

Concept Instruction in Science Education

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Introduction

Science and technology are the cornerstones of the modern world and are critically important for the progress of humanity. Science focuses on understanding the principles of how nature works and acquiring new knowledge using systematic and empirical methods, while technology enhances people's lives by applying this scientific knowledge in practical ways, offering innovations. This combination has a significant impact on various fields, including healthcare, communication, energy production, and agriculture. Scientific discoveries improve the diagnosis and treatment of diseases in the field of medicine, while communication technologies facilitate global connectivity. The use of renewable energy sources in energy production provides environmentally friendly solutions, and advanced technologies in agriculture enable more efficient and sustainable production. Science and technology serve as important driving forces for economic growth. Therefore, investing in science and technology is indispensable for the development and well-being of societies. The 21st century is considered the age of science and technology, and living in this era is regarded as an indicator of a society's level of development. In this context, prioritizing science and technology is essential for societies to sustain their existence and independence. Individuals in the 21st century are expected to possess qualities such as being explorative, inquisitive, critical thinkers, innovative, continually self-improving, having effective communication skills, being entrepreneurial, and being able to integrate knowledge from various fields (Karamustafaoğlu, 2018).

In our current era, technology and technological tools have become integrated into nearly every aspect of life. Both improving economic and social conditions relies heavily on technology and its products. The development of technology and ensuring the correct use of these technologies hold special importance in the field of science (Demirci, 2017). Therefore, in the age of technology, there is a greater need to prioritize science education. Science classes can equip students with scientific thinking skills, enhance their research abilities, and provide them with the foundation to contribute to future technological advancements. The effective implementation of science education can be a critical step for the sustainability of future technological developments.

The rapid changes in science and technology have directly influenced the changing needs of individuals and society, as well as innovations and developments in teaching and learning approaches (MEB, 2018). The impact of technological and scientific advancements on the lives of individuals and communities is considered a significant topic in science education. Objective assessments can be made on subjects that affect societal and individual life, and in this context, the concept of science literacy has gained importance (Özden, 2020). Science classes can serve as an important tool in developing this literacy. These classes can provide students with skills in scientific thinking, critical thinking, problem-solving, and understanding technology. This can contribute to individuals using scientific knowledge effectively and addressing the challenges they encounter, ultimately contributing to the development of science and technology-based progress in society.

Science Teaching and Its Purpose

People have always been driven by the desire to explore nature, learn the secrets of the relationships between beings and events, control events, and benefit from nature. This desire has guided people in order to live a more comfortable and safe life. This endeavor against nature has led to the emergence of today's technology. For this reason, Natural Sciences are of great importance for the development and development of countries. Countries that want to progress in science and technology attach great importance to science education (Demirci & Mutlu, 2017).

In schools, science courses are conducted with the aim of making students scientifically literate, helping them understand the process of acquiring knowledge, and teaching them the logic of the scientific methods used in obtaining scientific knowledge (Demirbaş, 2017). Thus, the goal is for students to continue their lives as individuals who research, question, think critically, and solve problems. Considering the importance of science in the development of societies, it is of great importance to raise individuals possessing these qualities.

Children are highly sensitive to their immediate surroundings, full of energy, curious, driven by a desire to explore, and possess strong imaginations and inquisitive qualities. Science courses provide the most suitable environment to trigger these natural abilities, expand children's thought processes, and encourage them to inquire (Tezel & Bıyık, 2018).

The instructional vision of science courses has been defined in a manner that aims to cultivate individuals with scientific literacy, in alignment with the objectives of science education (MEB, 2013). The concept of scientific literacy encompasses all cognitive, affective, and psychomotor competencies that enable the understanding, monitoring, internalization, and conscious use of scientific and technological advancements, thereby enhancing an individual's quality of life and the ability to preserve the natural environment (Hastürk, 2017).

Science Curriculum and Development

Adapting to changing world conditions and all kinds of technological advancements is possible through the shaping and updating of the education system according to these changes. In our country, the Ministry of National Education creates educational curricula to keep up with these developments. These educational plans should have specific objectives. In general, the objectives that all educational programs should have can be summarized as follows (Gücüm & Kaptan, 1992).

- Creating a realistic and coherent worldview,
- Understanding and explaining the conceptual structure of science,
- Developing the skills necessary for the application of scientific methods,
- Adapting to innovations in the field of science and technology,
- Fostering an effective sense of citizenship for society.

The Science Curriculum, published in 1926, was not only the first comprehensive program of the Republic period but also based its foundation on Dewey's concepts of "Life Knowledge, Collective Instruction, and Trade School" (Arslan, 2007).

In 1936, 1948, 1968, 1980, 1992, 2004, and 2013, science education programs were updated in accordance with the changing education systems and technological advancements. Since 1980, constructivist-based teaching programs have been adopted in many countries around the world. In our country, significant changes were also made to the science education program in 2004. It was observed that this program was carefully prepared to meet the requirements of the constructivist approach (Anılan & Atalay, 2020).

In the parallel with the updates made in the teacher training process, curriculum have also been updated. Most recently, in 2018, changes were made to the science education program, adopting a spiral approach for different topics and grade levels, and emphasizing recurring achievements and explanations. Additionally, it emphasized the acquisition of targeted learning outcomes in a single stage, along with a holistic perspective (Anılan & Atalay, 2020; MEB, 2018).

The main objectives of the science course curriculum published in 2018 are as follows (MEB, 2018):

1. Providing fundamental knowledge about astronomy, biology, physics, chemistry, earth and environmental sciences, and science and engineering applications.
2. Encouraging the adoption of scientific process skills and a research approach in the process of exploring nature and understanding the human-environment relationship, enabling the generation of solutions to problems encountered in these fields.
3. Raising awareness of the mutual interaction between individuals, the environment, and society; fostering a sense of sustainable development related to society, the economy, and natural resources.

4. Taking responsibility for everyday life issues by using knowledge based on science, scientific process skills, and other life skills.
5. Developing awareness of career opportunities related to science and entrepreneurship skills in the field of science.
6. Assisting in understanding how scientists create scientific knowledge, the processes through which this knowledge passes, and how it is used in new research.
7. Stimulating interest and curiosity in events occurring in nature and the immediate environment, fostering attitudes.
8. Emphasizing the importance of safety in scientific work and creating an awareness of safe practices in scientific research.
9. Developing the ability to make judgments, scientific thinking habits, and decision-making skills using socio-scientific topics.
10. Promoting the adoption of universal moral values, national and cultural values, and scientific ethical principles.

Concepts and Their Characteristics

What is a Concept?

There are many definitions of the concept. One of these definitions is made by Tokcan (2021) as follows: "A concept represents a category used to group similar objects, people, events, ideas, and processes." According to Senemoğlu (2020), the definition of a concept is as follows: "Concepts not only enable individuals to distinguish a group of entities, events, ideas, and processes from other groups but also help them establish relationships with other groups, entities, events, ideas, and processes. For example, concepts like psychology, sociology, educational psychology distinguish each field of science from others and also assist in establishing the relationships between one field of science and other fields. These concepts guide us in understanding the connections between different disciplines and help us evaluate knowledge more comprehensively. Concepts play a significant role in structuring, understanding, and expressing our thoughts and assist in organizing knowledge in a meaningful way."

Concepts are the naming of common characteristics by combining facts, events, and objects. Concepts are the fundamental units of our thoughts and shape our thinking process. Through concepts, we create meaning by thinking, speaking, and writing. These concepts serve as our means of understanding and communication because they help us organize and express the complex world in an understandable way by identifying common features. Concepts aid us in making sense of knowledge and expanding our worldview (Şimşek, 2019).

Concepts are the fundamental building blocks of an individual's thought processes and are important elements that make up their cognitive structure (Klausmeier, 1992; cited in Özmen, 2020).

Concepts represent a form of knowledge and structure in the human mind that encapsulates variable common characteristics among different objects and phenomena. A concept is expressed with a single word and often reflects a specific meaning (Ülgen, 2004).

Upon examining the provided definitions, it is possible to say that concepts are essentially mental images. In this context, it can be said that concepts, in fact, have abstract qualities. All concepts are abstract in nature, even though some may contain concrete examples, others are entirely abstract (Şimşek, 2019). Concepts might be related to how we perceive phenomena because they are mental representations of phenomena. Therefore, concepts do not have a concrete existence.

Concepts formed in people's minds may differ from each other because concepts are shaped by their experiences. Therefore, the mental images of concepts formed in the minds of different individuals can differ. For example, when the word "table" is mentioned, an image is formed in all of our minds. This mental image can vary depending on our experiences, age, education, and other factors. Concepts can vary among individuals, different cultures, and societies. Moreover, even the characteristics of concepts we develop over time can change (Şimşek, 2019).

How we structure concepts in the educational process is essential, as concepts are interconnected. Incorrectly learned concepts can affect the proper understanding and learning of related concepts in the future and may sometimes pose a significant obstacle (Şimşek, 2019).

Based on the concept definitions provided so far, a general definition might be as follows: Concepts are mental images that are fundamental to individuals' thought processes, can be formed in the human mind, and allow for the distinguishing of individuals, groups, phenomena, ideas, or processes with similar qualities from others, as well as for establishing connections with others.

General Characteristics of Concepts

Concepts are expressed through language and are named with words or compound words. Regardless of the linguistic structures used to represent them, all concepts have characteristics such as learnability, usability, comprehensibility, prevalence, and effectiveness (Senemoğlu, 2020).

1. Learnability: The acquisition of concepts occurs at a later stage. Concrete concepts are easier to learn compared to abstract concepts.
2. Usability: Concepts have various application areas. Within these areas, some concepts are frequently used, while others are used more rarely.
3. Clarity: Concepts should be clear and understandable in a way that reaches a consensus of meaning among experts in the field.
4. Generality: Concepts are organized from general to specific.
5. Strength: Concepts become powerful when they facilitate the understanding of other concepts and problem-solving situations. In this way, they promote effective learning.

Sever (2021) summarized the general characteristics of concepts as follows: Concepts are the building blocks of knowledge, and they are generalizable. Since concepts are mental images, they are abstract in nature. They serve as the communication language of knowledge and play a role in shaping it. Additionally, they enable us to perceive

knowledge and define its boundaries. Concepts are fundamental elements that facilitate learning.

The Importance of Concepts in Science Education

Anagün & Duban (2016) stated that the purpose of science education is for learners to understand, describe, and explain natural phenomena with scientific facts throughout their educational journey. They should learn scientific methods, allowing them to analyze and explain the events they encounter through a scientific lens. Anagün & Duban (2016), following Jenkins, also convey that the aim of science education in schools is to assist students in learning some of the ways that can be used for them to understand the world.

The aim of science education is to present situations that students encounter in their daily lives in the learning environment once again, allowing them to look at these situations from a scientific perspective. It also aims to foster curiosity towards nature and nurture individuals who question, investigate, produce, and think. In this context, the goal of science education can only be achieved when students meaningfully learn the concepts taught in class. Learning abstract concepts is a more challenging process compared to concrete concepts, especially in science lessons where abstract concepts are more prevalent (Anagün & Duban, 2016). To ensure meaningful learning of the abstract concepts in science education, it is essential to make these concepts as concrete as possible.

Concept Teaching

Bacanak, Küçük, and Çepni have stated that concept teaching is a process that should be considered starting from the early years of primary education. In this process, it is highly important for students to learn fundamental abstract science concepts fully and correctly, as it will be crucial for them to understand these concepts in secondary and later stages of education (cited in Anagün & Duban, 2016). In other words, ensuring that the concepts taught in science classes are taught accurately and comprehensively from the beginning of students' education can prevent possible misconceptions in their future years and assist in their educational journey.

Concept teaching, which plays a vital role in a student's learning journey, is carried out through two different approaches (Şeker, 2010):

- Teaching Concepts through the Traditional Method (Instruction through Presentation)
- Teaching Concepts through the Modern Method (Instruction through Discovery)

In Turkey, the constructivist learning approach, initiated in pilot schools during the 2004-2005 academic year, became widespread across the country from the 2005-2006 academic year (Teyfur & Teyfur, 2012). In an education system based on the constructivist approach, it is more appropriate to use the modern method for concept teaching. This is because traditional concept teaching aims to provide students with direct information. However, according to Canpolat, starting concept teaching directly from the definition can lead to some difficulties (Canpolat & Pınarbaşı, 2002). In the

traditional method, the definition of the concept is directly provided, and students are expected to memorize it. The teacher remains in a constant transmitter role, while students passively assume a receiver role.

In modern constructivist education, students are in an exploratory, questioning, researching, problem-solving position. They are more actively involved in the teaching process. As expressed by Sever (2021), students play an active role in their learning process and construct their own learning. At this stage, teachers should consider students' individual differences and offer various teaching methods to ensure that students have access to knowledge.

Concept Teaching Levels

Senemoğlu (2020) classified the levels of concept teaching, which form the basis of cognitive development, as follows:

Concrete Level and Recognition Level Concept Teaching: At these levels, students

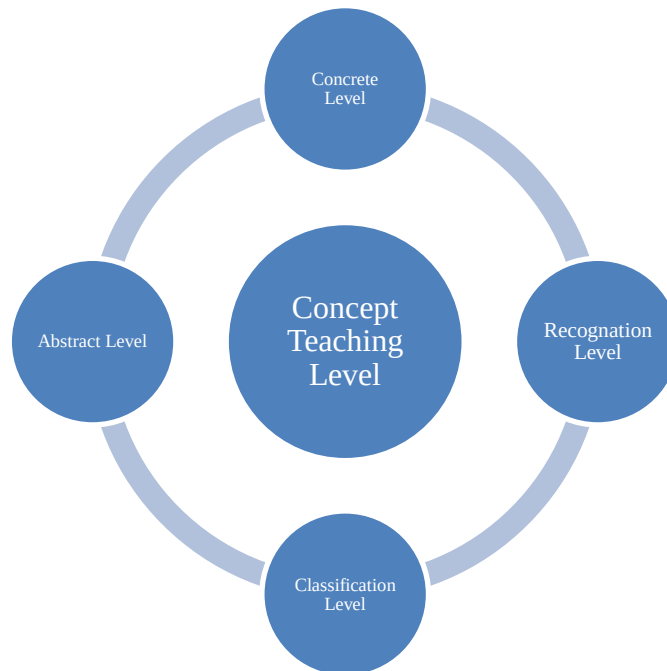


Figure 1. *Concept teaching levels diagram*

can learn many concepts in places such as family, friends, and neighborhood, which are their daily living areas. At this level, the concept itself or its picture is brought to the classroom and shown to the students. Then, the name of the item is given to the student to establish a relationship between the item and its name. After this process is done correctly, the student is given feedback. Then, the item is shown again to check the learning (Senemoğlu, 2020).

Beginning Level of Classification Concept Teaching: In this level, students are presented with at least two different examples of the concept, along with one or two examples that are not related to the concept. Then, students are encouraged to establish a relationship between the concept and its name. Opportunities are provided for

students to discover the critical features of the concept. Definitions are provided in a way that helps students understand the concept, and then students are given new examples and examples that are not appropriate for the concept, so that they can define and classify the concept in different situations. Finally, feedback is given to students (Senemoğlu, 2020).

Advanced Classification and Abstract Level Concept Teaching: Students are supported by providing examples and non-examples related to the concept as they prepare to learn the concept. Students are helped to identify examples and non-examples and develop strategies. Students are encouraged to acquire the names and properties of concepts. Opportunities are provided for students to use the concepts, and then feedback is given (Senemoğlu, 2020).

Techniques Used in Concept Teaching

Concept Maps

Concept maps are a learning strategy that focuses on the classification and visualization of information, thoughts, and attitudes around a key concept. Concept maps are visual tools that show the relationships and hierarchies between concepts. They allow students to organize how they relate concepts in their mental worlds in a concrete and visual way (Gödek et al., 2019). From this perspective, it can be said that it is a useful technique for both students and teachers. While creating concept maps, students have the opportunity to develop the ability to sort concepts in a logical order and relate each concept (Tokcan, 2021). Teachers, on the other hand, can easily identify gaps and misunderstandings thanks to the visual presentation of concept maps (Gödek et al., 2019).

The benefits of concept maps can be listed as follows (Kaptan, 1998):

- Helps to make information meaningful and to ensure its sustainability.
- Supports the visual presentation of the subject to be conveyed.
- Allows for the organization of mixed information.
- Provides the opportunity to observe and summarize the entire content of the lesson.
- Ensures that the core concept is clearly defined.
- Helps to identify the relationships between the core concept and other concepts.
- Provides the opportunity to notice the conflicts, differences, and differences between concepts.
- Makes confusing concepts clear.
- It is a tool that can be used in different lessons and teaching processes.
- Can be used at every stage of the lesson.
- Contributes to the student taking an active role.

Concept Networks

Concept networks are schematic tools called semantic networks that represent students' perceptions, thoughts, and concepts and principles in written teaching materials in a consistent way (Ayas, 2019).

The reasons for using concept networks in the educational process can be listed as follows (Ayas, 2019):

- To reveal and evaluate students' old knowledge,
- To show the relationships between concepts,
- To create new relationships between concepts and group them,
- To facilitate the collaboration of teachers and students,
- To enable students to review the information they have learned and to build relationships between them,
- To contribute to students' better thinking and better understanding of the subject.

Concept Puzzles

According to the Turkish Language Institution, a puzzle is defined as a game that is organized in various ways and aims to find by thinking and researching. In cases where concepts are not known enough, what is told and read in books may be boring for students. Including concept puzzles at the beginning of the unit will help to eliminate this situation. Students will have the opportunity to develop their independent learning skills thanks to concept puzzles (Tokcan, 2015).

The benefits of using concept puzzles in teaching can be listed as follows (Ayas, 2019):

- Ensuring the learning and sustainability of concepts,
- Providing a learning environment where students are active,
- Making verbal lessons more interesting and enjoyable,
- Making students mentally active and gaining practical thinking skills,
- Ensuring collaborative learning between students in case of group work,
- Providing students to realize independent learnings in the teaching process and develop problem-solving skills.

Conceptual Change Texts

Conceptual change texts are texts that help students to recognize their existing conceptual misconceptions and reveal the contradictions between scientific knowledge and students' mental misconceptions. These texts are aimed at developing students' conceptual understanding by eliminating misconceptions (Kılıçoğlu, 2020; cited in Akbaş, 2021).

Conceptual change texts are an important teaching tool or material in terms of providing meaningful learning using different methods. It is seen that the teaching carried out in this way is very useful in terms of awareness, meaningfulness, and sustainability (Yalçinkaya & Karaca, 2021).

In conceptual transformation texts, a scenario is first presented and a question is asked accordingly. Then, common erroneous thoughts related to the presented scenario are conveyed and why these erroneous thoughts are wrong are explained with reasons and examples. After this explanation, the correct thought is presented and supported by examples (Şimşek, 2019).

Information Maps

Information maps are schematic teaching tools that show the information and relationships between these information in a graphical way in a text (O'Donell, 1994).

According to O'Donell (1994), information maps have the power to build more effective connections between thoughts than other graphic organizers. These connections can be grouped into three categories.

1. Dynamic connections express the cause-and-effect relationship.
2. Static connections describe the structural relationship between thoughts.
3. Deepening connections express the relationships that develop knowledge.

Since the summary of the text in information maps is easier to extract than in a plain text, it can help students learn concepts and information more easily. Relationships between concepts can be understood more easily. Knowing the relationship between concepts is important for storing information in the mind in a more permanent and efficient way (Görge, 2001).

Concept Cartoons

Cartooning is an art form that represents an important form of visual language that conveys messages using symbols and images and affects human emotions. Cartoons are used in various ways for educational purposes. Especially as places where humor is used effectively, they appear as tools with significant effects in learning and teaching processes in terms of their psychological effects (Tokcan, 2015).

Concept cartoons used in education have many features that differ from other cartoons. Although concept cartoons look like other cartoons that have visual features, they aim to provide opportunities for students to interpret and understand concepts instead of humorous elements (Sexton, 2010).

Concept cartoons, introduced by Brenda Keog and Stuart Naylor in 1991, are an approach that aims to support students in revealing their thoughts, encouraging their thinking skills, and developing their understanding abilities (Naylor & Keogh, 2013).

In concept cartoons, two or more characters who come together about events encountered in everyday life share questions or ideas through speech bubbles. Since concept cartoons do not directly provide the correct answer, they can help students change their existing misconceptions and misconceptions through discussion and the process of cognitive balancing (Canpolat & Pınarbaşı, 2002).

The purposes of using concept cartoons can be listed as follows, as the most frequently mentioned among teachers and teacher trainers (Gödek et al., 2019):

- Develops students' thinking skills and allows them to meet different perspectives.
- Provides support to gain the ability to ask questions for students.
- Provides a starting point to start the research and investigation processes.
- Encourages participation and increases students' motivation.
- Provides the opportunity to apply scientific concepts in everyday life.
- Makes it easy to understand by summarizing and rearranging the subject.
- Can be used in extracurricular activities such as homework and science clubs.
- Encourages families and society to be interested in science.

Characteristics of Concept Cartoons

The characteristics that should be included in concept cartoons have been listed by Naylor and Keogh as follows (Tokcan, 2015):

- Should include alternative perspectives that cause misconceptions in students identified in research.
- Should use short texts that students can understand, and concept cartoons appropriate for age groups should be presented with dialogues.
- Concept cartoons should offer alternative views that students can find logical.
- Alternative views that correspond to the misconceptions defined in research should be included in concept cartoons.
- Attention should be paid to the adaptability of scientific thoughts to everyday life to enable students to make connections between science and everyday life.
- Among alternative views, there should also be ideas that are scientifically accepted.
- Views should be presented on equal terms in a way that students will not easily reach the correct answer and can lead to scientific conflicts.
- Concepts should be presented by associating them with everyday events.
- Thoughts should be expressed in short and understandable sentences as much as possible.
- Scientific thinking style should also be included in concept cartoons.
- Thoughts in concept cartoons should be similar in terms of expression style and should avoid clichés avoided from textbooks.

- The ideas in concept cartoons should be determined as a result of research. This can increase validity and credibility.

Benefits of Concept Cartoons

In a teaching environment where concept cartoons are used, students have an active role. Concept cartoons that participate in teaching processes in line with the constructivist approach make the lesson both fun and help to reveal the understandings that students have formed in their minds about the concept because they contain characters that offer different perspectives. The benefits of concept cartoons can be listed as follows:

- Concept cartoons contribute to students' thinking skills (Keogh & Naylor, 2000).
- Concept cartoons provide opportunities for formative assessment, allowing students to discover their own ideas and teachers to prepare the learning environment in line with these ideas (Stephenson & Warwick, 2002).
- Concept cartoons are an important tool for identifying students' misconceptions because they contain misconceptions expressed comfortably (Keogh et al., 1998).

Concept cartoons provide students with alternative perspectives, allowing them to develop their ideas. It also increases students' motivation, allowing students to participate more in class (Gödek et al., 2019).

Summary

This text provides information on the importance of science education, the definition of concepts used in the field of science, and the levels of teaching in science education. Science aims to satisfy the desire to understand nature, control events, and benefit from the natural world. To fulfill this desire, objectives are set in science education, such as imparting scientific literacy, teaching the process of obtaining scientific knowledge, and developing inquiry skills.

Concepts are the fundamental building blocks of science and are at the center of the learning process. Concepts are mental images used to group and understand similar objects, events, ideas, and processes. Among the general characteristics of concepts are learnability, usability, clarity, generality, and strength.

In science education, the teaching of concepts can be carried out using traditional (teaching through presentation) and modern (teaching through discovery) methods. In the traditional method, concepts are taught directly to students with definitions, while in the modern method, students are actively encouraged to explore and understand the concepts. Due to the adoption of a constructivist approach in modern education, teaching concepts using modern methods is more commonly preferred.

Concept teaching can occur at different levels, including the concrete level, recognition level, classification level, and abstract level. Different strategies are used to teach concepts at each level, and students are guided at different levels.

Concept teaching is an essential component in helping students understand and improve their applications in the field of science. Effectively teaching concepts to students ensures the success of science education.

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