (2) elimination and separation stage; (3) compilation and category development stage; (4) validity and reliability stage; (5) the stage of transferring the data to the SPSS package program for digitization of qualitative data.

Stage 1: Naming Stage

At this stage, a temporary list of sentences containing anthropomorphism was made in each of the four textbooks. In this process, the books were read once again, and each sentence supposed to contain anthropomorphism was underlined and coded. For example, in the sentence "If all the genes of the baby are normal and if all the genes fulfil their functions, the baby will be born healthy (Book B, p. 149)", "fulfilling a function" was marked as an anthropomorphic discourse. These sentences were transferred to a Microsoft Word file on the computer and then printed out for analysis independently from other texts in the book. It was checked whether certain anthropomorphism was clearly expressed in each sentence, and those that were not obvious were marked with coloured pencils to be eliminated later.

Stage 2: Elimination and Separation Stage

At this stage, each anthropomorphic discourse was analysed in terms of its common features with other anthropomorphic discourses by using "content analysis" techniques (Saban, Koçbeker, & Saban, 2006; Yıldırım & Şimşek, 2016). In this process, the anthropomorphic discourse in each sentence was analysed in terms of (1) the human quality it represents and (2) the biological concept it is associated with. In such a sentence, both the anthropomorphic discourse and the biological concept associated with this discourse were determined. For example, in a sentence such as "All four haploid cells formed by meiosis in males differentiate and gain the ability of fertilizing and turn into sperm (Book B, p. 41)", "having the ability" was marked as an anthropomorphic discourse and "cell" was marked as a biological concept associated with this discourse. It should be noted here that not all sentences supposed to contain anthropomorphic discourse represented a valid anthropomorphism. For this reason, only actions requiring high-level human emotion, thought or behavioural skills were evaluated. For example: "to fulfil a function", "to control", "to use", "to need". At this stage, the extraction

process of a total of 144 sentences, since they do not contain any real anthropomorphism, was carried out based on the following four criteria.

a. Sentences in which the anthropomorphic verb is passive. In such a sentence, it is not known who performed the anthropomorphic action. For example, since it is not known by whom the tRNAs are used in the statement "tRNAs can be used repeatedly during protein synthesis (Book D, p. 24)", such sentences in passive structure were not evaluated.

b. Discourses that are understood to have qualities other than human qualities when the Turkish dictionary is examined. For example, although the word "rich" has a human nature, it also corresponds to the meanings of adjectives "efficient", "showy", "abundant" in the Turkish dictionary. In this case, the expression "Blood rich in carbon dioxide (CO2) released by cellular respiration in the tissues is pumped from the right ventricle to the pulmonary artery (Book C, p. 137)" does not have a figurative meaning according to the Turkish dictionary. Similarly, the word "to suck" is included in the Turkish dictionary as an action (absorb) specific to both human and non-human beings. According to the dictionary, the absorption of water by the soil, the absorption of nutrients by the small intestine, the sucking/absorption of light by plants do not have a figurative meaning. Therefore, sentences such as "Different pigments suck/absorb light of different wavelengths… (Book D, p. 71)" were not evaluated.

c. Abbreviations on the images. While the discourses such as "Messaging Ribonucleic Acid" in the text were taken into consideration, their mRNA abbreviations on the images were extracted because the anthropomorphism was not obvious in such symbols.

d. Anthropomorphic discourses used for technical concepts and not directly related to biology. These statements were eliminated because they were not directly related to biology. One of these sentences was about the learning of the machine and the other was about the learning of the robot. For example: "These robots are machines that work like another neural network process where layered and complex code is written to 'learn' its environment" (Book C, p. 19).

e. Anthropomorphic discourses whose frequency is 1. The anthropomorphic discourses that were encountered once and not encountered again in the books were eliminated. These sentences were about a stressed plant, an insidious virus, and a zygote on a journey. Examples: "Viruses that cause hepatitis B and C are

insidious" (Book A, p. 149), "….zygote undergoes embryonic developmental stages called morula, blastula and gastrula through a series of mitotic divisions in its journey" (Book C, p. 21).

Stage 3: Compilation and Category Development Stage

After extracting 144 sentences, a total of 1074 sentences containing valid anthropomorphism were obtained. At this stage, the anthropomorphic discourses in these sentences were arranged again in alphabetical order together with the biological concepts they were related to, and the sentences were revised for the third time. A sample sentence was chosen for each anthropomorphic discourse. Thus, a list of anthropomorphic discourses was created by compiling 1074 biological concepts and examples that were assumed to best represent the anthropomorphism with which they were related. This list was compiled for two main purposes: (1) to use it as a reference for collecting 1074 biological concepts under a certain category of anthropomorphic discourse; and (2) to validate the data analysis process and interpretations of this study.

Finally, 19 conceptual categories were developed, taking into account the common features of anthropomorphic discourses. In this process, first of all, each anthropomorphic discourse was examined in terms of its human qualities based on a pre-created list of anthropomorphic discourses and coded with a certain code (for example, to fulfil a function, to control, to use, to need). These codes were later classified as anthropomorphic discourse in terms of human properties attributed to non-human beings and transformed into conceptual categories. For example, all anthropomorphic discourses under the category of "fulfilling a function" basically assume that a biological object works to fulfil a certain function, serving a certain purpose. An example is, "Endosperm serves the function of providing the nutrients needed by the embryo during seed germination" (Book A, p. 131). Actions such as serving a function, undertaking a task, performing a function, fulfilling a duty, being in charge of and being responsible for were classified under this category. The classification process in the category development process continued until all three researchers reached a consensus. It should be noted here that some biological concepts related to anthropomorphic discourse were also combined. For example, all samples such as mast cell, muscle cell, liver cell, plant cell, fibroblast and white blood cell were combined under the name of "cell". The information on which book and page an anthropomorphic discourse takes place is given in code in

parentheses at the end of the sentence in question. In this context, the abbreviation "A/B/C/D" in parentheses symbolized the book type and "p" symbolized the page number.

Stage 4: Validity and Reliability Stage

Validity and reliability are the two most important criteria used to ensure or increase the reliability of study results. In this context, "Reporting the collected data in detail and explaining how the researcher reached the results are among the important criteria of validity in a qualitative study (Yıldırım & Şimşek, 2016, p. 270). Specific to this study, two important processes were carried out to ensure the validity of the study results: (1) the data analysis process, especially how the 19 anthropomorphic discourse categories were reached, was explained in detail; (2) in the study, the examples that are assumed to best represent the 19 categories formed from 1074 anthropomorphic discourses were compiled and all of these examples were included in the findings section. In other words, in the processing and interpretation of the findings, the sentences containing anthropomorphic discourse in the textbooks were used as the main data source, and each of the sub-features constituting each conceptual category was supported with at least one example (with direct quotations).

Three important strategies were followed to ensure the reliability of the study. First, the three researchers, who are the writers of this article, worked together in harmony at every stage of the study (for example, creating the research design, writing the research questions, collecting the data, analysing the data, developing the categories, and interpreting the results) from the beginning to the end of the study, and tried to achieve consensus to decide in any case of conflict. In order to confirm whether the anthropomorphic discourses given under the 19 conceptual categories developed in the study represent these categories, the opinions of two different experts were consulted. Two lists were given to both faculty members who are experts in biology teaching: (1) a list of 1074 anthropomorphic discourses in alphabetical order; and (2) a list of 19 conceptual categories (with short explanations) in random order. Using both lists, the experts were asked to match the anthropomorphic discourses in the first list with 19 conceptual categories in the second list, so that none of them were left out. Next, these matchings were compared to the researchers' own categories. The numbers of consensus and disagreement were determined in all comparisons, and the reliability of the study was calculated using Miles and Huberman's (2016)

formula (i.e. Reliability = Consensus / Consensus + Disagreement). In the reliability study conducted specifically for this study, a consensus (reliability) of 94% and 91% was achieved, respectively. The first expert expressed disagreement about 64 anthropomorphic discourses. In this case, reliability = 1010 / 1010 + 64 = 0.94. The second expert expressed disagreement about 89 anthropomorphic discourses. In this case, reliability = 985 / 985 + 89 = 0.91. These calculations showed that the desired level of reliability was achieved in the study.

Stage 5: Transferring Data to SPSS Package Program for Digitization of Qualitative Data

After a total of 1074 anthropomorphic discourses were defined and 19 conceptual categories formed by anthropomorphic discourses were developed, all data were transferred to the SPSS statistical program, and their frequencies (f) and percentages (%) were calculated.

RESULTS AND DISCUSSION

According to the general findings obtained from this study, 177 biological concepts that were anthropomorphized in high school biology textbooks were identified (Table 1). The first ten of these concepts were as follows: cell (12.76%); living being (7.17%); enzyme (4%); deoxyribonucleic acid (3.91%); plant (3.82%); gene (2.89%); hormone (2.89%); bacteria (2.7%); chromatid (2.33%); and tissue (2.14%).

Table 1. Biological Concepts Exposed to Anthropomorphism (n=177)

No.	Biological concept	f	%*	No	Biological concept	f	%*	No	Biological concept	f	%*
1	Cell	137	12.76	61	Cerebellum	4	0.37	121	Electron	1	0.09
2	Living being	77	7.17	62	Lung	3	0.28	122	Endocrine system	1	0.09
3	Enzyme	43	4.0	63	Plant root	3	0.28	123	Carnivorous	1	0.09
4	Deoxyribonucleic acid	42	3.91	64	Endoplasmic reticulum	3	0.28	124	Mouse	1	0.09
5	Plant	41	3.82	65	Fibrinogen	3	0.28	125	Physical digestion	1	0.09
6	Gene	31	2.89	66	Genetic variation	3	0.28	126	Phosphate bond	1	0.09
7	Hormone	31	2.89	67	Liver	3	0.28	127	Omnivorous	1	0.09
8	Bacterium	29	2.7	68	Chromosome	3	0.28	128	Hydrogen ion	1	0.09
9	Chromatid	25	2.33	69	Herbivorous	3	0.28	129	Pituitary	1	0.09
10	Tissue	23	2.14	70	Autotroph	3	0.28	130	Cell wall	1	0.09
11	Allele	19	1.77	71	Parasite	3	0.28	131	Light dependent reaction	1	0.09
12	Archaea	19	1.77	72	Ribosome	3	0.28	132	Interferon	1	0.09
13	Inorganic molecule	19	1.77	73	Gland	3	0.28	133	Skeletal system	1	0.09
14	Brain	18	1.68	74	Producer	3	0.28	134	Skeleton	1	0.09
15	Nucleus	17	1.58	75	Axolotl	2	0.19	135	Cardiac valve	1	0.09
16	Ribonucleic acid	17	1.58	76	Brain lobe	2	0.19	136	Capsaicin	1	0.09
17	Nervous system	16	1.49	77	Plant stem	2	0.19	137	Carbonic acid	1	0.09
18	Animal	16	1.49	78	Plant hair	2	0.19	138	Carbon monoxide	1	0.09
19	Species	16	1.49	79	Bug	2	0.19	139	Butterfly	1	0.09
20	Virus	15	1.4	80	Diaphragm	2	0.19	140	Bone marrow	1	0.09
21	Cell membrane	14	1.3	81	The circulatory system	2	0.19	141	Bone	1	0.09

No.	Biological concept	f	%*	No	Biological concept	f	%*	No	Biological concept	f	%*
22	Organic molecule	14	1.3	82	Ecosystem	2	0.19	142	Chemoautotroph	1	0.09
23	Organ	13	1.21	83	Phloem	2	0.19	143	Keratine	1	0.09
24	Food	9	0.84	84	Fungus	2	0.19	144	Lizzard	1	0.09
25	Light	9	0.84	85	Golgi apparatus	2	0.19	145	Chromatin	1	0.09
26	Body	8	0.74	86	Heterotroph	2	0.19	146	Bird wing	1	0.09
27	Kidney	8	0.74	87	Hypothalamus	2	0.19	147	Tail fin	1	0.09
28	Receptor	8	0.74	88	Rib	2	0.19	148	Limbic system	1	0.09
29	Cytoskeleton	7	0.65	89	Carbohydrate	2	0.19	149	Lipid	1	0.09
30	Ear	7	0.65	90	Chloroplast	2	0.19	150	Fungal spore	1	0.09
31	Protein	7	0.65	91	Vacuole	2	0.19	151	Melanin pigment	1	0.09
32	Vein	7	0.65	92	Sense of smell	2	0.19	152	Fruit	1	0.09
33	Muscle	7	0.65	93	Xylem	2	0.19	153	Stomach	1	0.09
34	Electron Transport Chain	6	0.56	94	Lymph	2	0.19	154	Mitochondria	1	0.09
35	Embryo	6	0.56	95	Lysosome	2	0.19	155	Neurotransmitter	1	0.09
36	Haemoglobin	6	0.56	96	Nucleotide	2	0.19	156	Oxygen	1	0.09
37	Skin	6	0.56	97	Pathogen	2	0.19	157	Spine	1	0.09
38	Nucleic acid	6	0.56	98	Pollen	2	0.19	158	Autophagy	1	0.09
39	Population	6	0.56	99	Bile	2	0.19	159	Autonomic nerve	1	0.09
40	Antibody	6	0.56	100	Centrosome	2	0.19	160	Ovary	1	0.09
41	Decomposer	5	0.47	101	Stoma	2	0.19	161	Pancreas	1	0.09
42	Immune system	5	0.47	102	Bud	2	0.19	162	Pericardial fluid	1	0.09
43	Photoautotroph	5	0.47	103	Alga	2	0.19	163	Placenta	1	0.09
44	Heart	5	0.47	104	Mouth	1	0.09	164	Plastid	1	0.09
45	Organ system	5	0.47	105	Actin-myosin	1	0.09	165	Plasmodium	1	0.09
46	Organelle	5	0.47	106	Algae	1	0.09	166	Protozoa	1	0.09
47	Seed	5	0.47	107	Antibiotic	1	0.09	167	Pseudopod	1	0.09
48	Energy	5	0.47	108	Antigen	1	0.09	168	Rhodopsin	1	0.09
49	Phospholipid	4	0.37	109	Whale	1	0.09	169	Sinoatrial node	1	0.09
50	Chlorophyll	4	0.37	110	Plant shoot	1	0.09	170	Onion	1	0.09
51	Coleoptile	4	0.37	111	Excretory system	1	0.09	171	Respiratory system	1	0.09
52	Community	4	0.37	112	Adrenal gland	1	0.09	172	Spirulina	1	0.09
53	Substance	4	0.37	113	Corpus callosum	1	0.09	173	Surfactant	1	0.09
54	Mitosis	4	0.37	114	Flower	1	0.09	174	Trachea	1	0.09
55	Spinal bulb	4	0.37	115	Spleen	1	0.09	175	Salt	1	0.09
56	Spinal cord	4	0.37	116	Starfish	1	0.09	176	Salivation	1	0.09
57	Euglena	4	0.37	117	Tongue	1	0.09	177	Reproductive system	1	0.09
58	Consumer	4	0.37	118	Ectoderm	1	0.09				
59	Vitamin	4	0.37	119	Endoderm	1	0.09		Total	1074	100
60	Leaf	4	0.37	120	Endodermis	1	0.09				

* Numbers in the table may not add up to the total due to rounding.

A total of 1074 anthropomorphic discourses related to 177 biological concepts were classified into 19 categories (Table 2): (1) to fulfil a function; (2) to control; (3) to use; (4) to need; (5) to help; (6) to have the ability; (7) to communicate; (8) to fight; (9) to know; (10) to repair; (11) to be a sister; (12) to love; (13) to cooperate; (14) to be a killer; (15) to have a tendency; (16), to be a companion; (17) to decide; (18) to allow; (19) to sleep.

Table 2. Categories of Anthropomorphic Discourses in Textbooks

Anthropomorphic discourse	Biological Concept	f	%*
1.“to fulfil a function”	“cell”(21), “enzyme”(18), “tissue”(16), “inorganic molecule”(15), “hormone”(14), “gene”(10), “living being”(9) , “organ”(9), “allele”(8), “organic molecule”(8), “bacteria”(7), “nutrient”(7), “Electron Transport Chain”(6), “Ribonucleic acid”(6) , “Deoxyribonucleic acid”(5), “ear”(5), “vessel”(5), “decomposer”(4), “kidney”(4), “cytoskeleton”(4), “nucleic acid”(4), “organelle”(4), “heart”(3), “protein”(3), “endoplasmic reticulum”(3), “community”(3), “genetic variation”(3), “fibrinogen”(3), “receptor”(2), “brain”(2), “plant stem”(2), “plant root”(2), “plant hair”(2), “insect”(2), “nucleus”(2), “circulatory system”(2), “cell membrane”(2), “light”(2), “liver”(2), “carbohydrate”(2), “muscle”(2), “chlorophyll”(2), “vacuole”(2), “sense of smell”(2), “lymph”(2), “lysosome”(2), “bile”(2), “centrosome”(2), “ vitamin”(2), “ribosome”(2), “seed”(2), “mouth”(1), “lung”(1), “actin-myosin thread”(1), “antibody”(1) , “immune system”(1), “cerebellum”(1), “excretory system”(1), “adrenal gland”(1), “flower”(1), “spleen”(1), “skin”(1), “tongue”(1), “diaphragm”(1), “ecosystem”(1), “ectoderm”(1), “endoderm”(1), “Golgi apparatus”(1), “haemoglobin”(1), “skeletal system”(1), “rib”(1), “bone marrow”(1) , “keratin”(1), “coleoptile”(1), “chromatin”(1), “chromosome”(1), “tail fin”(1), “melanin pigment”(1), “stomach”(1), “neurotransmitter”(1), “spine”(1), “spinal bulb”(1), “ovary”(1), “pancreas”(1), “placenta”(1), “plastid”(1), “onion”(1), “respiratory system”(1), “stoma”(1), “consumer”(1), “reproductive system”(1), “producer”(1), “virus”(1), “leaf”(1).	296	27.56
2.“to control”	“nucleus”(15), “gene”(14), “nervous system”(14), “hormone”(13), “allele”(11), “brain”(9), “deoxyribonucleic acid”(5), “spinal cord”(4), “enzyme”(4), “cell membrane”(3), “spinal bulb”(3), “bacteria”(2), “hypothalamus”(2), “nucleic acid”(2), “organic molecule”(2), “protein”(2), “species”(2), “plant”(2), “kidney”(1), “endodermis”(1), “endocrine system”(1), “pituitary”(1), “cytoskeleton”(1), “light”(1), “chromosome”(1), “limbic system”(1), “lipid”(1), “fungus spore”(1), “autophagy”(1), “sinaotrial node”(1), “stoma”(1), “virus”(1).	123	11.45
3.“to use”	“living being”(34), “cell”(19), “plant”(17), “bacteria”(6), “animal”(5), “virus”(5), “photoautotroph”(5), “consumer”(3), “chloroplast”(2), “producer”(2), “herbivorous”(2), “autotroph”(2), “parasite”(2), “algae”(1), “tissue”(1), “ecosystem”(1), “carnivorous”(1), “omnivorous”(1), “butterfly”(1), “chemoautotroph”(1), “chlorophyll”(1), “mitochondria”(1), “ribonucleic acid”(1).	114	10.61
4.“to need”	“living being”(23), “cell”(18), “plant”(15), “body”(8), “embryo”(5), “tissue”(3), “bacteria”(3), “enzyme”(2), “animal”(2), “virus”(2), “heterotroph”(2), “decomposer”(1), “brain”(1), “plant root”(1), “cell membrane”(1), “heart”(1), “liver”(1), “muscle”(1), “herbivorous”(1), “autotroph”(1), “plasmodium”(1), “population”(1), “spirulina”(1), “plant shoot”(1), “seed”(1), “species”(1).	98	9.12
5.“to help”	“enzyme”(15), “light”(6), “bacteria”(4), “skin”(4), “organ”(4), “euglena”(4), “cell”(3), “gland”(3), “hormone”(3), “energy”(3), “muscle”(3), “virus”(2), “vitamin”(2), “leaf”(2), “food”(2), “phloem”(2), “xylem”(2), “hemoglobin”(2), “cytoskeleton”(2), “cell membrane”(2), “lung”(1), “cerebellum”(1), “kidney”(1), “vessel”(1), “diaphragm”(1), “physical digestion”(1), “cell wall”(1), “muscle”(1) , “skeleton”(1), “rib”(1), “chlorophyll”(1), “ear”(1), “bird wing”(1), “fruit”(1), “oxygen”(1) , “organelle”(1), “pericardial fluid”(1), “protein”(1), “pseudopod”(1), “saliva secretion”(1).	90	8.38
6.“to have the ability”	“cell”(20), “living being”(6), “bacteria”(6), “animal”(5), “species”(3), “pollen”(2), “axolotl”(2), “energy”(2), “plant”(2),	61	5.68

Anthropomorphic discourse	Biological Concept	f	%*
	"deoxyribonucleic acid"(1), "lung"(1), "antibiotic"(1), "embryo"(1), "kidney"(1), "starfish"(1), "mouse"(1), "gene"(1), "lizard"(1), "ear"(1), "substance"(1), "parasite"(1), "vein"(1).		
7."to communicate"	"deoxyribonucleic acid"(24), ribonucleic acid ""(7), "cell"(4), "gene"(4), "cell membrane"(2), "nucleotide"(2), "nervous system"(2) , "coleoptile"(1), "leaf"(1), "corpus collosum"(1), "skin"(1), "hormone"(1), "ribosome"(1).	51	4.75
8."to fight"	"cell"(12), "species"(9), "pathogen"(2), "population"(2), "immune system"(2), "virus"(2), "animal"(2), "bacteria"(1), "brain"(1), "living being"(1), "antibody"(1), "organic molecule"(1).	36	3.35
9."to know"	"cell"(5), "antibody"(4), "plant"(4), "receptor"(4), "brain"(2), "cell membrane"(2), "virus"(2), "immune system"(2), "antigen"(1), "hydrogen ion"(1), "interferon"(1), "capsaicin"(1), "coleoptile"(1), "protein"(1) , "ribonucleic acid"(1), "salt"(1).	33	3.07
10."to repair"	"deoxyribonucleic acid"(7), "mitosis"(4), "cell"(3), "living being"(2), "tissue"(3), "ribonucleic acid"(2), "gene"(2), "inorganic molecule"(2), "organic molecule"(2), "surfactant"(1), "chromosome"(1), "bone"(1), "Golgi apparatus"(1).	31	2.89
11."to be a sister"	"chromatid"(25), "cell"(1).	26	2.42
12."to love"	"archae"(19), "phospholipid"(4).	23	2.14
13."to cooperate"	"organ system"(5), "enzyme"(4), "brain"(2), "brain lobe"(2), "kidney"(1), "light dependent reaction"(1), "community"(1), "cell"(1), "autonomic nerve"(1), "rhodopsin"(1).	19	1.77
14."to be a killer"	"cell"(14), "fungus"(2), "alga"(2), "whale"(1).	19	1.77
15."to have a tendency"	"population"(3), "hemoglobin"(3), "inorganic molecule"(2), "electron"(1), "cell"(1), "carbon monoxide"(1), "substance"(1), "animal"(1), "living being"(1), "proton"(1).	15	1.4
16."to be a companion"	"cell"(14), "organic molecule"(1).	15	1.4
17."to decide"	"cerebellum"(2), "substance"(2), "phosphate bond"(1), "brain"(1), "carbonic acid"(1), "animal"(1), "living being"(1), "species"(1).	10	0.93
18."to allow"	"cell membrane"(2), "cell"(2), "trachea"(1), receptor"(1), "heart valve"(1), "heart"(1), "coleoptile"(1).	9	0.84
19."to sleep"	"seed"(2), "bud"(2), "plant"(1).	5	0.47
Total		1074	100

* Numbers in the table may not add up to the total due to rounding.

Category 1. Anthropomorphism as "to fulfil a function"

In this dominant category, it was determined that 93 different biological concepts were anthropomorphized as "to fulfil a function" (27.56%). "cell"(21), "enzyme"(18), "tissue"(16), "inorganic molecule"(15), "hormone"(14), "gene"(10), "living being"(9) , "organ"(9), "allele"(8), "organic molecule"(8), "bacteria"(7), "nutrient"(7), "electron transport chain"(6), "ribonucleic acid"(6) were the most frequently anthropomorphized biological concepts. In this category, it was emphasized that biological structures such as cells, enzymes and tissues were specialized in line with a certain task and purpose. Examples are as follows:

• "White blood **cells**, which are **in charge of** the body's immune system, neutralize bacteria and viruses thanks to lysosomes" (Book A, p. 83).

• "The **enzymes responsible for** fermentation are found in the cytoplasm of the cell" (Book D, p. 94).

• "Providing support to the plant, performing photosynthesis, storing and transmitting substances are among the **tasks undertaken by** the parenchyma **tissue**" (Book D, p. 157).

• "**Inorganic molecules act as** regulators in the body…" (Book A, p. 58).

• "The hormone that has completed its **task** is broken down in the target cell or liver" (Book C, p. 40).

• "There are **genes responsible for** protein synthesis on DNA…" (Book D, p. 26).

• "If all the genes of the baby are normal and all the genes fulfil their functions, the baby will be born healthy" (Book B, p. 149).

• "Every **living being** fulfils a **function** in the ecosystem" (Book B, p. 116).

• "Autotrophic **bacteria are responsible for** the nitrogen cycle" (Book B, p. 115).

• "…Ribonucleic acid is **responsible for** protein synthesis" (Book D, p. 23).

Category 2. Anthropomorphism as "to control"

In this category, it was determined that 32 different biological concepts were anthropomorphized as "to control" (11.45%). "nucleus"(15), "gene"(14), "nervous system"(14), "hormone"(13), "allele"(11), "brain"(9), "deoxyribonucleic acid"(5) were the most frequently anthropomorphized concepts. In this category, it was emphasized that various biological structures, such as the nucleus, gene and nervous system, kept certain biological events under control. Examples are as follows:

• "…Cells divide under the **control** of the **nucleus**" (Book B, p. 45).

• "The **nucleus** is the **headquarters** of the cell" (Book A, p. 90).

• "**Genes control** genetic traits such as eye colour, blood type, hair color and fingerprints" (Book A, p. 51).

• "The somatic **nervous system controls** skeletal muscles" (Book C, p. 36).

• "The **hormone** auxin **controls** the division, growth and differentiation of cells" (Book D, p. 130).

• "...multi-allelic in humans can be explained by the **control** of blood groups A, B, 0 by more than one **allele**" (Book C, p. 145).

• "The left **brain controls** the right side of the body, and the right **brain controls** the left side of the body…" (Book C, p. 30).

• "**Deoxyribonucleic acid governs** all vital events in the cell…" (Book A, p. 51).

• "The **enzymes controlling** glycolysis are common to all living things" (Book D, p. 88).

• "The **cell membrane controls** the entry and exit of substances into the cell" (Book A, p. 79).

Category 3. Anthropomorphism as "to use"

In this category, it was determined that 23 different biological concepts were anthropomorphized as "to use" (10.61%). "living being"(34), "cell"(19), "plant"(17), "bacteria"(6), "animal"(5), "virus"(5), "photoautotroph"(5) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "**Living beings** first **use** carbohydrates to obtain energy" (Book A, p. 34).

• "The energy molecule **used** by all **living beings** is ATP" (Book D, p. 65).

• "Cancer **cell**s **use** more sugar than healthy cells" (Book, p. 37).

• "**Plant**s **use** water to produce food" (Book D, p. 69).

• "According to a scientific study, **bacteria** can pass antibiotic tests in the laboratory **using** a kind of Trojan Horse strategy" (Book D, p. 172).

• "**Animals use** both their hormonal and nervous systems to regulate their metabolic functions" (Book A, p. 53).

• "Those who **use** light energy to produce their food are called **photoautotrophs**" (Book B, p. 107).

Category 4. Anthropomorphism as "to need"

In this category, it was determined that 26 different biological concepts were anthropomorphized as "to need" (9.12%). "living being"(23), "cell"(18), "plant"(15), "body"(8), "embryo"(5), "tissue"(3), "bacteria"(3) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "**Living things need** energy to survive" (Book A, p. 18).

• "Because the energy **need** of muscle tissue **cells** is high, there are many mitochondria in the cytoplasm" (Book C, p. 84).

• "During segmentation, embryonic **cells** obtain their nutritional **needs** from the cytoplasm" (Book C, p. 240).

• "**Plants** obtain their basic **needs** from soil, air and water" (Book D, p. 113).

• "Only **plants** can synthesize all the vitamins they **need**" (Book A, p. 47).

• "…The **body needs** oxygen and nutrients…" (Book C, p. 292).

• "…The **embryo needs** nourishment" (Book D, p. 152).

• "**The tissue's need for oxygen increases** during intense exercise" (Book C, p. 143).

• "Some **bacteria** absolutely **need** an oxygenated environment to survive" (Book A, p. 125).

• "**Viruses** absolutely **need** a living cell to reproduce" (Book A, p. 152).

Category 5. Anthropomorphism as "to help"

In this category, it was determined that 40 different biological concepts were anthropomorphized as "to help" (8.38%). "enzyme"(15), "light"(6), "bacteria"(4), "skin"(4), "organ"(4), "euglena"(4), "cell"(3), "gland"(3), "hormone"(3), "energy"(3) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "The carbon dioxide in the erythrocyte forms carbonic acid **with the help of the enzyme** carbonic anhydrase…" (Book B, p. 185).

• "…Pyruvic acid is converted into acetyl-CoA molecule **with the help of enzymes**" (Book D, p. 89).

• "Chloroplast produces glucose and oxygen from water and carbon dioxide **with the help of** sunl**ight**" (Book A, p. 85).

• "Herbivores have **bacteria** in their digestive tract that **help** the digestion of cellulose" (Book B, p. 107).

• "…in some vertebrates, the **skin helps** excretion through perspiration" (Book A, p. 19).

• "Organs such as the salivary gland, liver and pancreas **help** digestion." (Book B, p. 99).

• "Do the **cells** get **help** from each other in the substance transmission in the phloem?" (Book D, p. 157).

• "The decomposition of water molecules into electrons, protons and oxygen with the **help** of **light** energy is called photolysis" (Book D, p. 73).

• "The **cell membrane** regulates the entry and exit of substances into the cell and **helps** maintain the cell shape" (Book A, p. 90).

• "**Vitamins** are **auxiliary** organic substances necessary for the fulfilment of vital functions" (Book A, p. 58).

Category 6. Anthropomorphism as "to have the ability"

In this category, it was determined that 22 different biological concepts were anthropomorphized as "to have the ability" (5.86%). "cell" (20), "living being" (6), "bacteria" (6), "animal" (5) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "Four haploid **cell**s formed by meiosis in males differentiate and gain the **ability** to fertilize…" (Book B, p. 41).

• "**Sperm** acquires its **ability** to fertilize in the chemical environment of the female reproductive system" (Book C, p. 223).

• "Mutations that increase the **ability** of a **living being** to adapt to the environment are called beneficial mutations" (Book D, p. 170).

• "…However, as the level of development of **living beings** increases, their regeneration **abilities** decrease" (Book B, p. 29).

• "Some **bacteria have the ability** to move thanks to flagella" (Book A, p. 125).

• "Vertebrate **animals have the ability** of surviving in almost any environment on earth" (Book A, p. 138).

Category 7. Anthropomorphism as "to communicate"

In this category, it was determined that 13 different biological concepts were anthropomorphized as "to transfer information, to communicate" (4.75%). "deoxyribonucleic acid"(24), "ribonucleic acid"(7), "cell"(4), "gene"(4), "cell membrane"(2), "nucleotide"(2), "nervous system"(2) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "…The relevant message is **transferred** to RNA by the **DNA** molecule in the nucleus" (Book A, p. 94).

• "**Messenger ribonucleic acid transfers** the code or message it receives from DNA for protein synthesis to the ribosome" (Book A, p. 51).

• "The hair **cells** in the inner ear are stimulated according to gravity or linear motion and **inform** the cerebellum of this situation" (Book C, p. 63).

• "A **cell** has an effective **communication system** regarding the metabolic events that take place throughout its life. This system is known as the "signal transmission system" (Book B, p. 19).

• "…In this case, a hereditary disease occurs in the baby, as some metabolic activities in the body are directed according to **the misinformation conveyed by** mutant **genes**" (Book B, p. 93).

• "The cell membrane enables **cells** to connect and **communicate** with each other" (Book A, p. 79).

• "The **nervous system** can **transmit messages** faster, while the effects of hormones last longer" (Book C, p. 40).

• "**Hormones** are chemical **messengers** that regulate the structure and functions of tissues and organs" (Book C, p. 40).

Category 8. Anthropomorphism as "to fight"

In this category, it was determined that 12 different biological concepts were anthropomorphized as "to fight" (3.35%). "cell"(12), "species"(9), "pathogen"(2), "population"(2), "immune system"(2) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "…Some of these **lymphocytes attack** the antigen while others wait until they encounter the antigen again" (Book C, p. 161).

• "There are types of granular white blood **cells** that **fight** against bacteria and

viruses that spread throughout the body" (Book C, p. 144).

• "…The adaptable species survive, the other **species** lose the **war**" (Book D, p. 168).

• "**Populations** of prey and predators within a community **fight** for survival through various adaptations" (Book C, p. 261).

• "Increased cell death due to **virus attack** causes T cells to die as well" (Book C, p. 166).

• "Autoimmune diseases occur as a result of the **immune system attacking** the body's own molecules" (Book C, p. 165).

Category 9. Anthropomorphism as "to know"

In this category, it was determined that 16 different biological concepts were anthropomorphized as "to know, to recognize" (3.07%). "cell"(5), "antibody"(4), "plant"(4), "receptor"(4), "brain"(2), "cell membrane"(2), "virus"(2), "immune system"(2) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "Glycoproteins are molecules that enable **cells** to **recognize** each other" (Book A, p. 41).

• "**T-Lymphocytes recognize** and destroy diseased cells and provide cellular immunity" (Book C, p. 144).

• "…The allergen that then re-enters the body is **recognized** by **antibodies** in the mast cell" (Book C, p. 165).

• "**Plants**, like other living things, have to **know** their environment in order to survive" (Book D, p. 132).

• "Foreign substances that have entered the body are **recognized** through **receptors**" (Book C, p. 161).

• "The **cell membrane recognizes** nutrients, hormones and microorganisms thanks to the receptors it carries" (Book A, p. 79).

• "The **proteins** on the virus surface **recognize** and adhere to targets in the protein, carbohydrate or fat structure on the cell surface" (Book A, p. 147).

Category 10. Anthropomorphism as "to repair"

In this category, it was determined that 13 different biological concepts were anthropomorphized as "to repair" (2.89%). "deoxyribonucleic acid"(7), "mitosis"(4), "cell"(3), "living being"(2), "tissue"(3), "ribonucleic acid"(2), "gene"(2) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "An abnormality occurring in one of the DNA strands can be **repaired** by **DNA** based on the reciprocal order of bases" (Book D, p. 22).

• "**Mitosis** ensures reproduction in unicellular, while it provides growth,

development and tissue **repair** in multicellular organisms" (Book B, p. 19).

• "…Otherwise, **mitosis** provides tissue **repair** in multicellular organisms" (Book B, p. 16).

• "…Schwann **cells** envelop, protect and **repair** the axon" (Book C, p. 23).

• "**Living things** need nutrients to grow, develop, and **repair** tissues and organs…" (Book A, p. 18).

• "**Ribonucleic acid** cannot replicate and **repair** itself like DNA" (Book D, p. 23).

• "…Researchers found that the **gene** called TP53, which has the ability to **repair** damaged DNA, is 20 times more abundant in elephants than humans" (Book A, p. 157).

Category 11. Anthropomorphism as "to be a sister"

In this category, it was determined that two different biological concepts were anthropomorphized as "to be a sister" (2.42%). The most frequently anthropomorphized biological concepts were "chromatid" (25), "cell" (1), respectively. Examples are as follows:

• "…These chromatids are called **sister** chromatids because they contain the same DNA" (Book B, p. 17).

• "Gene exchange between non-sister chromatids of homologous chromosomes is called crossing over" (Book B, p. 153).

• "Telophase 1 and cytokinesis occur simultaneously and two **sister cells** are formed" (Book B, p. 37).

Category 12. Anthropomorphism as "to love"

In this category, it was determined that 2 different biological concepts were anthropomorphized as "to love" (2.14%). The most frequently anthropomorphized biological concepts were "archaea"(19), "phospholipid"(4), respectively. Examples are as follows:

• "…Some archaea that can survive at -20 °C thanks to their genetic features are called **cold-loving** archaea" (Book A, p. 127).

• "Thermophiles are archaea that **like** extremely hot environments" (Book A, p. 127).

• "The head regions of phospholipid molecules facing both outside and inside the cell are **hydrophilic (water-loving)**, while the tail regions facing inside the cell membrane are hydrophobic (not water-loving)" (Book A, p. 39).

Category 13. Anthropomorphism as "to cooperate"

In this category, it was determined that 10 different biological concepts were anthropomorphized as "cooperating" (1.77%). "organ system"(5), "enzyme"(4), "brain"(2) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "…This problem is overcome by the **cooperative work** of **organ systems** in the body for homeostatic balance" (Book C, p. 20).

• "An organ system is a group of **organs** that **cooperate** to perform a vital bodily function" (Book A, p. 22).

• "**Enzymes** usually **work in teams**, digestion of proteins down to amino acids is an example of enzymes **working as a team**." (Book A, p. 44).

• "The **brain** in the central nervous system **cooperates** closely with the spinal cord" (Book C, p. 28).

Category 14. Anthropomorphism as "to be a killer"

In this category, it was determined that 4 different biological concepts were anthropomorphized as "to be a killer" (1.77%). "cell"(14), "fungus"(2), "alga"(2), "whale"(1) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "Some of the lymphocytes have the ability to destroy viruses and cancer cells… These types of lymphocytes are called natural **killer cells**" (Book C, p. 144).

• "Some cells in the T-lymphocyte clone generate helper T cells and **killer T cells**" (Book C, p. 162).

• "The **killer fungus** waits for the most opportune moment and delivers its killing blow" (Book C, p. 256).

• "…For example, *Caulerpa taxifolia*, the **killer alga**, is an invasive species that has spread to Mediterranean waters" (Book C, p. 260).

• "The fact that **killer whales** had to feed on otters in recent years has greatly reduced the otter population" (Book C, p. 260).

Category 15. Anthropomorphism as "to have a tendency"

In this category, it was determined that 10 different biological concepts were anthropomorphized as "to have a tendency" (1.40%). "population"(3), "haemoglobin"(3), "inorganic molecule"(2), "electron"(1) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "The **tendency** of populations to form groups is an adaptation to increase individuals' chances of survival" (Book C, p. 281).

• "Low pH reduces the **tendency** of haemoglobin towards oxygen..." (Book C, p. 183).

• "In simple diffusion, inorganic molecules **tend to** move in their environment" (Book A, p. 95).

• "In electron transport chain, **electrons have a tendency to** descend from a higher energy level to a lower energy level (Book D, p. 98).

Category 16. Anthropomorphism as "to be a companion"

In this category, it was determined that 2 different biological concepts were anthropomorphized as "to be a companion" (1.40%). "cell"(14) and

"organic molecule"(1) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "Sieve tube elements consist of **companion cells**, phloem parenchyma, and phloem sclerenchyma" (Book D, p. 119).

• "**Companion cells** in the leaves of some plants help nutrients pass into the sieve tube elements" (Book D, p. 119).

Category 17. Anthropomorphism as "to decide"

In this category, it was determined that 8 different biological concepts were anthropomorphized as "to decide" (0.93%). "cerebellum"(2) and "substance"(2) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "The **cerebellum decides** what changes will be made in the movements of the joints and muscles" (Book C, p. 33).

• "The **indecisive** carbonic acid turns into bicarbonate and hydrogen ions" (Book C, p. 185).

Category 18. Anthropomorphism as "to allow"

In this category, it was determined that 7 different biological concepts were anthropomorphized as "to allow" (0.84%). "cell membrane"(2), "cell"(2), "trachea"(1) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "The **cell membrane** does not **allow** the passage of large water-soluble molecules but **allows** the passage of water" (Book A, p. 97).

• "The end walls of the **trachea** are perforated, **allowing** water to flow through the wood pipes" (Book D, p. 119).

Category 19. Anthropomorphism as "to sleep"

In this category, it was determined that 3 different biological concepts were anthropomorphized as "to sleep" (0.47%). "seed"(2), "bud"(2), "plant"(1) were the most frequently anthropomorphized biological concepts. Examples are as follows:

• "Fruits protect **dormant seeds**…" (Book D, p. 152).

• "Abscisic acid inhibits germination by encouraging the **seed** to **go dormant**" (Book D, p. 153).

According to the Turkish dictionary, the sleeping of the plant seed and the sleeping of the human are expressed with the same verb. However, in the English equivalent of this verb, the word "dormant" is used for the plant seed, while the word "sleeping" is used for the human. Since this study was carried out according to the Turkish dictionary, the word "sleeping", which is the equivalent of the verb used in Turkish, was used in the naming of the category since it is the word that best fits the category.

This study gave ideas about how often and for which biology concepts anthropomorphic expressions are used in high school biology textbooks in Turkey. When the data of the study were analysed, the following results were noted: (1) 1074 anthropomorphic discourses associated with 177 biological concepts were identified; (2) the most frequently anthropomorphized concepts are cell (12.76%), living being (7.17%), enzyme (4%), DNA (3.91%), plant (3.82%), gene (2.89%), hormone (2.89%), bacteria (2.7%), chromatid (2.33%), and tissue (2.14%); (3) the anthropomorphic discourses found in biology textbooks were classified in 19 categories-to fulfil a function (27.56%), to control (11.45%), to use (10.61%), to need (9.12%), to help (8.38%), to have the ability (5.68%), to communicate (4.75%), to fight (3.35%), to recognize (3.07%), to repair (2.89%), to be a sibling (2.42%), to love (2.14%), to cooperate (1.77%), to be a killer (1.77%), to have a tendency (1.4%), to be a companion (1.4%)), to decide (0.93%), to allow (0.84%), to sleep (0.47%).

The findings showed that anthropomorphic discourses were used very frequently in high school biology textbooks, with an average of 269 per book. While some researchers have argued that it is undesirable to use anthropomorphic discourse in the language of science (Byrne et al., 2009; Coley & Tanner, 2012; Kallery & Psillos, 2004; Moore et al., 2002; Shtulman, 2006; Taber & Watts, 1996; Tamir & Zohar, 1991), available evidence indicates that a pure, objective language of biology without anthropomorphic discourse is nearly impossible. In this context, the results of this study revealed that instead of giving up on anthropomorphism, anthropomorphic discourse should be used in a controlled way, especially in biology textbooks. These results reinforced the views of researchers, who generally argued that a language of biology without anthropomorphism-in other words, a pure and objective language of science-is unthinkable. For example, Zohar and Ginossar (1998), Taber, de Trafford and Quai (2006) stated that anthropomorphism may have pedagogical value in learning environments and may provide some benefits to students. If an original scientific thought can only be expressed through anthropomorphism, or if anthropomorphic discourse is an irreplaceable language tool of a biological concept, it is inevitably used. In such a situation, perhaps the only way to talk about a biological phenomenon is to resort to anthropomorphism, and it is impossible to express this phenomenon in other words. For example, “Killer T

Cells that fight germs in the body" (Book C, p. 144, 162). The term "killer cells" is used scientifically even in biology dictionaries. Such discourse can fill a gap both in the vocabulary of biology and in the mental schema of the student. Therefore, instead of giving up anthropomorphic discourses, ways to use them in a controlled way should be sought.

There are some important points that both writers and teachers should pay attention to in the use of anthropomorphic discourses about biology concepts in biology lessons and textbooks. These expressions should be used very carefully because students can derive very different meanings from anthropomorphic discourses other than reality, or they can develop misconceptions. For example, the word "sibling/sister", which is an indication of a human-specific kinship relationship, is transferred to the chromosome arms in the cell, which are copies of each other, as "sibling chromatids/sister chromatids" (Book B, p. 17, 37, 153). Such anthropomorphic discourses can cause polysemy problems. If we take the sibling example here, there are different types of sibling in humans, such as full sibling, half-sibling, identical twin sibling, and fraternal twin sibling. Two chromosome arms, called "sister chromatids" in biology, are copies of each other and have the same gene sequence. In humans, this only applies to siblings with identical twins. This is not the case for fraternal twins, normal siblings or half-siblings. In this case, what type of sibling would students liken to the discourse of sister chromatids? When students do not liken it to identical twin sisters, they will inevitably be mistaken. When such discourses are encountered in classroom environments, the possible risks can be minimized by the teacher explaining them. In textbooks, on the other hand, it may be more difficult to reduce the risks because there is no mutual dialogue between the author and the reader. For this reason, anthropomorphism should be used in biology textbooks only when necessary. The writer's ability to produce meaning and his/her experience with metaphor are important in the clarity of a book's text. As a socio-cultural entity, a person continues his/her life by acquiring scientifically valid information. The more the information that the individual has is purified from the confusion of concepts, the more solid the individual's mental schema will be. The target should be accurate and reliable information. Considering all that has been said, the random or careless use of anthropomorphic discourses in biology textbooks can create knowledge gaps, which can be filled by students with ideas

that may cause misconceptions (Gregory, 2009; Kallery & Psillos, 2004; Legare, Lane, & Evans, 2013; Wood, 2019). For example, students may develop a misconception that the DNA molecule or cell membrane is alive. In a previous study, Dikmenli and Çardak (2004) reported that an important source of biological misconceptions is biology textbooks. Some researchers claimed that an important source of misconceptions is anthropomorphic discourses (Legare, Lane & Evans, 2013; Moore et al., 2002; Sinatra, Brem & Evans, 2008). For example, Sprinkle (2006) argued that anthropomorphic discourse causes misunderstanding of the theory of evolution and reinforces misunderstandings based on intuitive teleological and essentialist biases.

It was seen that some of the anthropomorphic discourses used in biology textbooks consisted of stereotyped terms and idioms embedded in the language. For example: "nucleus being the ruler of the cell" (Book A, p. 90), "Messaging Ribonucleic Acid" (Book A, p. 51), "Sister chromatid" (Book B, p. 17). These examples were the product of stereotypical anthropomorphic discourses found in all areas of biology and resembled what some researchers call "dead metaphor" (Cruse, 1986; Lakoff & Johnson, 1980). The dead metaphor refers to metaphors that are used continuously and extensively, often without realizing that it is a metaphor. An impression emerged that such anthropomorphic discourses were added to the language of biology over time and were generally used in a literal sense.

CONCLUSION

Anthropomorphic discourses in textbooks are often used to create a meaning for the definition of a phenomenon. However, when learning biology, it is important to be careful to be clear and understandable, and to inform readers that anthropomorphism is only a way of speaking and making sense, not a true description of a phenomenon. Anthropomorphic discourse can be used if it fills a semantic gap. These semantic gaps can occur when a word, phrase or sentence does not match what is meant. In such cases, the meaning can be expanded by referring to discourses in daily life or anthropomorphic discourses. However, we are of the opinion that it is not appropriate to use an expression in biology textbooks just to make it attractive, that is, as a decorative ornament.

Not much is known about the views of biology textbook writers on anthropomorphism and their reasons for using it in biology textbooks. Do the writers use anthropomorphism because they believe it is a good educational tool

for students to understand biological concepts, or because of the lack of other suitable alternative frameworks? Anthropomorphism can be seen as a solution to the problem of being able to explain abstract and difficult biological concepts. Is the use of anthropomorphism related to the writers' knowledge and understanding of science? Future studies should seek answers to these questions. Biology teachers' knowledge of anthropomorphism is also important in filtering textbooks. Teachers do a great job while using textbooks. Teachers should step in to avoid possible conceptual confusion. In future studies, high school students and teachers can be asked questions about anthropomorphic discourses in biology textbooks and their views can be researched.

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