Chapter 3

In the Context of Environmental Education and Zero Waste: Metacognitive Awareness, Reasoning and TPACK Applications

Ayşegül Tongal[1]

Abstract

This chapter explores the integration of environmental education and the zero waste approach with metacognitive awareness, reasoning skills, and the Technological Pedagogical Content Knowledge (TPACK) framework. It begins by presenting the conceptual foundations of environmental education, emphasizing the need to develop environmental ethics and sustainability-oriented behaviors in response to ongoing ecological crises. Informal learning environments such as nature-based activities, ecological site visits, and science museums are highlighted as effective contexts for fostering metacognitive awareness, value-based learning, and student engagement in real-world environmental challenges. Furthermore, the chapter discusses the critical role of reasoning in enabling students to analyze environmental issues through inductive, deductive, causal, and ethical lenses. These reasoning skills are essential for cultivating critical thinking, scientific inquiry, and responsible decision-making. The TPACK model is introduced as a powerful framework for equipping teachers with the ability to design interdisciplinary and technology-integrated lessons that promote sustainability education. A sample learning activity, "My Zero Waste School," illustrates how environmental, pedagogical, and technological knowledge can be synthesized to create active, inquiry-based learning experiences. Overall, the chapter emphasizes the importance of combining formal and informal learning environments, higher-order thinking skills, and digital pedagogies to empower future generations as environmentally responsible global citizens.

1 Dr, Akdeniz Üniversitesi, tongalaysegul@gmail.com, 0000-0002-4340-8423

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1. Conceptual Foundations of Environmental Education

The environment is a system that forms the basis of human life on both physical and socio-cultural levels with its dynamic structure in which all living and non-living beings interact (Kayan, 2018). The relationship between humans and their environment is in a constant process of change and transformation rather than a fixed and static structure. However, during this process, individuals often tend to see the environment only as a tool to meet their needs. This instrumentalizing approach causes the unconscious consumption of natural resources, the disruption of ecosystem balances and the emergence of environmental problems that are difficult to reverse (Fettahlıoğlu, 2018). In this context, the development of an understanding of environmental ethics is of vital importance for individuals to gain a responsible, respectful and sustainable perspective towards nature. Restructuring the interaction of humans with the environment in line with the principles of sustainability has also become a necessity in order to leave a livable world for future generations. At this point, environmental education emerges as a fundamental tool that enables individuals to gain the ability to analyze the causes of environmental problems on scientific grounds, develop solution proposals, and exhibit environmentally sensitive behaviors (Sağdıç & Şahin, 2024). This concept was first systematically addressed by the International Union for Conservation of Nature (IUCN) in 1970, and it was revealed that environmental problems have an educational, ethical, and social dimension. This approach shows that environmental education is a holistic educational process that shapes individuals' environmental attitudes, value judgments, and behavioral patterns (Koç & Soykan, 2020).

The basic components of environmental education can be listed as awareness development, knowledge acquisition, value construction, attitude formation and transformation into behavior. These components aim to enable individuals to integrate information into their daily lives and to develop a critical, analytical and solution-oriented approach to environmental problems (Karataş, 2013). In this context, environmental education was given a more systematic structure at an international level with the UNESCO-UNEP Joint Environmental Education Conference held in Tbilisi, Georgia in 1977, which is considered one of the milestones of environmental education. In this conference, it was emphasized that environmental education is of vital importance in terms of changing the individual's attitudes and behaviors towards the environment positively, understanding the causes and consequences of environmental problems and developing solutions, and turning to sustainable life practices through social participation (Karataş, 2013; Saraç, 2017). Integrating current themes such as sustainable development, climate change, biodiversity loss, waste management and energy efficiency into environmental education programs is very important for individuals to be trained as environmental actors. In this respect, environmental education is a learning area that is at the centre of contemporary education systems and is directly associated with 21st century citizenship skills.

2. Zero Waste Approach and Educational Role of Informal Learning Environments

Waste management, one of the fundamental problems that threaten environmental sustainability in today's world, causes the degradation of ecosystems, the depletion of natural resources and the increase of environmental pollution. In this context, innovative and holistic approaches that aim to prevent waste formation at its source have become central to environmental protection policies. Among these approaches, the concept of "zero waste" stands out as one of the most advanced visions of sustainable environmental management in both theoretical and practical contexts (Zaman & Lehmann, 2013).

The concept of zero waste was first put forward by chemist Paul Palmer in the 1970s and found a place in the literature with the company called "Zero Waste Systems Inc." (Gül & Yaman, 2021). This concept is defined as a "total system approach" that aims to redesign products, processes and systems at their source and to minimize the production of harmful substances (Curran & Williams, 2012). In other words, zero waste aims to optimize the resource cycle by restructuring production and consumption processes in a way that does not harm nature.

Zero waste practices include multidimensional goals such as preventing waste generation, careful and efficient use of natural resources, establishing effective waste collection systems and creating social awareness (Curran & Williams, 2012). This approach should also be considered as an educational transformation process. Because individuals' waste production, consumption habits and behaviors regarding recycling are directly related to their knowledge, attitudes and values.

While the vast majority of developed countries have produced systematic and effective solutions in terms of waste management, this process in developing countries is generally limited due to reasons such as lack of infrastructure, inadequate supervision and low level of social awareness (Ömürbek et al., 2019). In Turkey, one of the most concrete steps taken in recent years to increase environmental awareness is the "Zero Waste

Project" launched in 2017. Within the scope of this project, many public institutions, especially municipalities, are implementing various strategies to dispose of and recycle waste without harming the environment. At this point, the relationship between environmental education and zero waste management plays a decisive role.

The main purpose of zero waste education is to provide permanent behavioral changes in individuals beyond the level of knowledge. For this, the individual is expected to internalize the critical importance of environmental sustainability for living life (MEB, 2018). In order for this awareness to be effective, it must be consistently supported in the family environment and the individual's social environment.

Today, it is widely accepted that environmental education is not only a process based on the transfer of cognitive knowledge; it is a multidimensional and holistic structure shaped by the individual's value system, social environment and lifelong learning experiences. In this context, students' environmental awareness and sustainable behaviors should be supported by active participation, cooperation and experience-based learning processes. The increasing inclusion of recycling-focused activities in educational programs in particular provides an important opportunity for students to develop positive attitudes towards the environment. However, it is known that environmental behaviors develop depending on the interaction of individual motivation, social interaction, value-based orientations and educational interventions (Mrema, 2008). Therefore, zero-waste-based environmental education implemented to create environmental awareness and ensure behavioral change should be structured in a way that ensures students' active participation in the learning process. In this context, the 2018 Science Curriculum aims to include significant structural changes within the scope of environmental education, enabling individuals to directly observe and explore nature, analyze human-environment interactions within the framework of scientific process skills, and develop solution proposals based on these analyses (MEB, 2018). The program also defines the development of sustainable development awareness within the framework of individual-society-nature interactions as a fundamental achievement. However, focusing solely on traditional classroom teaching methods may be insufficient in achieving these goals. Because the contemporary education approach aims to make learning more permanent, meaningful, and functional by moving it to different contexts of the individual's life. At this point, informal learning environments stand out as powerful tools to increase the impact of environmental education.

Informal learning covers the processes in which the individual carries out unstructured, unplanned but experience-based and meaningful learning (Degner et al., 2022). This form of learning is mostly shaped by the individual's own interests and curiosities and is based on daily life experiences. Informal learning environments such as nature walks, ecological farm visits, observations made in recycling facilities or science museum trips provide students with opportunities to directly observe, discover and experience environmental processes (Bodzin et al., 2010a). Such experiences significantly increase the permanence of learning, student motivation and environmental responsibility awareness by making abstract environmental problems more concrete and understandable for students. In this direction, the integration of formal and informal learning environments in environmental education plays a critical role in the development of sustainable environmental behaviors (Hung et al., 2012). In particular, informal learning areas such as nature walks, ecological farms, recycling facilities, and science museums allow students to directly interact with the environment and observe, discover, and experience environmental processes (Bodzin et al., 2010b). Such learning environments increase the permanence and motivation of learning by making abstract environmental problems more concrete and understandable for students.

Informal learning processes also increase students' metacognitive awareness levels. Metacognitive awareness means that an individual monitors, evaluates and organizes his/her own learning (Yücel & Özkan, 2015). When students observe environmental problems in activities carried out in informal environments, they use higher-level thinking skills such as producing solutions to these problems, looking at events from different perspectives and developing alternative decisions more actively.

Informal learning also supports the development of value-based achievements such as environmental ethics, sensitivity, and responsibility (Zhao & Wang, 2022). It is not possible for students to develop environmental sensitivity only with cognitive knowledge. A holistic approach that includes affective and value dimensions is needed. In this context, environmental education activities carried out in informal learning environments are powerful tools that enable students to empathize with the environment, question their attitudes towards nature, and develop responsibility towards nature.

Many studies in the literature point to the effect of informal learning on the development of environmental awareness. Researchers emphasize that environmental education should start from a young age and that this process should not be limited to classroom activities (Erdal et al., 2013; Ören et al., 2010). Similarly, it is shown that environmental activities carried out at the primary and secondary school levels play a critical role in gaining environmental awareness in students (Gülay, 2011; Nalçacı & Beldağ, 2012). It is stated that informal learning spreads over a very wide range, and individuals gain learning experiences in many areas, from museum visits to watching television, from social interactions to nature observations (Stocklmayer & Gilbert 2003). Similarly, it is stated that the process of discovering new information and learning through experiences in the individual's daily life constitutes the essence of informal learning (Bozdoğan, 2012).

As a result, environmental education should be supported by informal learning environments where it is possible to learn by experience in order to be effective and permanent. In this context, informal learning processes make it possible to address environmental education holistically in terms of emotion, attitude, value and responsibility. At the same time, it increases individuals' metacognitive awareness and enables them to develop more conscious and strategic approaches to environmental problems.

3. Metacognitive Awareness in Environmental Education

In the information age, where scientific and technological developments are advancing at a dizzying pace, the production-consumption balance has been disrupted on a global scale, and factors such as population growth, unconscious consumption patterns, wars, unplanned urbanization and industrialization have caused critical problems that threaten environmental sustainability (Pepe et al., 2014).

Initially emerging on a local or regional scale, these environmental problems have systematically expanded over time and have transformed into ecological threats affecting the entire planet, defined today as global environmental crises. In this context, many conferences and policy-oriented meetings held at the international level draw attention to the causes of environmental problems and try to develop solution proposals. Prominent events include the Stockholm Conference (1972), the Tbilisi Conference (1977), the International Congress on Environmental Education and Training (1987), the Thessaloniki Conference (1997) and the 37th General Conference of UNESCO (2013). The common emphasis of these conferences is that environmental education is a fundamental tool in preventing environmental degradation (Lin, 2002). However, despite these international efforts and education policies, it is seen that the expected improvements in environmental problems have not been achieved and ecological threats continue to increase. This situation reveals that environmental education should develop students' values, participate in environmental actions and use their cognitive and metacognitive skills in this process. In this direction, educational practices should focus on students developing a sustainable lifestyle and gaining ecological responsibility awareness (Yıldız et al., 2005).

As stated in the environmental education model, students' active participation in solution processes for environmental problems is of great importance. However, in order for this participation to be effective, students must have the ability to monitor, evaluate the activities they participate in, and organize their own learning processes (Taşkın & Şahin, 2008). At this point, metacognitive awareness stands out as a basic mental skill that increases the effectiveness of environmental education (Flavell, 1979).

Metacognitive awareness is a high-level thinking skill that refers to an individual's capacity to recognize, monitor, evaluate, and organize their own cognitive processes. This concept, first theorized by Flavell (1979), is related to an individual's awareness of how they think and their control over these thought processes. According to Flavell (1979), metacognition is a person's knowledge of their thinking processes and their ability to use this knowledge effectively in planning, monitoring, and organizing learning.

Metacognitive abilities generally consist of two basic components. Metacognitive knowledge and regulation of cognition (Muijs & Bokhove, 2020). Cognitive knowledge includes the level of knowledge an individual has about their own learning processes, task characteristics, and strategies. For example, when an individual knows the difficulty level of a task, which learning strategies are more effective, or which techniques work under which conditions, cognitive knowledge is in effect. This type of knowledge includes levels of consciousness such as knowing what you know and knowing how you learn (Garner & Alexander, 1989).

On the other hand, the regulation of cognition includes the individual's ability to plan, monitor, evaluate and, when necessary, restructure cognitive processes. This dimension is critical in terms of the individual's ability to recognize the problems encountered throughout the learning process, develop solutions, change strategies and optimize learning (Schunk & Zimmerman, 2012). For example, a student who realizes that his/her attention is distracted during learning and changes the environment or tries a different learning method is a concrete example of the regulation of cognition. In the context of environmental education, this ability enables the student to analyze, apply and transfer information to new environmental situations. In this way, the student can carry out the responsibilities he/she has taken regarding the environment at an internalized level of consciousness.

4. Reasoning Skills in Environmental Education

The increasing complexity of global environmental problems also requires individuals to be able to critically evaluate information and make solution-oriented decisions. In this context, environmental education should aim to support students' higher-order thinking skills. The most important of these skills is reasoning, that is, the processes of analyzing, evaluating, and inferring information (Zeidler & Nichols, 2009).

Reasoning is the systematic thinking process that an individual carries out to solve a problem or make sense of a phenomenon. In this process, the individual tries to reach logical conclusions by bringing information together. Reasoning is generally classified into the following types;

• *Inductive Reasoning:* It involves reaching generalizations from specific observations. For example, students can make general inferences about climate change from drought examples they observe in different regions.

• *Deductive Reasoning:* Inferences are made about specific situations based on general principles. For example, the effects of a local thermal power plant can be evaluated based on the information that "fossil fuels cause environmental pollution."

• *Causal Reasoning:* It establishes cause-effect relationships between events. Students can analyze the reasons behind environmental degradation and reveal ecological effects.

• *Ethical Reasoning:* It involves realizing that environmental problems have ethical dimensions and making decisions based on values (Sadler & Zeidler, 2005).

Environmental education is a process that aims to enable students to interpret, discuss, and relate this information to real-life problems. In this context, reasoning supports students' higher-order thinking skills, such as questioning environmental events, producing solution proposals, and evaluating scientific evidence (Almasri, 2024). Environmental decisions are usually multidimensional. Individuals are expected to have skills such as critical thinking, comparing alternatives, and making ethical assessments. Reasoning skills developed in these processes enable individuals to approach environmental problems more consciously and responsibly. For example, it is seen that behaviors such as recycling or energy saving are also based on the individual's ability to establish cause-effect relationships, predict social consequences, and make long-term inferences (Ardoin et al., 2018).

5. Technological Pedagogical Content Knowledge (TPACK) in Environmental Education

Today's understanding of education reveals that teaching approaches based solely on knowledge transfer are inadequate in the face of the increasing complexity of environmental problems. In this context, the Technological Pedagogical Content Knowledge (TPACK) framework, which enables teachers to use their pedagogical, technological and content knowledge in a holistic manner for the effective implementation of environmental education, stands out as an important conceptual tool (Mishra & Koehler, 2006a). With the transition to an information society, the integration of technology into education-teaching processes has become an inevitable necessity. In this transformation process, teachers are expected to have the competence to effectively integrate the two knowledge areas with technology. In this context, Technological Pedagogical Content Knowledge (TPACK), originally named Technological Pedagogical Content Knowledge (TPACK), has emerged as a theoretical framework developed to define teacher competencies in a more holistic manner (Mishra & Koehler, 2006).

The TPACK framework is built on the theory of Pedagogical Content Knowledge (PCK) (Gudmundsdottir & Shulman, 1987). In his study analyzing the basic knowledge components of teaching, he emphasized that teachers should also have pedagogical knowledge to effectively transfer this content to students. Technological knowledge as a third dimension and thus defined the TPACK triple knowledge system (Mishra & Koehler, 2006b). These are Content Knowledge (CK), Pedagogical Knowledge (PB) and Technology Knowledge (TK). The types of knowledge that emerge at the intersections of these three areas reflect the teacher's cognitive and practical competence in the teaching process. TPACK also explains how these types interact with each other. For example, Technological Pedagogical Knowledge emerges from the intersection of pedagogical knowledge and technology knowledge, while Technological Content Knowledge develops from the interaction of content knowledge and technology knowledge. At the highest level, TPACK emerges from the combination of these three components and defines the teacher's holistic knowledge structure on how to effectively teach a specific content through appropriate pedagogical methods and digital tools (Harris et al., 2009).

The originality of the Technological Pedagogical Content Knowledge (TPACK) model is based on the clear and systematic definition of the relationships between the content knowledge, pedagogical knowledge and technological knowledge that form the basis of the model. This framework also theoretically clarifies the complex types of knowledge that arise from the dual and triple intersections of knowledge fields (Mishra & Koehler, 2006b).

• *Field Knowledge (CF):* Refers to the in-depth knowledge that the teacher has about the disciplinary content that he/she is responsible for teaching. This knowledge covers the conceptual structure, basic principles, theoretical foundations and application methods of a field.

• *Pedagogical Knowledge (PC):* Refers to general teaching knowledge that includes elements such as learning theories, teaching strategies, classroom management, assessment techniques and teaching design appropriate to the cognitive development levels of students. This type of knowledge is necessary for the planning and implementation of effective teaching processes regardless of any content.

• *Technological Knowledge (TK):* Represents the teacher's competence in using information and communication technologies. This includes information on how to make software, hardware, internet-based applications, digital tools and online resources functional for pedagogical purposes.

The compound knowledge types resulting from the binary and ternary interactions of these three basic knowledge types constitute the dynamic structure of the TPACK model:

• *Pedagogical Content Knowledge (PCK):* Based on its classical definition, this type of knowledge includes the ability to teach a specific content in a way that is appropriate for student characteristics and learning principles.

• *Technological Pedagogical Knowledge (TPK):* This component refers to knowledge about the integration of technology into pedagogical processes. The teacher must know how to use a specific technology (e.g. simulation software, augmented reality, interactive applications) in a way that supports pedagogical goals. TPK focuses on how the use of technology transforms learning processes.

• *Technological Content Knowledge (TAK):* Knowledge about the use of technologies specific to a particular discipline. For example, the use of geographic information systems (GIS) to improve map reading skills in geography lessons or the use of digital sensors to collect data in science lessons are within the scope of TAB.

Technological Pedagogical Content Knowledge (TPACK), which is located at the point where the three knowledge areas (AB, PB, TB) overlap, represents the integrated knowledge structure that allows teachers to teach a certain content to students with appropriate pedagogical approaches and effective technology integration (Mishra & Koehler, 2008).

The TPACK framework is a very important theoretical tool for effective instructional design and implementation, especially in the digital age, as it enables teachers to address content, pedagogy and technology in an integrated and interactive manner rather than in isolation. This model aims to bring together technological competence and pedagogical creativity in teacher training programs, while also providing guidance in the construction of interdisciplinary learning, digital literacy and contemporary learning environments.

TPACK defines teachers' competence in teaching interdisciplinary content related to the environment by integrating pedagogical strategies and digital technologies appropriate to student characteristics. This model consists of the interaction of components such as field knowledge (e.g. ecology, sustainability, waste management), pedagogical knowledge (e.g. project-based learning, collaborative learning), and technological knowledge (e.g. digital maps, augmented reality applications, online simulations) (Koehler et al., 2013).

Environmental education aims to develop students' higher-level cognitive and affective skills, such as critical thinking, decision-making, and responsibility, beyond increasing their ecological awareness (Palmer et al., 1998). The TPACK approach allows teachers to design technology-supported instruction to achieve these goals. For example, students can monitor environmental changes with the help of satellite images or geographic information systems (GIS), exchange ideas in online environmental issues forums, or conduct experiments in virtual laboratories. In fact, environmental education practices based on the TPACK approach can also contribute to the development of scientific reasoning, problem-based learning, and digital citizenship skills.

As a result, restructuring environmental education in line with the requirements of the digital age is directly related to the development of teachers' TPACK competencies (Chai et al., 2010). In this context, teacher training programs need to provide teacher candidates with both environmental knowledge and the ability to transfer this knowledge by integrating it with pedagogical and technological dimensions.

5.1. Sample Event

Event Name: "My Zero Waste School"

Duration: 2 class hours (80 minutes)

Course Area: Science / Social Studies / Information Technologies (Interdisciplinary)

Grade Level: 6th–7th grades (Middle School)

TPACK Components:

Field Knowledge (AB): Recycling, waste types, environmental awareness, sustainable living

Pedagogical Knowledge (PB): Collaborative learning, argumentation-based teaching, project-based learning

Technological Knowledge (TB): Canva, Padlet, Tinkercad, Google Jamboard, e-portfolio tools

Objectives and Achievements

Students:

Classify waste types.

Explain the recycling process through modeling.

Develop solution suggestions for zero waste goals in their schools.

Present their environmentally sensitive projects using digital tools.

Defend and evaluate their ideas with argumentation skills.

Metacognitive Awareness and Reasoning Goals

Planning their own learning process (prior knowledge assessment)

Comparing different solutions

Discussing the feasibility of solution suggestions

Event Steps

1. Preparation and Motivation (10 min)

The teacher initiates the discussion by asking the question, "Can a school exist without producing any garbage?"

Students share their ideas anonymously on Padlet.

Research and Data Collection (15 min)

Students, divided into groups, learn about topics such as zero waste, waste separation, school waste data, etc. through digital resources (short videos, graphics, infographics) shared by the teacher.

Modeling and Design (25 min)

Each group designs their own "Zero Waste School Model" using Canva or Tinkercad.

Includes solutions such as recycling bin placement, waste reduction strategies (e.g. composting system), reusable material applications, etc.

Each group presents their designs to the class and justifies why they chose these solutions.

Other groups present their critiques digitally on Google Jamboard.

Self-Assessment and E-Portfolio (10 min)

Students record their contributions and learning in an e-portfolio system (e.g. Seesaw).

The teacher scores student products using rubrics that assess cognitive and affective development levels.

Assessment Tools

Student e-portfolios

Rubrics for argumentation quality

Student self-assessment forms

Intra-group assessment surveys

Concept Map (TPACK Integration)

Technology: Digital presentation tools, modeling software

Pedagogy: Discussion, cooperative learning, constructivist approach

Field Knowledge: Zero waste, environmental protection, sustainability

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