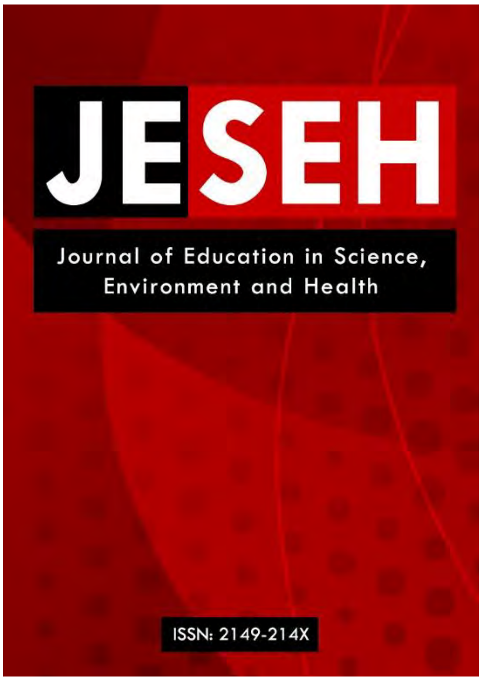

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Abstract

As a result of human beings' activities to dominate nature and transform it for their own benefit as they continue to advance in science and technology, environmental problems such as climate change have become the biggest threat faced by the biosphere in the current century. One of the biggest problems of humanity today is the scarcity of water resources. It is important to reveal the meanings attributed to the concept of water in biology textbooks in order to identify and eliminate the deficiencies or gaps between the concepts related to the subject. The main purpose of this study is to analyze how the concept of water is presented in secondary school biology textbooks. In line with this purpose, answers to the following questions were sought: What biological concepts is water associated with in biology textbooks and how often is it used? Under which categories can the concept of water be classified in biology textbooks? In the study, document analysis was conducted on four biology textbooks published by the Ministry of National Education to be taught in high schools in the 2023-2024 academic year. A qualitative methodology based on inductive logic was used to analyze the data. How water is emphasized in biology textbooks was discussed, and categories were developed to conceptualize explanations about water. These categories were: water as a substance in the structure of organisms, water as a habitat for organisms, water as a substance involved in chemical reactions, water as a human health factor, water as an essential requirement for organisms, water as an environmental problem factor and water as a scarcity factor. According to the results of the textbook content analysis, it was seen that the relationships between water and health concepts in the category of water as a human health factor were well structured. In the study, it was seen that the concept of water was presented in accordance with the target achievements in line with the secondary school biology course curriculum and that the key concepts were given literally. However, it was revealed that the concept of water in textbooks should be structured according to the principles of the systems thinking approach.

Introduction

It is estimated that organic life on earth first started in water and then spread throughout the world. Looking at the past, it is seen that human communities settled down, started agriculture and established civilizations on the banks of water. The civilizations established around the Nile River in Egypt, the Euphrates and Tigris in Mesopotamia, the Yellow River in China and the Ganges River in India are examples of these. This shows that human beings were aware of the need to live close to fresh water to survive. Early civilizations knew the importance of water in preventing life-threatening famine. Water was also considered a vital substance by ancient philosophers. For example, Thales (624-548 BC) argued that all substances on earth were composed of water. According to him, the building block of all substances was water. Things that did not look like water were also made of water or were a kind of water that had changed. In short, the main substance of the world was water. Hippocrates (460-370 BC), in his study "On airs, waters and places", questioned the relationship between environmental factors and human health, and the effects of wind, seasons and water on human physical and mental health. Aristotle (384-322 BC), on the other hand, attributed the differences between the peoples of Europe and Asia to climatic differences and stated that countries with favorable climatic conditions would develop faster.

As a result of human beings' activities to dominate nature and transform nature for their own benefit as they continue to advance in science and technology, environmental problems such as climate change have become the biggest threat faced by the biosphere in the current century. The most important substance associated with climate change is water, because climate change affects the water cycle, and the water cycle affects the climate. As a result of these interactions, problems related to water resources, energy, food, health and biodiversity arise for human beings. Water is a substance consisting of two molecules of hydrogen and one molecule of oxygen, has its own important physical and chemical properties, provides living organisms with the opportunity to live thanks to these properties, fills seas, lakes and rivers and is normally in liquid form.

More than two-thirds of the earth is covered with water. Land covers 29% of the earth's surface. There is approximately 1.3 billion km^3 of water on Earth. This water is found in oceans, rivers, lakes, underground, in clouds, and also in solid form in glaciers and ice sheets. Only 2.5-3% of the water on Earth is fresh water, and most of this water is trapped in glaciers and ice sheets and locked in frozen soil. These water resources are inaccessible, that is, they cannot be used. This reduces the amount of usable freshwater in liquid form on Earth to 1%. For every bathtub full of seawater on Earth, there are only 4 teaspoons of fresh water in all lakes, rivers and the atmosphere. Of this 1%, 74% is used in agriculture, 15% at home and 11% in industry. The availability of usable water is vital for the diversity of living organisms in freshwater ecosystems, food security and sustainable development. Therefore, freshwater resources need to be protected.

One of the biggest problems faced by humanity today is limited water resources. Sustainability of water resources is at the root of many problems such as food security, energy need, population growth, economic growth, climate change and biodiversity loss. Water is vital for the continuation of human existence. Access to usable water and water quality issues are among the biggest challenges of humanity today. Important topics such as weather and climate cannot be adequately understood or explained without a basic scientific understanding of the water cycle and the properties of water. Therefore, understanding the dynamic nature of water systems is becoming increasingly important as water scarcity and other water problems arise in many countries due to factors such as drought and pollution (Sadler, Nguyen, & Lankford, 2017). Although Türkiye seems to be a country that does not face water problems, it is a country on the edge of water scarcity. There was a 40.5% increase in the total amount of water consumed between 1990 and 2010.

Pan and Liu (2018) investigated secondary school students' understanding of groundwater as a system and whether their understanding was related to attitudes towards groundwater use and conservation. Analysis of student drawings showed that students generally had an incomplete and disconnected understanding of the groundwater system. Correlation analysis showed that students' levels of understanding correlated with their perceptions of environmental impacts as well as environmental concerns about groundwater issues. These findings once again emphasized the importance of developing students' systematic thinking abilities and their understanding of environmental systems. The findings also showed that understanding the characteristics of the groundwater system (its internal structure and its relationship with the larger environment) is important for understanding the environmental impacts of groundwater problems and for raising environmental awareness.

Covitt, Gunckel, and Anderson (2009) examined the development of students' understanding of water within environmental systems. The researchers developed a framework of grounded curricular goals for water literacy and documented the challenges students faced in achieving these goals. Water-related environmental literacy requires an understanding of the state changes of water as a substance and of large-scale interconnected natural and human-engineered systems, ranging from atomic-molecular such as solutions to large watersheds, groundwater, and human water treatment and distribution systems. The researchers' assessments of primary and secondary school students showed that nearly all students had some important understandings about water that educators could improve. However, the researchers also found that most students did not consider water and other materials with the systems thinking approach and did not take into account the invisible aspects of water systems at the atomic-molecular level and at landscape scales. The results revealed that a discrepancy existed between students' informal explanations of water in environmental systems and scientific explanations of these systems. This study on students' understandings showed that they were not developing basic water literacy in school and that the current K-12 standardized science curriculum did not support water literacy development. The researchers discussed curriculum practices and recommendations that can help students develop a richer understanding of water systems at various scales. Although many areas must be addressed to prepare students for civic responsibilities, the importance of creating a strong K-12 science curriculum that provides students with the tools to make conscious decisions should not be overlooked.

As with groundwater, the fact that water systems are often hidden and invisible causes students to encounter some conceptual challenges when learning this subject. Although many students can easily appreciate the fact that water can be stored underground, they have limited understanding of the connections between surface water and groundwater and the connections between geologically mediated waters (Sadler et al., 2017). The state change of water as a substance and the water cycle can also be included in these challenges. Groundwater is often a missing component in students' conceptualization of the water cycle (Shepardson, Wee, Priddy, Schellenberger, & Harbor, 2007). Despite the importance of water and basic water-related concepts in developing scientifically literate individuals, surprisingly few studies have focused on the concept of water in the context of textbooks. In the existing literature, it is seen that researchers have mostly focused on issues such as the water cycle understanding of students and teacher candidates in various age groups (Ben-Zvi Assaraf & Orion, 2005a; Cardak, 2009). There are also past studies revealing that students have misconceptions or alternative concepts about water (Dickerson, Callahan, Van Sickle, & Hay, 2005) and focusing on addressing such misconceptions through strategies such as mental model building (Reinfried, 2006). Regarding water, students have misconceptions or alternative understandings, especially about the water cycle, and these misconceptions have the potential to hinder their understanding of accurate explanations of the movement of water into and out of the atmosphere (Romine, Schaffer, & Barrow, 2015). Since cycle is a process that operates in different times and places, it is a difficult concept for students to understand. Agelidou, Balafoutas, and Gialamas (2001) stated that students generally perceive substance cycles as time-based natural cycles, such as the cycle of life or the cycle of seasons, rather than the transportation and state change of substance, as in the example of the water cycle. In order to learn the water cycle, students need to have knowledge about the properties of water and the heat exchange between the Earth and the Sun. In addition, the concepts of energy transfer during the water cycle are difficult for most students because they relate to a state of substance that is mostly invisible. Discussions about energy levels, such as potential and kinetic energy, tend to be abstract rather than concrete, which increases the likelihood of misunderstanding (Canpolat, 2006; Henriques, 2002). There are also studies that question students' water literacy. For example, Yentür, Sözcü, and Aydınözü (2022) investigated the water literacy levels of high school students. As a result of the analysis, it was concluded that high school students in Türkiye Istanbul sample were moderately water literate. In terms of the sub-dimensions of water literacy, it was observed that they had medium level literacy in water awareness and water sensitivity and high level literacy in water saving. In addition, it was determined that the variables such as gender, school type, grade level, parents' education level, family income level were effective on the water literacy levels of high school students.

Ozalemdar (2019) analyzed the biology textbooks used in secondary education institutions in Türkiye in 2016 and prepared by the Ministry of National Education in order to reveal the importance of water in biology education. The researcher classified the concept of water according to the units in the textbooks and emphasized that the units generally focused on the structure and properties of water. The findings revealed that water has a special place in biology education and that biology education is an important tool in conveying the importance of water for living things. Hussein (2018) conducted a critical study on water scarcity discourses in textbooks and education policy in Jordan. This study analyzed how the discourse of water scarcity is constructed in Jordanian textbooks to understand its role in improving education on environmental sustainability. Teachers and students were also interviewed about water scarcity. The framing of the causes of water scarcity in textbooks tends to move towards a trend towards increasing water resources. However, it is also important to reduce water demand or to save water in better management of water resources. The water scarcity discourse constructed in textbooks presents best practices and aims to shape students' behavior towards the environment. This is especially true in water conservation.The students are advised to use water more efficiently and reduce water waste at the household level, as well as in gardening and farming practices. The textbooks in Jordan emphasize environmental sustainability and encourage individuals to become agents of change by changing their daily behavior towards the use of environmental resources.

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 accurate in terms of scientific content. Dikmenli and Çardak (2004), in their study on misconceptions in high school 1st grade biology textbooks, determined the misconceptions in the unit "Cell, the Basic Unit of Life" in the 2003-2004 academic year. They analyzed 4 high school 1st grade biology textbooks and found misconceptions in 3 of them. As a result of the analysis, 14 misconceptions and 10 missing information were identified. Dikmenli (2010) analyzed the analogies used in secondary school biology textbooks in line with certain criteria and found that the use of analogies in biology textbooks is quite common. The researcher reported that many metaphorical expressions and analogies were used in the textbooks. In this study, it was revealed that the analogies used in high school biology textbooks were generally structural, verbal, simple, embedded activating and concrete-abstract type analogies. Despite the advances in instructional technologies and material design, textbooks remain important today. Textbooks are frequently used by both students and teachers, especially in schools where written exams are common and laboratory facilities are limited. Teachers and students see textbooks as reliable sources of information. Therefore, content analysis is very important for textbooks to be efficient. In terms of the function of textbooks, these tools must be qualified because students see textbooks as the source of all information. In order for the textbooks to fully perform their functions, they must be scientifically adequate and in accordance with the objectives of the secondary education biology curriculum. Analyzing secondary school biology textbooks prepared in line with curriculum objectives, identifying deficiencies, if any, and eliminating them in the next textbooks is important for the quality of biology teaching.

Significance of the Study

Although the above-mentioned studies provide useful information about students' ideas about water, little is known about how biology textbooks conceptualize water and water systems. Effective teaching in biology classes depends on the communication strategies used by textbook writers and teachers. Biology by its very nature involves abstract concepts at the microscopic and sub-microscopic levels. Especially in a situation where the students lack sufficient terminology, how to teach a new and abstract concept is an important problem. In such cases, establishing common bonds necessary for communication between individuals becomes difficult, communication weakens and mental confusion begins. In order to avoid such confusion, the writer, who is the source of communication, often aims to use simple, clear and understandable sentences while trying to explain a concept such as water. There is no detailed research on how often the concept of water is used in secondary school biology textbooks and which biological concepts it is associated with. Therefore, it is necessary to analyze how water, which is of vital importance for the future of the biosphere and all living things in it, is presented in biology textbooks. Constructivist epistemology argues that it is important to reveal what students already know and understand about scientific concepts, because prior knowledge affects subsequent learning. If good learning outcomes are to be achieved, previous ideas should not be ignored, because they can form the basis of conceptual restructuring which in turn can lead to meaningful learning. From this perspective, explanations about water in biology textbooks affect students' conceptual framework and effective learning. For this reason, the concept of water in textbooks needs to be analyzed and filtered. Revealing the meanings attributed to the concept of water in biology textbooks is important in terms of identifying and eliminating the deficiencies or gaps between the concepts related to the subject. In this study, how water, which is of vital importance for the future of humanity, is conceptualized in biology textbooks was examined. It was revealed how the explanations about water in the textbooks were presented to the reader. We believe that by analyzing the concept of water in biology textbooks, ideas and suggestions that can be useful for textbook writers, teachers, students and curriculum developers can be developed.

Purpose of the Study

The main purpose of this study is to analyze how the concept of water is presented in secondary school biology textbooks. In line with this purpose, answers to the following questions were sought: (1) Which biological concepts is water associated with in biology textbooks and how often is it used? (2) Under which categories can the concept of water be classified in biology textbooks?

Method

In this study, using a qualitative research model, document analysis method was used as a data collection technique. The document analysis method is defined as collecting, reviewing, questioning and analyzing documents as the primary data source in research data. Document analysis includes the analysis of written materials containing information about the phenomenon or phenomena targeted to be investigated (Yıldırım and Şimşek, 2016, p. 189). The document source of the study consists of secondary school biology textbooks.

Biology Textbooks Analyzed

Four biology textbooks were published by the Ministry of National Education for high school students for the 2023-2024 academic year. Therefore, in this study, four biology textbooks for 9th, 10th, 11th and 12th grades prepared in line with the secondary biology curriculum were analyzed. These textbooks were used in high schools all over Türkiye with the approval of the Ministry of National Education. No comparison was made between the textbooks in terms of content, as the textbooks were a continuation of each other. The textbooks were coded as Book A (9th grade), Book B (10th grade), Book C (11th grade) and Book D (12th grade).

Book A: Acar, B., Tousun, Z.D., Vurgun, A., Sarız, M. (2022). *Secondary School Biology 9 Textbook*. Ministry of National Education publications, 6965. (Accepted as a textbook by the decision of the Ministry of National Education, Board of Education and Discipline numbered 8 and dated 18.04.2019).

Book B: Bagatır, A., Yüceler, B.B., Atalay, N., Tokgöz, H., Yılmaz, U.G. (2021). *Secondary School Biology 10 Textbook*. Ministry of National Education publications, 6770. (Accepted as a textbook with the decision of the Ministry of National Education, Board of Education and Discipline numbered 78 and dated 28.05.2018).

Book C: Dolaşık, N., Bakioğlu, T., Sahranç, U., Yılmaz, U.G. (2023). *Secondary School Biology 11 Textbook*. Ministry of National Education publications, 8885. (Accepted as a textbook by the decision of the Ministry of National Education, Board of Education and Discipline numbered 02 and dated 04.01.2023).

Book D: Olgun, H., Topu, M., Akad, İ., Doğan Abdioğlu, M. (2022). *Secondary School Biology 12 Textbook.* Ministry of National Education publications, 8877. (Accepted as a textbook by the decision of the Ministry of National Education, Board of Education and Discipline numbered 95 and dated 28.11.2022).

Analysis of Data

A qualitative methodology based on inductive logic was used for the analysis. Each book was carefully read in its entirety by all four researchers, paying attention to the text and visuals. The researchers independently took notes about the water-related explanations they encountered in the textbooks. In the four biology textbooks analyzed, many sentences and images containing explanations about water were identified. However, only 671 of them were evaluated in this study. The reasons why the rest were excluded from the scope of the study are given in detail in "Stage 2" below. The analysis and interpretation of the explanations about "water" were carried out in the following stages: (1) naming stage, (2) eliminating and sorting stage, (3) reviewing and category development stage, (4) ensuring validity and reliability stage, (5) transferring the data to the SPSS package program for digitizing qualitative data.

Stage 1: Naming Stage

At this stage, a provisional list of water-related explanations was made in all four textbooks. In this process, the books were read once more, and the explanations about water were underlined and coded. For example, "water " was marked as an environmental problem factor in the sentence "*When chemicals and pollutants exceed the normal value in ground and surface waters and disrupt the physical, chemical and biological structure of water, this is called water pollution* (Book B, p. 172)". These sentences were transferred to a Microsoft Word file on the computer and then printed out to be analyzed independently of other texts in the book. In each sentence, it was checked whether water was mentioned explicitly and whether it contained any visuals, and those that were not explicit were marked with a colored pencil to be eliminated later.

Stage 2: Eliminating and Sorting Stage

At this stage, "content analysis" technique (Saban, Koçbeker, & Saban, 2006; Yıldırım & Şimşek, 2016) was used to analyze each explanation about water in terms of common characteristics with other explanations about water. In this process, the explanation in each sentence was analyzed in two aspects: (1) the category it represents in terms of meaning and (2) the biological concepts it is related to. In such a sentence, both the category that the explanation about water belongs to in terms of meaning and the biological concepts related to water were determined. For example, a sentence such as "*Water undergoes photolysis in the light-dependent reactions of photosynthesis* (Book D, p.84)" was categorized as "*water as a substance involved in chemical reactions*" and the water-related biological concepts in this sentence were marked as "*photosynthesis, light, reaction, water, photolysis*". Water-related concepts were listed separately for each category. It should be noted that not all sentences containing the term "water" represented the concept of water in terms of meaning. Therefore, such sentences were excluded from the evaluation. For example, the Turkish equivalent of "chickenpox", an infectious disease, is "water flower". The sentences containing such nomenclature were not included in the evaluation. In addition, the terms "water" used in the experimental procedures and multiple-choice question texts at the end of the units were not included in the evaluation.

Stage 3: Reviewing and Category Development Stage

After the sorting process, 671 sentences containing explanations about water were obtained. The distribution of these sentences according to the books is shown in Table 1. At this stage, these sentences were rearranged in alphabetical order with the meaning they expressed and the biological concepts they were related to, and the sentences were reviewed for the third time. A sample sentence was selected for each category. Thus, a list of categories was created by compiling the 671 sentences deemed to best represent the meaning they express. This list was compiled for two main purposes: (1) to use it as a reference source for grouping 671 sentences under certain categories and (2) to validate the data analysis process and interpretations of this study. Finally, 7 conceptual categories were developed by considering the common features related to the meanings of the explanations in the sentences. In this process, firstly, based on the previously created category list, the sentences of each category were analyzed in terms of their meaning and coded with a certain code (e.g. health, scarcity, environmental problem). These codes were then transformed into conceptual categories. For example, the explanations in the sentences under the category "water as a scarcity factor" all associate water with a possible danger of scarcity. For example, "*The global population is predicted to reach 9 billion by 2050, and 65% of the population will face severe water scarcity* (Book B, p.180)". The categorization in the category development process continued until all four researchers reached a consensus. It should be noted that in each sentence of the categories, while listing the biological concepts related to water, synonyms were combined under the name of the most frequently repeated one. For example, living being, organism, plant organism, animal organism, photosynthetic organism, consumer organism, microorganism, transgenic microorganism, prokaryotic organism were all combined under the name "organism". Information on the book and page in which a sentence explanation was found was coded in parentheses at the end of that sentence. In this context, the abbreviation "A/B/C/D" in parentheses symbolized the book type and "s" symbolized the page number.

Table 1**.** Percentage of sentences containing water-related explanations in secondary school biology textbooks

Textbooks	n	%
Book A	194	28,91
Book B	126	18,78
Book C	127	18,93
Book D	224	33,38
Total	671	100

Stage 4: Ensuring Validity and Reliability

Validity and reliability are the two most important criteria used to ensure or increase the credibility of research 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 research (Yıldırım and Şimşek, 2016, p.270). Specific to this research, two important processes were carried out to ensure the validity of the research results: (1) The data analysis process, especially how the 7 concept categories were reached, was explained in detail. (2) The examples that were assumed to best represent the 7 categories created from 671 sentence explanations 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 explanations related to water in the textbooks were used as the main data source, and each conceptual category was supported with examples, i.e. direct quotations.

Three important strategies were followed to ensure the reliability of the study. First, the four researchers, who are the writers of this article, studied in harmony and acted together at every stage of the study from the beginning to the end (e.g., creating the research design, writing the research questions, collecting data, analyzing the data, developing categories, and interpreting the results) and tried to achieve consensus to make decisions in case of any disagreement. Two separate expert opinions were consulted in order to confirm whether the in-sentence explanations given under the 7 conceptual categories developed in the study represented the categories in question. Two lists were given to two faculty members who are experts in the field of biology education: (1) a list of 671 in-sentence explanations arranged in alphabetical order and (2) a list of 7 conceptual category titles arranged randomly. Using both lists, the experts were asked to match the explanations in the first list with the 7 conceptual categories in the second list, leaving none out. Then, the pairings made by these two experts were compared with the researchers' own categories. For example, the statement "*Many diseases such as tooth decay, gum diseases, diarrhea, typhoid, cholera, hepatitis, intestinal parasites are caused by improperly washed food and dirty water* (Book c, p.110)" was placed in the category of "Water as an environmental problem factor" by the researchers, while it was included in the category of "Water as a health factor" by the expert. In this way, the number of agreement and disagreement was determined in all comparisons and the reliability of the study was calculated using Miles and Huberman's (2016) formula (Reliability = Agreement / Agreement + Disagreement). In the reliability study conducted specifically for this study, an agreement (reliability) of 94% and 96% was achieved, respectively. The first expert disagreed on 37 sentences, and reliability was calculated as = 634 / 634 + 37 = 0.94. The second expert disagreed on 29 sentences, and reliability was calculated as = 642 / 642 + 29 = 0.96. These calculations showed that the desired level of reliability was achieved in the study.

Stage 5: Transferring Data to SPSS Package Program for Digitizing Qualitative Data

After a total of 671 sentences were identified and 7 conceptual categories formed by in-sentence explanations were developed, all data were transferred to the SPSS statistical program and their frequencies (f) and percentages (%) were calculated.

Findings

According to the general findings of this study, a total of 671 sentences containing explanations about water were identified in the 9th, 10th, 11th and 12th grade high school biology textbooks and classified under 7 categories (Table 2). The top ten of these categories were: Water as a substance in the **structure** of organisms (25.19%), Water as a **habitat** for organisms (21.16%), Water as a substance involved in **chemical reactions** (16.9%), Water as a human **health** factor (13.85%), Water as an essential **requirement** for organisms (9.99%), Water as an **environmental problem** factor (9.10%) and Water as a **scarcity** factor (3.72%). In addition, the types and frequencies of water-related concepts in each category are shown in Table 3. It should be noted that at least three or more repeated concepts were included in this table.

Table 2. Categories of sentences with explanations about water in secondary school biology textbooks

Categories		n	%
1	Water as a substance in the **structure** of organisms	169	25,19
2	Water as **a habitat** for organisms	142	21,16
3	Water as a substance involved **in chemical reactions**	114	16,99
4	Water as a human **health** factor	93	13,85
5	Water as an essential **requirement** for organisms	67	9,99
6	Water as **an environmental problem** factor	61	9,10
7	Water as a **scarcity** factor	25	3,72
Total		671	100

Category 1. Water as a Substance in the Structure of Organisms

This dominant category contained 169 sentences (25.19%). This category focused on descriptions of water found in the cells, tissues, and organs or body systems of organisms. In particular, water in the roots, stems and leaves of plants, as well as water carried in plant vascular bundles, was an important component of this category.

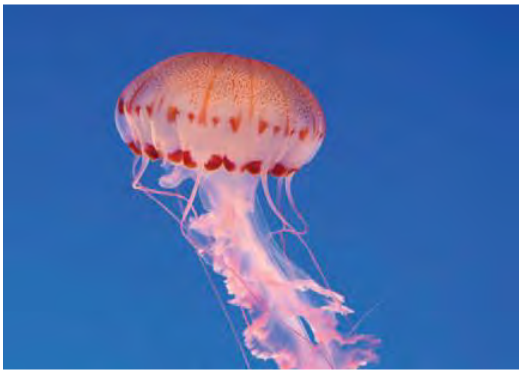

Figure 1. Jellyfish

For example: "*Plants living in arid or desert environments have storage parenchyma, called succulent parenchyma, which helps store water* (Book D, p.131)."

Table 3. Water-related concepts in secondary school biology textbooks

Category	Related biological concepts	f	%
1.“ Water as a substance in the structure of organisms”	“Water”132, “Cell”49, “Plant”40, “Leaf”24, “Xylem”23, “Mineral”23, “Water loss”21, “Transport”19, “Transpiration”16, “Tissue”15 , “Root”15, “Stem”14, “Body”14, “Stoma”13, “Substance”12, “Environment”11, “Absorption”11, “Acid”10, “Salt”10, “Vitamin”10 , “Steam”9, “Osmosis”9, “Ion”8, “Molecule”8, “Osmotic pressure”8, “Hormone”8, “Food”8, “Light”7, “Air”7, “Hydatode” 7, “Soil”6, “Organism”6, “Waste”6, “Base”6, “Turgor”6, “Root pressure”5, “Life”5, “Cuticula”5, “Vacuole”5, “Cohesion ”5, “Protein”5, “Water balance”5, “Guttation”5, “Gas”5, “Adhesion”4, “Hypertonic Environment”4, “Cell membrane”4, “Cytoplasm”4, “Synthesis”4 , “ATP”4, “Photosynthesis”4, “Glucose”4, “Lenticel”4, “Liquid”4, “Aminoacid”3, “Active transport”3, “Enzyme”3, “Kidney”3, “Evaporation” 3, “Cactus”3, “Desert”3, “Carbon dioxide”3, “Blood pressure”3, “DNA”3, “RNA”3, “Plasmolysis”3, “Selectively permeable membrane”3, “Sodium”3, “Seed”3, “Organ”3, “Reaction”3, “Fruit”3, “Poison”3, “Density”3, “Trichome”3.	739	24,49
2.“Water as a habitat for organisms”	“Water”120, “Life”41, “Organism”34, “Ecosystem”27, “Environment”24, “Plant”18, “Air”17, “Earth”17, “Fish”17, “Soil”14, “Atmosphere”13, “Light”11, “Species”11, “Body”10, “Freshwater”9, “Temperature”9, “Sea”9, “Adaptation”8, “Algae” 7, “Lake”7, “Animal”7, “Leaf”7, “Mineral”7, “Substance”7, “Carbon Dioxide”7, “Bird”6, “Cell”6, “Seaweed”6 , “Respiration”6, “Ocean”6, “Oxygen”6, “Ant”6, “Frog”5, “Reptile”5, “Coral”5, “Species diversity”5, “Wind”5, “Evaporation”4, “Hunting”4, “Insect”4, “Food”4, “Phytoplankton”4, “Turtle”4, “Transpiration”4, “Total water”4, “Gill”4, “ Climate”4, “Community”4, “Whale”3, “Energy”3, “Photosynthesis”3, “Sun”3, “Dolphin”3, “Türkiye”3, “Water cycle”3, “Cnidaria”3, “Protista”3, “Chloroplast”3, “pH”3, “Sal”3, “Organ”3, “Heat”3, “Root”3, “Amoeba”3, “Muscle”3, “River ”3, “Salt”3, “Condensation”3.	629	20,84
3.“Water as a substance involved in chemical reactions”	“Water”96, “Reaction”43, “Carbon Dioxide”27, “Molecule”25, “Substance”21, “Photosynthesis”20, “Oxygen”18, “Acid”17, “Catabolism”14, “Chemical bond”14 , “Enzyme”14, “Energy”13, “Light”12, “Cell”11, “Aerobic respiration”10, “Hydrogen”11, “ATP”9, “Food”9, “Glucose”9, “Electron” 8, “Fat”8, “Production”8, “Plant”7, “Chlorophyll”7, “Atom”6, “Vitamin”6, “Synthesis”5, “Atmosphere”5, “Bacteria”5, “Compound” 5, “Cell membrane”5, “Density”5, “Phospholipid”5, “Anaerobic respiration”4, “Galactose”4, “Ion”4, “Tissue”4, “Respiration”4, “Metabolism”4, “ Chloroplast”4, “Salt”4, “Organism”3, “Phosphorylation”3, “Hydrogen sulfide”3, “Fermentation”3, “Photolysis”3, “Product”3, “Environment”3, “Scientist”3 , “Proton”3, “Protein”3, “Digestion”3, “Consumption”3, “Fructose”3, “Hydrogen peroxide”3.	562	18,62
4.“Water as a human health factor”	“Water”41, “Ion (electrolyte)”19, “Blood”18, “Disease”18, “Nutrition”16, “Absorption”16, “Body”13, “Drinking water”12, “Enzyme” 12, “Gastric juice”11, “Vitamin”11, “Urine”10, “Hormone”10, “Intestine”10, “Matter”9, “Digestion”9, “Acid”9, “Cell” ”8, “Osmotic pressure”8, “Nutrition”7, “Stomach (Stomach)”7, “Water loss”7, “Cleaning”7, “Water consumption”6, “Thirst”6, “Exercise ”5, “Blood pressure”5, “Mineral”4, “Protein”4, “pH”4, “Eating”4, “Coffee”4, “Need”4, “Texture”4, “Diarrhea”4, “Bacteria”4, “Kidney”4, “Waste”4, “Liquid”4, “Temperature”4, “Drinking water”4, “Fruit”4, “Diabetes”3, “Environment”3, “Skin”3 , “Feces”3, “Pancreas”3, “Hypothalamus”3, “Fat”3, “Salt”3, “Constipation”3, “Chlorine”3, “Health”3, “Sodium”3, “Water balance” 3, “Total water”3, “Fresh water”3, “Water pollution”3.	418	13,85
5.“ Water as an essential requirement for organisms”	“Water”68, “Plant”39, “Soil”23, “Need”22, “Mineral”22, “Root”14, “Leaf”12, “Food”9, “Tree”8, “Life”8, “Organism”7, “Substance”6, “Fungus”6, “Cloud”5, “Air”5, “Cell”5, “Nitrogen”4, “Ion”4, “Salt”4, “Germination”3, “Absorption”3, “Photosynthesis”3, “Animal”3, “Hypha”3, “Hormone”3, “Human”3, “Xylem”3, “Oxygen”3, “Synthesis”3, “Environment”3.	304	10,07
6.“ Water as an environmental problem factor”	“Water”29, “Waste”19, “Soil”16, “Organism”16, “Environment”14, “Water pollution”13, “Earth”11, “Wind”6, “Light”6, “Purification”6 , “Industry”6, “Pollutant”5, “Acid rain”5, “Agriculture”5, “Habitat loss”5, “Erosion”5, “Ecosystem”5, “Environmental problem”5, “Climate change”5, “pH”5, “Poison”5, “Extinction”4, “Heavy metal”4, “Human”4, “Plant”4, “Acid”4, “Recycling”4, “Air pollution”4, “Temperature”4, “Reproduction”4, “Fire”4, “Life”4, “Nitrogen”4, “Environmental pollution”4, “Substance”3, “Enzyme”3, “Atmosphere” 3, “Radioactive pollution”3, “Garbage”3, “Degradation”3, “Fish”3, “Steam”3, “Phosphorus”3, “Rain”3, “Sea”3, “Drinking water” 3, “Carbon footprint”3, “Metal”3, “Hunting”3, “Forest”3.	292	9,68
7.“ Water as a scarcity factor”	“Water”15, “Water footprint”11, “Earth”6, “Türkiye”5, “Fresh water”5, “Human”4, “Glacier”4, “Total water”4, “Consumption”4, “ Production”4, “Water scarcity”3, “Land”3, “Ocean”3, “Sea”3.	74	2,45
Total		3018	100

The fact that approximately two-thirds of the structure of single-celled organisms, fungi, plants and animals consists of water, and the issues such as how water is taken into an organism, where it is located and how it is excreted were evaluated in this category. The examples are as follows:

"98% of the jellyfish body consists of water (Figure 1) (Book A, p.17)*",*

"The most abundant component in all organisms is water (Book A, p.28)*",*

"70%-90% of the cytoplasm is water (Book A, p.96)*",*

"Many land animals have waterproof outer surfaces to reduce the loss of body water (Book B, 145),

"Thus, the water and ion balance of body fluids is maintained, blood pressure and blood volume increase (Book C, p.171)*",*

"Most of the cytoplasm of plant cells consists of water (Book D, p.161)*".*

In the sentences in this dominant category, 75 biological concepts were associated with water. These concepts were repeated 739 times (24.49%). Among these, "Water" (132), "Cell" (49), "Plant" (40), "Leaf" (24), "Xylem" (23), "Mineral" (23), "Water loss" (21), "Transport" (19), "Transpiration" (16), "Tissue" (15) and "Root" (15) were the most frequently associated biological concepts (Table 3). As can be seen in Table 3, the concepts associated with water in this category addressed water as a substance in the structure of organisms.

Category 2. Water as a Habitat for Organisms

This second category contained 142 sentences (21.16%). This category focused on explanations about the water in which organisms live. In particular, water was discussed as the natural habitat of aquatic and amphibian organisms living in saltwater ecosystems such as the sea and freshwater ecosystems such as lakes. For example, "Water is the habitat of many living creatures such as algae, corals, fish, dolphins and whales (Book A, p.28)".

Aristotle's classification of animals in ancient times as animals living in water and on land was the most important explanation representing this category. Explanations about biomes with unique living species and the impact of water on biodiversity in aquatic ecosystems were also discussed in this category. The examples are as follows:

"*In his classification, Aristotle grouped living things into two main groups as plants and animals, and then divided them into subgroups, classifying plants as grasses, shrubs and trees according to their structure and size, and animals as those living in water and on land and those that fly* (Book A, p. 139)",

"*Some of the archaea live in hot spring waters and volcano mouths* (Figure 2) (Book A, p.156)",

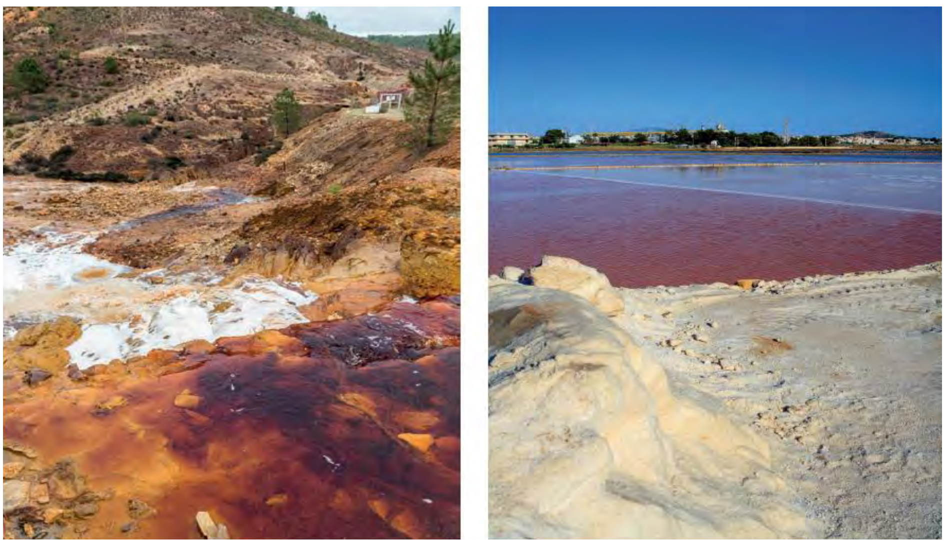

Figure 2. Archaea can survive in extreme environmental conditions.

"*Large-scale land or water ecosystems with distinctive climate characteristics and living species are called biomes* (Book B, p.139)",

"*Species diversity and distribution of communities in aquatic ecosystems depends on the depth, cleanliness, light transmittance of water and its distance from the shore* (Book B, p.211)",

"*Aquatic plants do not have stomata in the parts that remain in water* (Book D, p.136)."

In the sentences in this category, 68 biological concepts were associated with water. These concepts were repeated 629 times (20.84%). Among these, "Water" (120), "Life" (41), "Organism" (34), "Ecosystem" (27), "Environment" (24), "Plant" (18), "Air" (17), "Earth" (17), "Fish" (17) and "Soil" (14) were the most frequently associated biological concepts (Table 3). As can be seen in Table 3, in this category, the biological concepts associated with water reflected the idea that water is a habitat for many living organisms.

Category 3. Water as a Substance Involved in Chemical Reactions

This third category contained 114 sentences (16.99%). This category focused on explanations about water that plays a role in chemical reactions that usually occur in vivo and sometimes in vitro. Water molecules that react and emerge as reaction products, especially in digestion, cellular respiration and photosynthesis reactions, were described in this category.

For example, "*The basic elements that play a role in photosynthesis in photosynthetic eukaryotes, other than carbon dioxide and water, are chloroplast, light energy and pigments* (Book D, p.78)."

Water, which plays a role in enzymatic reactions, energy conversion reactions, catabolic and anabolic reactions occurring in water, was the subject of this category. The examples are as follows:

"*...During the reaction, three ester bonds are formed between glycerol and fatty acids and three molecules of water are released* (Book A, p.42)".

"*...The catalase enzyme in these cells breaks down millions of hydrogen peroxide molecules into water and oxygen every second, rendering them harmless* (Figure 3) (Book A, p.52)",

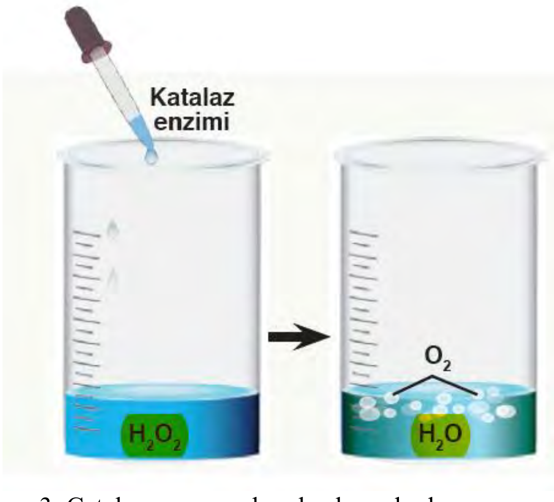

Figure 3. Catalase enzyme breaks down hydrogen peroxide

"The synthesis of organic substance from inorganic substances such as carbon dioxide and water with light energy is called photosynthesis, and the producers of photosynthesis are called photoautotrophs (Book B, p,146)",

"The hydrolysis of ATP with water to release the energy in its structure is called dephosphorylation (Book D, p.72)".

In the sentences in this category, 55 biological concepts were associated with water. These concepts were repeated 562 times (18.62%). Among these, "Water" (106), "Reaction" (43), "Carbon Dioxide" (27), "Molecule" (25), "Substance" (21), "Photosynthesis" (20), "Oxygen" (18), "Acid"(17), "Catabolism"(14), "Chemical bond"(14) were the most frequently associated biological concepts (Table 3). As can be seen in Table 3, in this category, biological concepts associated with water reflected the role of water in chemical reactions. The concepts such as hydrolysis, dehydration, photolysis and fermentation were also covered in this category.

Category 4. Water as a Human Health Factor

This fourth category contained 93 sentences (13.85%). This category focused on the importance of water in human health and environmental health. In particular, the importance of water in homeostasis and the effects of drinking water on the digestive and circulatory systems were addressed in this category. For example, "*The balance of intake and excretion of water required to maintain homeostasis in the body is carried out by the kidneys* (Book C, p.169)".

Water hygiene means that water is suitable for health. In this category, water hygiene was defined as a health requirement not only for drinking water, but also for water used for exercise, cooking and cleaning. The examples are as follows:

"To protect against viral diseases, hands should be washed thoroughly with soap and plenty of water before and after eating. (Figure 4) (Book A, p.195)",

Figure 4. To protect from diseases, hands should be washed with plenty of water and soap.

"*Cold water therapy, commonly known as ice bath, is one of the most common recovery methods used by athletes after competitions or trainings* (Book C, p.69)",

"Consuming fibrous foods, especially fruit, and taking the daily required amount of water prevents constipation (Book C, p.110)",

"*To maintain a healthy digestive system, it must be ensured that the food consumed and the water drunk are clean* (Book C, p.110)",

"Excessive intake or loss of water can cause death (Book C, p.166)",

In the sentences in this category, 58 biological concepts were associated with water. These concepts were repeated 418 times (13.85%). Among these, "Water" (41), "Ion" (19), "Blood" (18), "Disease" (18), "Food" (16), "Absorption" (16), "Body" (13), "Drinking water" (12), "Enzyme" (12), "Gastric juice" (11) were the most frequently associated biological concepts (Table 3). As can be seen in Table 3, in this category, the biological concepts associated with water reflected the role of water on human health.

Category 5. Water as an Essential Requirement for Organisms

This fifth category contained 67 sentences (9.99%). This category focused on water as an essential requirement for living organisms. In particular, the absolute need for water in order for organisms to maintain their vital activities and to continue their generation was addressed in this category. For example, "*All living things need water to carry out their metabolic activities* (Book B, p.144).

In this category, it was discussed that water is the most important inorganic substance required for biological structures, that all organisms living both on land and in water depend on water, that water is a necessity in enzymatic reactions, and that water is the best solvent. The examples are as follows:

"*Giraffes use their legs as well as their necks to bend down sufficiently when feeding or drinking from a source close to the ground.*(Figure 5) (Book A, p.187)",

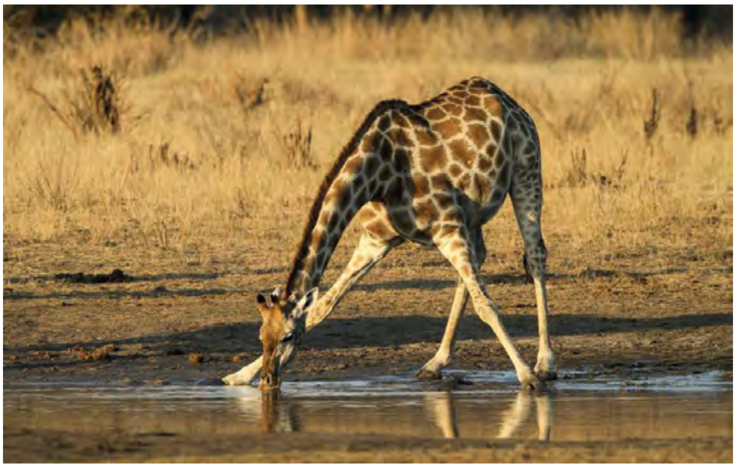

Figure 5. Giraffes spread their front legs sideways when drinking water.

"*Water is the most important inorganic substance necessary for the formation of biological structures and the realization of vital activities* (Book A, p.28)",

"Plants need water for photosynthesis (Book A, p.28)",

"Humans meet their water needs from drinks, food and water produced during metabolic activities (Book A, p.30)",

"*Water is vital for terrestrial organisms* (Book B, p.145)",

"The substances such as nitrogen, carbon, water, oxygen, sulfur and phosphorus are used cyclically for the continuity of life in nature (Book B, p.156)",

"*For living things, water is a good solvent and essential for the continuity of life* (Book B, p.159",

"*The continuity of human life depends on the regulation of the gain or loss of water and dissolved ions* (Book C, p.166)",

"*The environmental factors necessary for germination are suitable temperature, sufficient water and oxygen* (Book D, p.180)".

In the sentences in this category, 30 biological concepts were associated with water. These concepts were repeated 304 times (10.07%). Among these, "Water" (68), "Plant" (39), "Soil" (23), "Need" (22), "Mineral" (22), "Root" (14), "Leaf" (12). , "Food" (9), "Tree" (8), "Life" (8), "Organism" (7) were the most frequently associated biological concepts (Table 3). As can be seen in Table 3, in this category, biological concepts associated with water reflected the idea that water is an essential component for living organisms.

Category 6. Water as an Environmental Problem Factor

This sixth category contained 61 sentences (9.10%). This category focused on the relationship between environmental problems and water. In particular, the effects of water pollution as an environmental problem on the diversity and population of living organisms, as well as biodiversity and habitat loss due to water pollution were addressed in this category. For example:

"*The most important effect of air pollution, water pollution, soil pollution, radioactive pollution, sound pollution, acid rain, global climate change, erosion, destruction of natural habitats and forest fires as environmental problems is that they cause the extinction of living species that cannot adapt to the changing environment* (Book B, p.178)".

Since water is one of the most important environmental factors in terms of human health, issues such as determining whether the water is hygienic and whether it is suitable for health in terms of the minerals it contains by water analysis, and issues such as acid rain, pesticide contamination of water, heavy metals entering the water and negatively affecting the food chain were also addressed in this category. The examples are as follows:

"*...This system, which is the most advanced treatment method in technology, is used in the water treatment plants of municipalities and large industrial organizations to treat wastewater to meet the standards* (Book B, p.182)",

"*Acid rain lowers the pH of water and soil, which harms organisms, disrupts the cycle of matter in nature and the ecological balance* (Book A, p.31)".

"Some of these toxic substances are broken down by microorganisms in nature to become less harmful, while others accumulate in environments such as soil and water since they cannot be broken down (Book B, p.155)",

"Pesticides are dispersed into the environment by factors such as rainwater and wind, and many of them remain intact in nature for a long time (Book B, p.155)",

"*Heavy metals in soil and water are involved in the food chain and often bioaccumulate to a level that reaches harmful levels in living things in the upper trophic levels* (Book B, p.155)",

"*Acid rain lowers the pH value of water and soil and increases the solubility of toxic substances and heavy metals in the environment* (Figure 6) (Book B, p.175)",

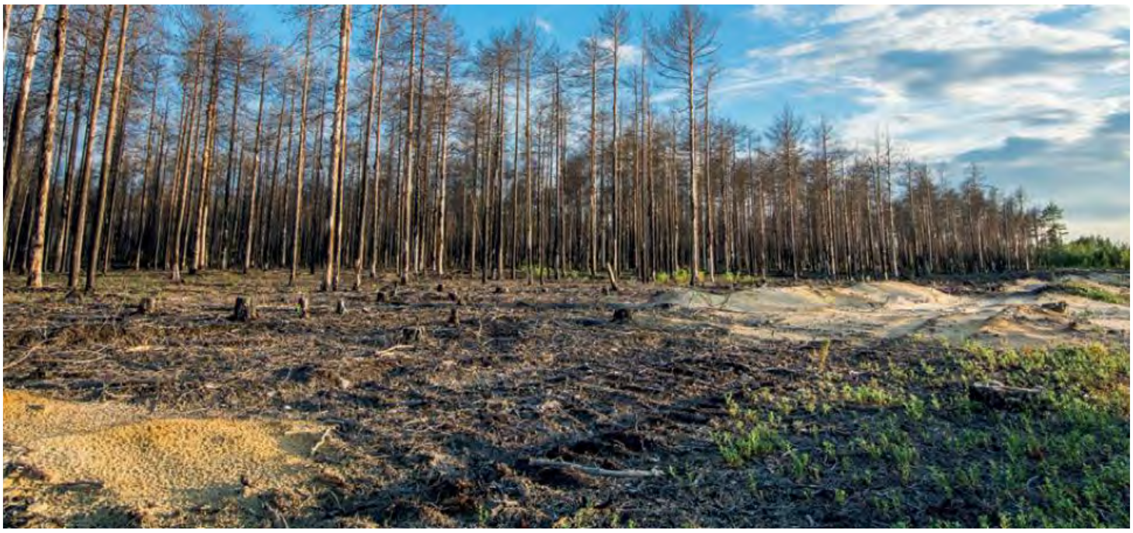

Figure 6. Negative effects caused by acid rain.

"*Heavy metals enter soil and water, creating negative effects on the food chain* (Book B, p.198)".

In the sentences in this category, 50 biological concepts were associated with water. These concepts were repeated 292 times (9.68%). Among these, "Water" (29), "Waste" (19), "Soil" (16), "Organism" (16), "Environment" (14), "Water pollution" (13), "Earth" (11), "Wind" (6), "Light" (6), "Treatment" (6), "Industry" (6), "Pollutant" (5) were the most frequently associated biological concepts (Table 3). As can be seen in Table 3, the explanations in this category reflect the issue of how water pollution, as an environmental problem, threatens the future of humankind.

Category 7. Water as a Scarcity Factor

This last category contained 25 sentences (3.72%). This category focused on the fact that water in nature that is drinkable or usable by living organisms is decreasing. In particular, the issue of how famine and diseases that are likely to occur as a result of the decrease in available water threatens people was discussed in this category. For example,

"*The global population is predicted to reach 9 billion by 2050, and 65% of the population will face severe water shortages* (Book B, p.180)".

The fact that increasing water shortage poses mortal threats to both humanity and all ecosystems in the biosphere, that Türkiye will be greatly affected by this problem in the future, and reducing water footprint and saving water were also addressed in this category. The examples are as follows:

"*The availability of sufficient and high quality water is a fundamental element of humanity's food security and freshwater ecosystems* (Book B, p.180)",

"*Contrary to popular belief, Türkiye is a country on the edge of water scarcity* (Book B, p.180)",

"*Between 1990 and 2010, the total amount of water consumed increased by 40.5%* (Book B, p.180)",

"*Urban use, agricultural irrigation, energy and production activities put great pressure on water resources* (Book B, p.180)",

"*However, in arid conditions, water is the most important stress factor for plants* (Book D, p.125)".

In the sentences in this category, 14 biological concepts were associated with water. These concepts were repeated 74 times (2.45%). Among these, "Water" (15), "Water footprint" (11), "Earth" (6), "Türkiye" (5), "Fresh water" (5), "Human" (4), "Glacier" (4) were the most frequently associated biological concepts (Table 3). As can be seen in Table 3, the explanations in this category reflected the issue of how water-related shortages threaten the future of humankind.

Discussion and Conclusion

Improving the explanations and understanding of water in textbooks in line with the curriculum is a special focus of biology teaching. Therefore, in this article, we discussed how water was emphasized as a curriculum subject in biology textbooks and we introduced a category to conceptualize understandings about water. These categories were: water as a substance in the structure of organisms, water as a habitat for organisms, water as a substance involved in chemical reactions, water as a human health factor, water as an essential requirement for organisms, water as an environmental problem factor and water as a scarcity factor (Table 2). There are a total of 15 water-related learning outcomes in the secondary school biology course curriculum on the subjects of "Basic Compounds in the Structure of Living Things", "Ecosystem Ecology and Current Environmental Problems", "Circulatory Systems", "Community Ecology" and "Photosynthesis". According to the results of the textbook content analysis, it is seen that the relationships between concepts were well structured in the categories of water as a substance in the structure of organisms, water as a habitat for organisms, water as a substance involved in chemical reactions and water as a human health factor (Table 3). Especially in the category of water as a human health factor, the relationships between water and health were explained in detail. It is important that water, which is an essential substance for all organisms to survive and continue their generatios, is of good quality and suitable for health. The quality of water can be determined by different water analysis methods. The properties of water suitable for human health and water-cleanliness-health-disease relationships were detailed in the texts.

Examining the categories put forward in this study, it was seen that the concept of water in biology textbooks was presented in line with the curriculum in accordance with the target achievements, and the key concepts were given literally (Table 3). However, we believe that water and similar topics in textbooks should be addressed in line with the systems thinking approach. Systems thinking offers a framework to reveal the interrelationships between objects rather than objects, and the order of change and processes rather than facts. In this study, while the concept of water was explained in secondary school biology textbooks, there were not enough statements explaining the complex interconnections of all living systems with each other. According to previous studies, when students do not use systems thinking strategy while describing the water cycle, they often ignore the components of the biosphere such as humans, plants and animals (Ben-Zvi Assaraf & Orion, 2005b). For example, the transfer of water from plants to the atmosphere involves energy that will facilitate the transition of water from a liquid to a gaseous state. Evapotranspiration occurs when the liquid water in plant leaves is heated by the sun and enters the atmosphere as water vapor. A similar process occurs when animals release liquid water through respiration, sweating and waste production. The energy absorbed by water molecules causes a change of state in the atmosphere that transfers radiant energy to kinetic energy (Pitman, 2003).

The textbooks have well-structured explanations of water-related scientific concepts in parts, but the coherence between these parts is weak. A systems thinking approach is crucial for a good understanding of topics such as water and its cycle. Studies conducted with primary and secondary school students show that they generally do not think of water in dynamic, cyclical systems (Ben-Zvi Assaraf & Orion, 2005b). Students often show little awareness of the connections between water in one place and water in another. Students tend to focus on the atmospheric components of the water cycle, ignoring groundwater, surface water, and water-related processes in biotic systems (Ben-Zvi Assaraf & Orion, 2010).

In the biology textbooks examined, surface water rather than groundwater was addressed in many texts in different categories. Mostly, explanations about visible water such as sea, lake and rivers stood out. Previous studies indicated that there were learning difficulties related to invisible, abstract groundwater. Therefore, detailed explanations of the connections between groundwater and surface water and the relationships between concepts related to the water cycle as a system in the biosphere could have been included. This is important considering students' misconceptions about groundwater (Sadler et al., 2017). According to previous research results, students often have difficulty understanding water and the abstract processes of the water cycle. For example, many students think that groundwater is found in underground sewers and have misconceptions about the size of aquifers. They also view groundwater as a dead end in the hydrological cycle (Ben-Zvi Assaraf & Orion, 2005a; 2010; Covitt et al., 2009; Dickerson et al., 2005; Dickerson, Penick, Dawkins, & Van Sickel, 2007).

It is important to consider environmental literacy strategies in general and water literacy strategies in particular when preparing biology textbooks. Although the analysis of water literacy in textbooks is a topic that should be investigated in the future, indicators of water literacy in the books are weak. According to previous research, there are four levels for advancing the learning outcomes of environmental literacy related to water systems.

At the first level (force dynamics), students' explanations of water tend to emphasize the role of humans in transporting and using water. At the second level, students continue to emphasize the role of actors in the movement of water but also begin to incorporate mechanisms and awareness of the physical world. The third level is characterized by partial descriptions of the types of aquatic science ideas that are prominent in school science. Thus, students begin to explain the properties of water and parts of the water cycle, but their explanations are often incomplete and not entirely accurate. The fourth and highest level of progress involves model-based explanations of aquatic science. At this level, students can conceptualize water and related processes at multiple scales (from molecular to global) in multiple locations (earth, surface, atmosphere, and human-made systems). The progress in water systems learning proposes five elements of students' explanations of water that are represented in each of the four successive levels. These elements are (1) structures and systems, (2) scale, (3) scientific principles, (4) representations, and (5) dependency and human action (Sadler et al., 2017).

In this study, it was observed that some of the causes and possible effects of water scarcity were mentioned superficially in biology textbooks. The category "water as a scarcity factor" was represented last (Table 2). The relationship between water scarcity and drip irrigation, which is important in making agricultural irrigation sustainable, and agricultural activities according to crop type were not discussed. The continuation of life on earth depends on the protection of usable water quality and the healthy sustainability of the water cycle. Therefore, explanations about water scarcity can be included more. In order to raise environmentally friendly and water literate individuals, the place, importance and ratio of usable water in the water cycle should be taught well, because Türkiye is a country suffering from water scarcity worldwide.

Explanations about water in textbooks should encourage students to think systemically. Hmelo-Silver and Pfeffer (2004) indicated that complex systems are common in the outside world and that making sense of such systems is challenging. Systems thinking often requires the establishment of relationship networks between concepts related to dynamic phenomena. In this context, it is important that individuals' representations of the water system overlap with the structure and function of the system. Textbooks should contribute to this overlap.

Teachers should not rely solely on textbooks to develop students' understanding of water in relation to natural and engineered systems. Teachers should include out-of-school learning environments in biology. It is known that water-related subjects in the traditional curriculum do not provide innovative teaching that will reduce the water footprint of individuals and raise the standard of water literacy (Irgar, 2020). It would be useful to design activities that students can carry out outside of school in order to associate water-related learning outcomes in the curriculum with their daily lives. Such activities should also be included in biology textbooks.

Understanding of the water system in the biosphere should enable students using textbooks to develop more complex water systems and participate in decision-making about environmental issues. There are some tips that both writers and teachers should pay attention to in their explanations about water in biology courses and textbooks. In line with the systems thinking approach, these explanations should reflect water as a system in the biosphere and refer to the changing processes of this system. Future research can be conducted on students' understanding of water beyond textbooks.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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