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The Effect of the Critical Thinking Based 4 MAT Instruction Applied in Science Education on Critical Thinking Dispositions

Sirin Ilkorucu[1], Menekse Seden Tapan Broutin[2], Mestan Boyaci[3]

[1]*Faculty of Education, Bursa Uludag University, Turkey, ilkorucu@uludag.edu.tr, ORCID ID: 0000-0003-1988-6385*
[2] *Faculty of Education, Bursa Uludag University, Turkey, ORCID ID: 0000-0002-1860-852X*
[3] *Ministry of National Education, Turkey, ORCID ID: 0000-0002-3998-7303*

ABSTRACT
The training of individuals who produce science is based on the way they think. Critical thinking is one aspect of thinking. The study's purpose is to analyze the effect of integrating critical thinking based on 4MAT (CT-4MAT) instruction to develop students' critical thinking dispositions. A pre-test post-test quasi-experiment design was used. It surveyed 60 7th-grade students (30 experiment and 30 control) attending a middle school in a city center in the northwest of Turkey. In the experiment group, the science curriculum, including the CT-4MAT instruction, was used, and in the control group, the science curriculum, not including this strategy, was used. The data were collected using the "Critical Thinking Disposition Inventory" and the "Attitudes and Views about Biodiversity Loss Scale". The analysis results showed a significant difference in favor of the experiment group students in terms of the scores of critical thinking disposition. The analysis results showed a significant difference in favor of the experiment group students in terms of the scores of critical thinking disposition. The experiment group evaluated themselves as more part of nature in their responses and dealt with biodiversity, the basis of sustainable living in critically. The control group's responses showed individuals do not solve problems concerning biodiversity and do not seek solutions unless the problems are affecting them. This study shows that the CT- 4MAT instruction helped to promote students' Critical thinking dispositions.

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Introduction

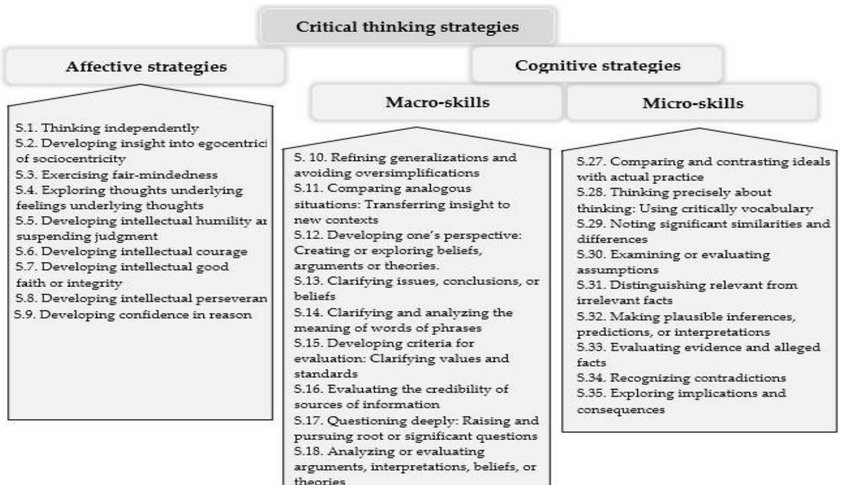
The current development of science and technology in recent years has led to a growing need for individuals who make and produce science for their societies. Educating individuals who can create a scientific product can primarily be achieved through the development of their thinking. The mission of educators should be not to transmit information but to raise individuals who reason, investigate and question to obtain information. It is of growing importance that teachers design, implement and evaluate guidance activities that contribute to social progress and facilitate the development of thinking systems. Thinking has many components. Critical thinking (CT) based on reasoning and questioning is thinking that must be taught and developed, starting from pre-school education. The development of CT also contributes to the development of students' skills of independently exploring, producing, using, and testing information and increases their pleasure of exploring (Romano, 1992). Che (2002) mentioned that CT is important to improve students' ability to think and reason, and essential for a person to meet the everyday personal, social, and professional demands of an ever-changing society. CT is one of the initial parts of scientific thinking and essential for cognitive skills in science education as understanding knowledge and creating relationships by analyzing this knowledge and producing new knowledge from the existing knowledge (Azar, 2010).

Critical Thinking and Critical Thinking Disposition

Ennis (1985) definesCT as reflective and logical thinking that focuses on believing and practicing. According to Ennis, what is thought and practiced here comprises practical activities such as asking questions, finding alternatives, and hypothesizing and designing experiments. Kurfiss (1988) explains CT as "a rational response to questions that can not be answered definitively and for which all the relevant information may not be available". Accordingly, CT is an exploration aiming to discover "a situation, phenomenon, question, or problem" to reach such a hypothesis or inference about them that can involve all available information and be satisfactorily justified. CT involves questioning all assumptions and seeking different views but not predisposing a particular outcome. According to Paul and Elder (2013), CT is a form of “thinking about any subject, content, or problem” by which one analysis, evaluates, and rearranges his or her thinking to improve the quality of thought. Paul (1990) describes CT as a combination of a set of abilities (skills) and strategies, and explains these strategies as affective and cognitive (micro and macro) dimensions, including 35 items. He describes his reason why he divided cognitive strategies into micro and macro skills as follows: “it is not about creating a precise distinction between mostly basic CT abilities (micro-skills) and the process of organizing these basic CT skills but rather providing teachers a way of thinking about these two levels of learning”. And, he notes that CT, in certain situations, involves running complex and holistic operations, and often includes many basic CT skills. For example, we use various micro-skills while reading a book. As shown in Figure 1, we synthesized these skills by linking them to the CT strategies.

Figure 1

CT Strategies



Note: CT Strategies have emerged as a combination of a set of abilities (skills) and strategies consisting of affective and cognitive (micro and macro) dimensions.

A good critical thinker can pose open and complete questions and problems, collect and evaluate relevant information, to effectively use and interpret abstract ideas. A good thinker can test hypotheses according to relevant criteria and standards, to open-mindedly think within different mindsets, to conclude and find solutions through reasoning, to produce and evaluate practical conclusions through assumptions and inferences, and to effectively communicate with others to solve complicated problems (Elder & Paul, 2010; Paul & Elder, 2013). Ennis (1985) distinguishes four CT abilities, including clarification, inference, decision-making, and problem-solving. The integration of these four abilities with CT dispositions covers all dimensions of the process of deciding what to believe or what to do. According to Brookhart and Nitko (2015), CT dispositions refer to mental habits that enable the use of appropriate CT and it is of importance to focus on students' habits. Yang and Chou (2008) emphasized that good critical thinkers certainly have CT skills, but this is not sufficient alone, so critical thinkers need to display, furthermore, an affective disposition. Ennis (1985, 1993, 2018) emphasizes that in CT,CT dispositions are as important as CT abilities and all of these dispositions and abilities could be needed in one important event. This system is expected to reflect the qualities of open-mindedness and openness to different ideas that scientists also should have. In this regard, the way by which a good critical thinker addresses a piece of information covers the abilities to discover the main source of a problem, to gather data on and find solutions to this problem, to consider its context, to evaluate results with their reasons through reasoning, and to effectively use means to make sure of the reliability of the information. Thus, it seems that CT occurs through a system in which thinking processes are integrated with the scientific path followed by scientists.

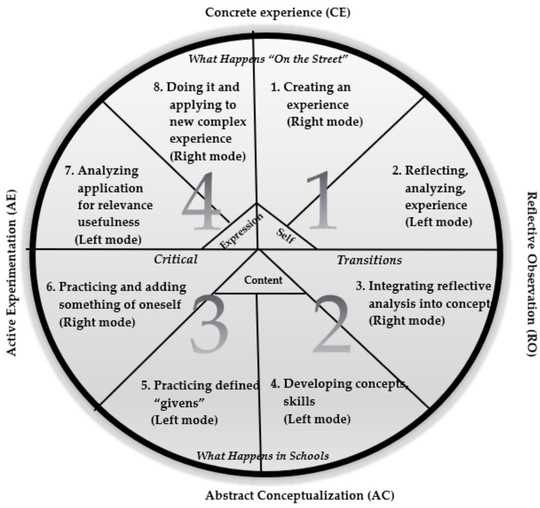
Various teaching models are used to educate people equipped with CT abilities as required by our age. The 4MAT (Four Mode Application Techniques) is a learning-focused approach and customizes learning with the learners' individual needs that can be useful for students to develop their CT skills. The 4MAT (Four Mode Application Techniques), developed by McCarthy (1983, 1990) is a teaching model that is designed by the relationship between the brain and education considering both learning styles and brain hemispheres and utilize Kolb's two-dimensional theory on information perception and information processing as a base for her quadrant model. He points out on two major premises of the 4MAT system: First, "people have major learning styles and hemispheric (right-mode/left-mode) processing preferences"; and second, "designing and using multiple instructional strategies in a systematic framework to teach to these preferences can improve teaching and learning". Eagleton and Muller (2011) note that CT occurs in the left cortical quarter of the brain associated with observation and feedback. Thus, the abilities used in the 4MAT model can be effective in developing an individual's CT abilities.

4MAT Teaching Model

The 4MAT, Bernice McCarthy's model, theoretically builds on David Kolb's (1976) "Experiential Learning Theory". According to the experiential learning cycle, learners should be able to be open to new experiences without prejudice to achieve effective learning (concrete experience), to observe and reflect on their experiences in many ways (reflective observation), to produce theories using the concepts formulated through observations (abstract conceptualization), and to make decisions based on these theories and solve problems (active experimentation). While reflective observation and active experimentation abilities are addressed as the information processing dimension, and abstract conceptualization and concrete experience abilities are addressed as the information perceiving dimension, Kolb (1976) describes the structure of his model as a simple definition of a learning cycle that shows how experiences are transformed into concepts to be used as guides when choosing new experiences. McCarthy (1983) develops an 8-step 4MAT system based on four primary learning styles and focusing on each quadrant in the right and left hemispheres. Figure 2 shows an overview of this 8-step system covering right- and left-hemispheric processing.

Figure 2

The 4MAT System



Note. Adapted from McCarty (1990)

McCarthy (1990) emphasize that in a curriculum using the 4MAT cycle, the teacher should ask the question "Why?" in the first quadrant, "What?" in the second quadrant, "How does it work?" in the third quadrant, and "What if?" in the fourth quadrant. McCarthy (1990) noted that in a curriculum using the 4MAT cycle, and a practitioner should aim at the question "Why?" in the first quadrant, "What?" in the second quadrant, "How does it work?" in the third quadrant, and "If" in the fourth quadrant. The teacher's role in the first quadrant is to make the content to be taught meaningful, and the student's role is to communicate with the teacher and friends and to associate the content with his or her life. In the second quadrant, the teacher has the role of transmitting information and the student has the role of comprehending information. In the third quadrant, the student uses the content and abilities, and the teacher serves as a guide. Lastly, in the fourth quadrant, the students are innovative, and the teacher supports the students' creativity. Throughout this entire cycle, the school administration is expected to support the teacher in terms of meeting needs (innovation, equipment, communication, etc.). According to McCarthy (2000), the 4MAT learning cycles' all parts are important; any part of the cycle is not more important than the whole cycle. Teaching in each quadrant provides a better learning area to students in that quadrant, while it can help students adapt and adjust to the teaching areas in the other quadrants. Thus, students can create different learning environments for themselves by making use of each other's different modes of learning in the learning process. A classroom can include students using these four different learning styles so that this model facilitates offering a mode of teaching appropriate to students having one of these learning processes. Thus, McCarthy (1990) suggested that the 4MAT model is suitable for teachers to improve their instructional design by employing diverse strategies in the cycle of learning (Figure 2).

Education on Sustainable Development's teaching practices by integrating CT-4MAT instruction

According to Caine and Caine (1991), students with CT are more equipped to feel as much as acquiring natural information on many subjects, the benefits of these abilities are noticed when they are used in a demanding area, and CT can indeed be integrated into every aspect of curricula. The concept of sustainability appears as a problem in many areas and with many applications. All these areas and applications have one expectation in common, which is to leave an enabling world for future generations. In recent years, different approaches have been developed in order to identify and define the key competencies required for sustainable development. These competencies describe the dispositions which individuals need in this world for acting and self-organization in various complex contexts and situations (Rieckmann, 2012; UNESCO, 2017). The acquisition of such skills and the awareness of such a need requires the maintenance and development of a critical mind. The key role of the teacher should be to recognize the potential capabilities of the students and to facilitate growth in understanding the values included in Education on Sustainable Development (Straková & Cimermanová, 2018). In this regard, it is of growing importance that teachers design, implement and evaluate guidance activities that contribute to social progress and facilitate the development of thinking systems. The United Nations Educational, Scientific and Cultural Organization (UNESCO), (UNESCO, 2017, p.7) in their publication, states that Education for Sustainable Development (ESD) is "holistic and transformational". Also, EDS is integrated not only with curriculum-related sustainability issues but also promotes interactive, student-centered education. Various teaching models are used to educate people with the methods required by our age to gain sustainability awareness. This research focused on biodiversity loss, one of the links of sustainable ecology. Biodiversity supports ecosystem functions such as freshwater, earth talk and climate change, and provides food or medicine. It is also important for people to realize that this connection is part of their biological diversity for the sustainable development of the world. Environmental awareness of biodiversity loss is essential to make conscious human decisions about the challenges of sustainability. The chapter "Human and Environment Relationships" included in the 7th-grade (13-14 aged students) science curriculum (Ministry of Naional Education [MoNE], 2017) aims at the acquisitions of inquiry, inference, discussion and suggestion associated with CT dispositions. Since the objective of this chapter is to help students to question current environmental problems widely encountered in recent years with their causes and effects, it is considered suitable to teach it with the 4MAT teaching model.

Research Problem

Concerning the implementation of CT in education, the literature includes research on CT teaching and its struggles (Willingham, 2008), on the qualities of CT teaching (Boisvert, 2015), and the place of CT in curricula (Chassé, 2010). In addition, there is very much research about the influence of the 4MAT teaching method on science education. Aktas and Bılgın (2015) analyzed the effect of the 4MAT learning framework on the academic attainments of seventh-grade learners. Furthermore, the study showed that the 4MAT model implementation enhanced participation and motivation. In addition, they found that regarding motivation, the 4MAT model is more effective than the traditional method. Sezginsoy Seker and Dikkartin Ovez (2018) designed the interdisciplinary concept model based on the 4MAT model for primary school students to examine the effect of students' level of attainment and their learning acquisitions. The study showed that students in the experiment group achieved all outcomes at the full learning level. Alanazi (2020) examine impacts of the application of 4MAT teaching model in enhancing seventh-grade students' conception of electricity in physics. The findings indicated that the 4MAT method was more effective than traditional approaches and for developing scientific thinking. Thus, purpose of this study brings a different perspective to teaching practices through the integration of CT skills with the 4MAT model as CT-4MAT instruction. This research focused on integrating biodiversity loss. This section aims to help students question current environmental problems and the loss of biodiversity with common causes and consequences in recent years in this context. Burford, Tamás and Harder (2016) pointed out that Sustainable Development Goal (SDG) and within it those focusing on ESD is to think or model knowledge narrowly and not being able to design relevant indicators for different ways of knowing such as critical thinking or "learning to learn". Also, Rieckmann (2012) highlighted that the ability to translate knowledge of ESD into systematic and anticipatory critical thinking actions is a need to be developed by students. For this purpose, the study aims to reveal the effects of the CT-4MAT instruction applied to a science

"Human and Environmental Relations" subject on students' CT dispositions and understand their critical views about the loss of biodiversity with common causes and consequences in this context. For this purpose this study seeks to provide answers to the following questions:

- Is there a significant difference between the experiment group students' pre-test and post-test scores for the CT Disposition Inventory and sub-dimensions (engagement, maturity, and innovativeness)?
- Is there a significant difference between the control group students' pre-test and post-test scores for the CT Disposition Inventory and sub-dimensions (engagement, maturity, and innovativeness)?
- Is there a significant difference between the experiment group students and the control group students in terms of their scores for the Attitudes and Views about Biodiversity Loss Scale?
- What views do the experiment group students and the control group students have about biodiversity loss according to the Attitudes and Views about Biodiversity Loss Scale?

Methods

Research Design

A pre-test post-test control group quasi-experimental research design was used in this study. The quasi-experimental design includes spontaneous groups (e.g., class) or volunteers and individuals are not randomly selected (Creswell, 2017).

Participants

The study is conducted with a total of 60 7th-grade students (13-14 years of age) attending a middle school in a city center in the northwest of Turkey, in the spring academic year 2017. The 30 students (14 girls and 16 boys) were spontaneously assigned as the control group and 30 students (11 girls and 19 boys) as the experiment group. Participants were recruited using convenience sampling, which allows researchers to reach people who best serve research purposes (Patton, 2002).

Data Collection Tools

The study used the UF/EMI CT Disposition Inventory (CTDI) developed by researchers at the University of Florida and adapted to Turkish by Ertas Kılıc and Sen (2014). The inventory, appropriate to the level of secondary school education, is a 5-point Likert-type scale consisting of three subscales and a total of 25 items. The inventory originally consists of 26 items. At the end of the reliability analyses in the adaptation study, the original eleventh item was not included in the Turkish version of the inventory. The engagement disposition, consisting of 11 items, measures reasoning ability and is related to an individual's ability to explain his or her reasoning used in the problem-solving and judging processes. The cognitive maturity disposition, consisting of 8 items, is based on the fact that an individual with high cognitive maturity, is aware of his/her thinking, and is objective and open to different points of view. The innovativeness disposition, consisting of 7 items, focuses on information desire and information-seeking individuals and is associated with innovative thinking and prominent effort to find the truth (Kilic and Sen 2014).

Ideas and Attitudes Towards Biodiversity Loss Scale developed by Soysal (2012) for secondary and high school students consist of four sections. The first section includes a 15-item Attitude for Biodiversity Loss (ABL) scale. The ABL consists of two subscales. The first scale aims at Concerned About Biodiversity Loss (CBL), and the second is aimed at Generating Solutions To Prevent Biodiversity Loss (GSPBL). The Cronbach's Alpha coefficient of the ABL originally applied to a sample of 712 persons was 0,89, CBL was 0,90, and generating solutions to prevent biodiversity loss

(GSPBL) was 0,52. In this study, the Cronbach's alpha coefficient for ABL was 0.87, for CBL was 0.80 and for GSPBL was 0.87. Each of the second, third and fourth sections includes 12 items, which makes a total of 36 items using a 5-point scale ranging from strongly disagree to strongly agree. The second section measures the causes of biodiversity loss. The third measures the effects of biodiversity loss. The fourth measures the prevention methods for biodiversity loss. Respondents classify the items on an impact scale ranging from one to ten. It takes approximately 25 minutes to complete the scale.

Data Collection Process

The study procedure lasted three weeks, with a total of 10 hours. The chapter "Human and Environment Relationships" covered in the 7th-grade science curriculum designed by the science curriculum, (MoNE, 2017) was taught. In the experiment group, critical thinking based 4MAT (CT-4MAT) instruction was used while in the control group, the science curriculum-oriented (CO) instruction was utilized. The CTDI was applied as a pre-test and post-test in the control and experiment groups to determine the effects of CT based-4MAT instruction and CO instruction on CT. The Ideas and Attitudes towards Biodiversity Loss Scale were applied to the research groups as a post-test and interpreted according to their CT dispositions.

The science classes in the section assigned as the control group were carried out with the acquisitions determined by the science curriculum (MoNE, 2017). Various visual aids, presentations and videos were used to support the teaching process, and activities in the coursebook were completed. For the experiment group, three lesson plans, including four-hour, four-hour, and two-hour classes, were designed and applied based on the CT strategies shown in Table 1 within the scope of the science curriculum (MoNE, 2017) These CT strategies are indicated in brackets (e.g. S14). The lesson materials for the CT-4MAT instruction were prepared by the researchers. Further details were given in Appendix A. Table 1 shows the acquisitions of the curricula applied to the experiment and control groups.

Table 1

CO Instruction's Acquisitions and CT-4MATInstruction's Acquisitions Based on Science Curriculum

Weekly Class Hour	CO instruction's acquisitions	CT-4MAT instruction's acquisitions
2	7.5.1- Ecosystems 7.5.1.1. Describes the concepts of ecosystem, species, habitat, and population and gives examples. (Information and comprehension step)	1- Ecosystems 1.1. Clarifies and analyses the concepts of the ecosystem, species, habitat, and population (S14, S28). 1.2. Establishes links between the concepts of the ecosystem, species, habitat, and population (S11, S29, S28). 1.3. Identifies significant similarities and differences between the concepts of the ecosystem, species, habitat, and population (S29).
6	2- Biodiversity 7.5.2.1. Questions the importance of biodiversity for natural life. (Analysis) 7.5.2.2. Discusses factors that threaten biodiversity based on research data and offer solutions. (Synthesis)	2- Biodiversity 2.1. Thinks independently about the importance of biodiversity for life (S1, S33). 2.2. Explores the implications and consequences of biodiversity (S35). 2.3. Questions factors threatening biodiversity (S3, S6). 2.4. Examines in-depth factors threatening biodiversity based on research data (S17). 2.5. Produces self-centered or community-based insights into solution proposals for threats to biodiversity (S1, S19). 2.6. Does critical reading and listening concerning solution proposals for threats to biodiversity (S21, S22).

2	7.5.2.3. Investigates extinct or endangered plants and animals in our country and the world and gives examples. (Application)	3. Extinct or endangered species 3.1. Examines in-depth extinct or endangered plants and animals in our country and the world (S17). 3.2. Assesses the reliability of information resources on extinct or endangered plants and animals in our country and the world (S16).

Note. S1, Thinking independently; S3, exercising fair-mindedness; S6; developing intellectual courage; S11, comparing analogous situations; S14, Clarifying and analyzing the meaning of words of phrases; S16, evaluating the credibility of sources of information; S17, questioning deeply:Raising and pursuing root or significant questions; S19, generating or assessing solutions; S21, reading critically: Clarifying or critiquing texts; S22, listening critically: The art of slient dialogue, S28, thinking precisely about thinking: Using critical vocabulary; S29, Noting significant similarities and differences; S33, evaluating evidence and alleged facts; S35, exploring implications and consequences.

The science curriculum (MoNE, 2017) recommends 6 hours for the biodiversity subject. For the acquisition "Investigates extinct or endangered plants and animals in our country and the world, and gives examples", the CT-4MAT instruction includes a separate 2-hour plan named "Extinct or endangered species".

Process of the CT-4MAT Instruction

The program created within critical thinking is implemented in 8 steps in total, according to the 4MAT teaching method. These steps were planned by considering the thinking styles of the students and the brain hemispheres. At each step, answers were sought to the questions of the students. The part of the planning and activities used for these steps are summarized below. Also, the lesson acquisitions are presented below.

2.1. Thinks independently about the importance of biodiversity for life (S1, S33).

2.2. Explores the implications and consequences of biodiversity (S35).

2.3. Questions factors threatening biodiversity (S3, S6).

2.4. Examines in-depth factors threatening biodiversity based on research data (S17).

2.5. Produces self-centered or community-based insights into solution proposals for threats to biodiversity (S1, S19).

2.6. Does critical reading and listening concerning solution proposals for threats to biodiversity (S21, S22).

Step 1: In this step, students were asked to establish a relationship between their own experiences, daily lives, and the concept of biodiversity and form an opinion about why they should learn about this subject. During the application, the students were divided into groups and worksheets containing photographs and questions related to the subject were distributed, and they were expected to answer the questions about the visual (Right hemisphere).

Step 2: In this step, the students were provided to share their opinions about the case study in step 1 in the class. Students were asked to explain their views on biodiversity in a classroom setting. The teacher allowed the students to discuss with each other, without commenting on the answers given by the students and directed the discussion with questions when necessary. In practice, while defending their ideas, students were asked to enrich the subject by giving examples other than the activity given to them and associating them more with daily life. The teacher did not intervene at this stage but had an idea about the students' prior knowledge and readiness. At this stage, students were expected to think creatively (Left hemisphere).

Step 3: This step was the step to start giving theoretical knowledge to students. In the third step, the teacher started to give information about the concept of biodiversity. However, giving information about the subject was done by considering the answers given by the students. In this step, the aim was to form the idea that students know something about the concept by relating the concept to their experiences. This was the step where students begin to say, "I already know something about this topic". Right hemisphere activities such as analogy and metaphor, which were used to obtain conceptual features, would lead students to the accurate information revealed by the teacher. In this step, lecture, question, and answer, discussion techniques were used (Right hemisphere).

Step 4: As a result of the achievements of the previous steps, some ideas were formed in the minds of the students. This step is the time for the teacher to explain and give information, and for the students, it is the time to listen, receive and learn what is told by the teacher. This step is the one commonly used by teachers in schools. During the application, the subject to the students; was explained by using methods and techniques such as plain lecture, problem-solving, question-answer, and activities were made for the information text on the subject. The worksheet was prepared and applied (Left hemisphere).

Step 5: At this stage, the process of producing or adapting something new has not started yet. Students need to acquire sufficient skills before developing new ideas and inventions. Students were allowed to work in partnership with each other, and activities where they could practice using the information given in the previous step, were presented. A sample activity from the worksheet given to the students regarding this step is given in Appendix A (Left hemisphere).

Step 6: This stage was where innovations and inventions begin. Students have gained sufficient knowledge about the subject. The ability of right-mode techniques to see possibilities, patterns, integrity was used here. In the process, various stations were created where the class discussed different topics, enabling students to focus on different topics. 6 worksheet activities were given in this step (Right hemisphere).

Step 7: In this step, students were expected to apply what they have learned to their lives. By making suggestions to the students, open-ended questions were asked about the concepts they learned. They were asked to research by giving performance and project tasks. Thus, students were expected to add new information to the concepts they learned. The process of students doing research on their homework and finding the answers, preparing presentations and posters was also included in this step (Left mode).

Step 8: The students presented their homework to their friends, and the appropriate assignments were displayed in the classroom. Students tried to create a model and shared what they learned with their friends. In this process, the students who prepared the homework were supported to be positively motivated about the subject. Other students participated in the topics told by their friends and were encouraged to ask questions freely (Right hemisphere).

Data Analysis

Before the assumption of independence of data, the assumption of normality of distribution, and the assumption of homogeneity of variance were tested by Shapiro-Wilk test as required for the application of parametric tests. Parametric and non-parametric tests were performed after that these assumptions were determined. An independent samples t-test was used to test whether there was a difference between the mean achievement scores, and for not normally distributed data, the Mann-Whitney U test was performed. Data analysis was performed using IBM SPSS Statistics 23 software, and significance levels were set at the 5% level. Descriptive statistics were utilized that the views of two research sample groups about biodiversity in terms of their scores for the ABL scale. The students' science achievement scores were used to test the homogeneity of the selected two groups. An independent samples t-test was used to test whether there was a difference between the mean achievement scores; it resulted in no significant difference ($t_{0.05}$=0.934, p>0 .05).

Findings

The Results of The Comparison of Experiment Groups Pre-test And Post-test Mean Scores Regarding CT Disposition And Subscales

This section presents the results of the analyses performed to assess CT dispositions for the biodiversity subject among the students taught using the CT-4MAT instruction and among the students taught using the CO instruction The first research question, whether there was a significant difference between the experiment groups' pre-test and post-test scores for the CT dispositions (engagement, cognitive maturity, and innovativeness), was first tested. To test whether there was a difference between the mean scores within the groups, the Wilcoxon signed-rank test was utilized. (See Table 2).

Table 2

Wilcoxon Signed-rank Test Results of The Experiment Students' Pre-test and Post-test Mean Scores on The CT Dispositions (Engagement, Cognitive Maturity, and Innovativeness)

Pretest-Posttest	Students	N	Mean ranks	Sum of ranks	z	p
Engagement	Negative ranks	5[a]	14.70	73.50	-2.954	0.003
$\bar{x}_{pre}$= 39.53, $\bar{x}_{post}$= 43.03	Positive ranks	23[b]	14.46	332.50		
	Ties	2[c]				
Cognitive Maturity	Negative ranks	5[a]	12.20	61.00	-3.390	0.001
$\bar{x}_{pre}$=25,57, $\bar{x}_{post}$=29,23	Positive ranks	24[b]	15.58	374.00		
	Ties	1[c]				
Innovativeness	Negative ranks	3[a]	11.17	33.50	-3.612	0.000
$\bar{x}_{pre}$=25,17, $\bar{x}_{post}$=29,77	Positive ranks	23[b]	13.80	317.50		
	Ties	4[c]				
Total CT Disposition	Negative ranks	4[a]	12.88	51.50	-3.724	0.000
$\bar{x}_{pre}$=90,27, $\bar{x}_{post}$=102,03	Positive ranks	26b	15.90	413.50		
	Ties	0[c]				

Note. a. Post-test < Pre-test b. Post-test > Pre-test c. Post-test = Pre-test

As seen in Table 2, there was a statistically significant difference at p< .005 between the experiment students' pre-test and post-test mean scores for the total CT disposition and sub-dimensions (engagement, cognitive maturity, and innovativeness). This difference was in favor of the post-test.

The Results of The Comparison of Control Groups Pre-test and Post-test Mean Scores Regarding CT Disposition and Subscales

As the second research question, for the CT dispositions (engagement, cognitive maturity, and innovativeness) whether there was a significant difference between the control group students' pre-test and post-test scores was analyzed. The results of the Wilcoxon Signed-range Test are given in Table 3.

Table 3

Wilcoxon Signed-rank Test Results of The Control Students' Pre-test and Post-test Mean Scores on The Total CT Dispositions (Engagement, Cognitive maturity, and Innovativeness)

Pretest-Posttest	Students	N	Mean ranks	Sum of ranks	z	p
Engagement	Negative ranks	10[a]	14.35	143.50	-0.814	0.416
$\bar{x}_{pre}$= 42,63, $\bar{x}_{post}$= 42,87)	Positive ranks	16[b]	12.97	207.50		
	Ties	4[c]				
Cognitive Maturity	Negative ranks	8[a]	12.69	101.50	-1.891	0.059
$\bar{x}_{pre}$= 27,20, $\bar{x}_{post}$= 27,73	Positive ranks	18[b]	13.86	249.50		
	Ties	4[c]				
Innovativeness	Negative ranks	14[a]	14.21	199.00	-0.988	0.323
$\bar{x}_{pre}$= 27,77, $\bar{x}_{post}$= 26,40	Positive ranks	11[b]	11.45	126.00		
	Ties	5[c]				
Total CT Disposition	Negative ranks	11[a]	14.23	156.50	-1.320	0.187
$\bar{x}_{pre}$= 97, 60, $\bar{x}_{post}$= 97,00	Positive ranks	18b	15.47	278.50		
	Ties	1[c]				

Note. a. Post-test < Pre-test b. Post-test > Pre-test c. Post-test = Pre-test

As seen in Table 3, for the CT dispositions (engagement, cognitive maturity, and innovativeness), there was not a statistically significant difference found between the control students' pre-test and post-test mean scores ($p >.005$).

The Results of The Research Group's Views About Biodiversity

This section presents the views of two research sample groups about biodiversity in terms of their scores for the Ideas and Attitudes Towards Biodiversity Loss Scale.

The third research question concerned the views of two research sample groups about biodiversity in terms of their scores for the IATBL scale. The research sample groups' responses in terms of the causes of biodiversity loss, the effects of biodiversity loss, and prevention methods for biodiversity loss are displayed in order Figure 3.

Figure 3

The Research Sample Groups Responses in terms of The Causes of Biodiversity Loss, The Effects of Biodiversity Loss, and Prevention Methods for Biodiversity Loss

Control Group

Causes of Biodiversity Loss	X̄	Effects of biodiversity loss	X̄	Prevention methods for biodiversity loss	X̄
Global warming	8.30	The deterioration of food web stability	8.40	The use of renewable energy instead of fossil resources	9.17
Forest fires	8.30	Disruption of the natural balance	8.20	Afforestation	9.10
Unconscious hunting	8.17	Reduction of people's food supply	8.10	Making recycling	8.83
Garbage left by the sea	8.10	Global warming	8.03	Preservation of endangered species in shelter	8.73
Use of fossil fuel	8.03	Drought	7.93	Prevention of overfishing	8.53
Deterioration of natural balance	7.80	The emergence of new diseases	7.77	Raising people's awareness through symposiums and conferences	8.53
Factory gases	7.47	Changes in the genetic structure of living things	7.70	Raising public awareness through school education	8.50
Natural disasters	7.27	Great animal migration	7.63	Equipping factory chimneys with filters	8.40
Disturbed urbanization	7.10	Natural selection	7.50	Giving a fine on those who harm nature	8.33
Nuclear leaks	6.83	Decrease in natural oxygen	7.43	The reproductive cloning of endangered species	7.77
Depletion of the ozone layer	6.73	Wars between countries	6.80	The reduction of spray and deodorant use	7.70
Wrong policies of politicians	5.20	The loss of people's life chances	6.67	The use of public transport	7.67

Experimental Group

Causes of Biodiversity Loss	X̄	Effects of biodiversity loss	X̄	Prevention methods for biodiversity loss	X̄
Forest fires	7.90	Natural selection	7.63	Raising public awareness through school education	8.93
Global warming	7.70	Decrease in natural oxygen	7.63	Giving a fine on those who harm nature	8.83
Garbage left by the seas	7.70	The emergence of new diseases	7.57	The use of renewable energy instead of fossil resources	8.70
Use of fossil fuels	7.60	Changes in the genetic structure of living things	7.40	Making recycling	8.63
Unconscious hunting	7.57	Global warming	7.40	Prevention of overfishing	8.33
Natural disasters	7.33	Disruption of the natural balance	7.23	Raising people's awareness through symposiums and conferences	8.30
Depletion of the ozone layer	7.27	The loss of people's life chances	7.20	Preservation of endangered species in shelter	8.30
Deterioration of natural balance	7.27	Reduction of people's food supply	7.17	The use of public transport	8.20
Factory gases	7.23	The deterioration of food web stability	7.13	Afforestation	8.07
Disturbed urbanization	6.93	Great animal migration	6.97	Equipping factory chimneys with filters	7.93
Nuclear leaks	6.57	Wars between countries	6.93	The reduction of spray and deodorant use	7.40
Wrong policies of politicians	6.27	Drought	6.77	The reproductive cloning of endangered species	7.37

Students' responses concerning the causes of biodiversity loss, the experiment group students considered "Forest fires" (Mean=7.90), "global warming" (Mean=7.70), and "garbage left by seas" (Mean=7.70) as the causes with the highest impact. The control group students considered "global warming" (Mean=8.30), "forest fires" (Mean=8.30), and "unconscious hunting" (Mean=8.17) as the causes with the highest impact. The experiment group students selected "politicians' wrong policies" (Mean=6.27), "nuclear leaks" (Mean=6.57), and "disturbed urbanization" (Mean=6,93) as the causes with the lowest impact, while the experiment group students selected "politicians' wrong policies" (Mean=5.20), "depletion of the ozone layer" (Mean=6.73) and "nuclear leaks" (Mean=6.83) as the causes with the lowest impact.

Students' responses concerning the effects of biodiversity loss, the experiment students selected the "natural selection" (Mean=7.63), "the reduction of oxygen in nature" (Mean=7.63), and "the emergence of new diseases" (Mean=7.57) as the highest effects. The control students selected "the deterioration of food web stability" (Mean=8.40), "the deterioration of natural balance" (Mean=8.20), and "the reduction of people's food resources" (Mean=8.10) as the highest effects. Concerning the lowest effects of biodiversity loss, the experiment students selected "drought" (Mean=6.77), "wars between countries" (Mean=6.93), and "great animal migrations" (Mean=6.97). The control students selected "the loss of people's life chances" (Mean= 6.67), "wars between countries" (Mean=6.80), and "the reduction of oxygen in nature" (Mean= 7.43) as the lowest effects.

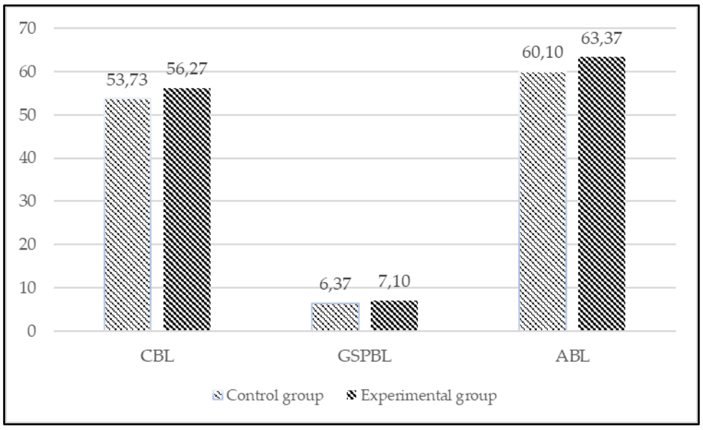
Students' responses to the prevention methods for biodiversity loss, the experiment students selected "raising public awareness through school education" (Mean=8.93), "giving a fine on those who harm nature" (Mean=8.83), and "the use of renewable energy instead of fossil resources" (Mean=8.70) as the most effective methods. The control students selected "afforestation" (Mean=9.10), "using renewable energy instead of fossil resources" (Mean=9.17), and "recycling" (Mean=8.83) as the most highly effective methods. The experiment students selected "the reproductive cloning of endangered species" (Mean=7.37), "the reduction of spray and deodorant use" (Mean=7.40), and "equipping factory chimneys with filters" (Mean=7.93) as the least effective methods. The control students selected "the use of public transport" (Mean=7.67), "the reduction of spray and deodorant use" (Mean=7.70), and "the reproductive cloning of endangered species" (Mean=7.77) as the least highly effective methods.

The Results of The Research Group Score Means of Attitudes Towards Biodiversity and Subscales

The last question concerned the experiment and control students' responses about the ABL scale and subscales displayed in Figure 4.

Figure 4

Means of Research Sample Students' Scores for Attitudes Towards Biodiversity and Subscales



According to Figure 4, the average CBL, GSPBL, and ABL scores, the experiment group score is higher.

Discussion

This study tries to explore the effects of the CT-4MAT instruction on students' CT dispositions and their attitudes and views about biodiversity loss. The analysis of the results showed that CT dispositions of the students taught using the CT-4MAT instruction were increased. While the experiment and control students' pre-test and post-test mean scores were compared within their respective groups, it was found that the mean scores of the experiment students increased, while those of the control students decreased. Similar results have been reported in studies conducted in Turkey. Yildirim & Sensoy (2011) reported that 7th-grade students' CT dispositions positively increased at the end of the 12-week education using modified CT lesson plans. Similarly, to this study, their lesson plans are based on one or more thinking strategies supporting the development of CT abilities. Similarly, Akyüz, Samsa Yetik and Keser (2015) found a considerable increase in pre-service teachers' CT disposition mean scores in the experiment group after the metacognitive guidance-based training, while pre-service teachers' mean scores very slightly increased in the control group. The education they applied was based on a model that allows students to monitor, organize and evaluate individual work, running parallel to the CT-4MAT instruction. A similar result was reported by Kiliç and Şen (2014) in a study with ninth-grade students. They investigated whether there was a difference in CT dispositions of the students to whom physics subjects were taught through a CT-based teaching model throughout one academic term. They applied the CTDI adapted to Turkish by Ertas Kilic and Sen (2014) as a pre-test and post-test. They found that the post-test mean scores of the experiment students receiving a CT-based education increased, while the post-test mean scores of the control students taught using the science curriculum decreased. The reason for the low level of CT dispositions in the groups taught using the science curriculum can stem from teachers' lack of competence to know how to integrate CT into their lessons or lack of will to integrate CT. The reason for the low CT abilities disposition among students in groups submitted to the Ministry of National Education Science Education program may be the fact that teachers do not have the skills (or the will) needed to integrate CT into their teachings and to their didactic sequences. It can be assumed that the 4MAT strategies used in the experiment group help teachers integrate CT into their teaching. This study also found a decrease in the innovativeness sub-dimension mean scores of the students taught using CO instruction. However, the innovativeness sub-dimension mean scores of the students taught using the CT-4MAT instruction increased. Considering that the innovation scores of the students taught by using the CT-4MAT instruction have increased, this result can be a guide for teachers who aim to develop innovative ideas for the awareness of the basic philosophy of the curriculum. There was also an increase in the post-test scores towards the total CT disposition and the sub-dimensions of the experiment group, while the post-test scores of the control group for the total inventory and innovativeness sub-dimension was lower than their pre-test scores. Innovativeness disposition involves seeking information and following innovations and thus should be developed in students as they are part of the future knowledge and technology society. Accordingly, the increased innovativeness disposition of the students taught using the CT-4MAT instruction is a significant result as it proves the contribution of the model to CT. In this regard, one result concerning the contribution of the 4MAT model to CT can be drawn from the fact that the CT disposition has been accentuated among students who have followed courses that integrates the 4MAT instruction.

When the causes of biodiversity loss, effects of biodiversity loss, prevention methods for biodiversity loss subscale mean scores were compared, in this study; the control group means scores were found higher than the experiment group. However, it is an interesting result that the experiment group's mean scores of attitudes towards biodiversity scale, aiming the concern and the solution attitude, were higher than the control group. The experiment students associated the causes of biodiversity loss with "forest fires", "global warming", and "marine litter". They associated the effects of biodiversity loss with "reduction of oxygen in nature", "natural selection", and "new emerging diseases". They associated the prevention methods for biodiversity loss with "raising public awareness through school education", "giving a fine on those who harm nature " and "using renewable energy instead of fossil resources". Students' responses were consistent with each other. In the responses of the students in the control group, the reasons for the decrease of biodiversity loss were "forest fires" and "global warming". The consequences of biodiversity loss were "the deterioration of the food web stability", "the deterioration of the natural balance", "the reduction of the people's nutrient resources", "Afforestation", "the use of renewable energy instead of the fossil resources" and "the recycling". Their responses were right but mostly given as memorized book knowledge. In the control group, students' responses to "the results of biodiversity loss" focused on the consequences of biodiversity loss for human life; while in the experiment group, the recommendations concerning the loss of biodiversity were based on solutions to be made by human society to combat this loss. In particular, the idea of students from the experiment group to provide a solution for the conservation of biodiversity in connection with the education of individuals on sustainability is worth noticing. Azar (2010) mentioned that students who have CT skills and CT disposition can use critical thinking efficiently in their lives. Therefore, students should be aware of what is expected from them in terms of thinker, explorer, and questioner considered in the textbooks. For this reason, these subjects should be considered for individuals in the textbooks to acquire critical thinking skills efficiently with the help of programs. Ennis (2018) emphasized on combining critical instruction and subject matter instruction has positive results for CT and subject matter learning and retention.

When evaluating the responses of students in the experiment and control groups to the Attitudes and Views about Biodiversity Loss Scale, we note that students in the experiment group dealt with the issue of biodiversity, the basis of sustainable living, while the control group preferred to highlight some causes and some results. When analyzed in this context, it is considered remarkable that biodiversity, which is an important source of sustainability, was treated with a critical view of all factors in the experiment group, whereas in the control group, appears as one or more reasons. In designing the idea of sustainability, it is clear that the individual will be able to realize that he and his natural processes have a holistic structure. It is noted that the choice of cause and effect and the recommendations were more disconnected in the control group. However, it is highlighted that students in the experiment group evaluated the reasons, results, and suggestions to be more compatible with each other in their responses. ESD competencies aim to ensure that individuals reflect their activities from a local and global perspective, taking into account their current and future social, cultural, economic, and environmental impacts (UNESCO, 2017).

Another result is that students in the experiment group accepted themselves as more part of nature in their responses. The control group, on the other hand, particularly in the responses to biodiversity outcomes, focused on responses that take into account human life rather than nature. The control group's responses showed that the individuals do not try to solve the problems and do not seek solutions unless the problems of biodiversity affect them. It is taken into account that students in the experiment group were aware that damage to nature will adversely affect biodiversity; they were trying to take precautions against problems that may occur and provide solutions. CT-4MAT training was considered effective in this regard. As stated by Franco, Maraques-Vieira and Tenreiro-Vieira (2018) education may not be the solution to all problems, but it does play a key role in finding solutions for The United Nation's Sustainable Development Goals challenges and a globalized future that require one not only to think but also to act critically. Kharrazi, Kudo and Allasiw (2018) mentioned that environmental educations' key goal is to develop critical thinking among students. They emphasized that critical thinking attains sustainable outcomes and enables thinking outside the confines of any present goals, targets, and indicators. According to the result of research, it is found that the average attitude score that measures concern and solution about the loss of biodiversity, the score of the experiment group was higher. Bilir and Ozbas, (2017) studied high school students' values, beliefs, and norms on the conservation of biodiversity in Turkey emphasized that ecological beliefs are crucial to pro-environmental behaviours in terms of awareness of consequences and awareness of responsibility. Furthermore, they believed that students' ecological beliefs, priorities, and self values can affect the intent to protect biodiversity. We can say that experiment group's biodiversity production awareness is more significant than the control group in terms of research results. For a critical view of the conservation, sustainable use of biodiversity and to provide solutions to problems that might arise, the most effective solution is to educate individuals by developing critical thinking with an appropriate teaching method. It is known that critical thinkers examine their sources of information from a logical point of view, that they can clearly express the evidence supporting the allegations in terms of similarities and differences, and that they try to get an idea of the results obtained. It is conceivable that the students who make a vision are evaluated with a more critical point of view on the reasons, the consequences, and the prevention of the decrease of biodiversity. UNESCO (2017, p.11) described specific learning objectives for SDGs as cognitive domain, socio-emotional domain, and behavioural domain. The cognitive domain comprises knowledge and thinking skills necessary to better understand the SDG and the challenges in achieving it. The socio-emotional domain includes social skills_that enable learners to collaborate, negotiate and communicate to promote the SDG as well as self-reflection skills, values, attitudes, and motivations that enable learners to develop themselves.

The behavioural domain is described as action competencies. From the research results, it can be interpreted that CB-4MAT education might be effective in the students' inferences related to cognitive awareness and in their attitudes that might lead to their behaviour. Wang and Woo (2010) implied that CT refers to a set of general skills that can be used in any subject or everyday life and deep knowledge of a discipline is necessary for critical thought. As Elder and Paul (2010) remarked, developing critical thinker students not only enables them to comprehend the fundamentals but also to become influential citizens who can reason ethically and act in the public interest. CT can alter and rework the mind of the students. Accordingly, the students taught using the CT-4MAT instruction evaluated the causes and effects of biodiversity loss and the prevention methods for biodiversity loss from a more critical point of view.

Conclusions and Implications

In the present study, researchers examined the CT-4MAT instruction effect in science education subjects on biodiversity. Following the implementation, this study shows that the CT-4MAT instruction help students to promote CT dispositions and evaluate the biodiversity from a more critical point of view. Moreover, when the research results are evaluated, it is understood that the application steps of the CT-4MAT instruction applied in this study make a positive contribution to the critical thinking disposition and that the students gain the desired critical thinking orientation and development. Accordingly, CT-4MAT instruction can be effectively used in secondary schools to improve critical thinking skills.

The CT-4MAT instruction could be considered more effective to ensure that CT is taught organized and well-thought-out. Thus, this instruction in the science education field could significantly benefit learning and teaching CT. Different scientific issues need to be evaluated critically in the science curriculum, so teachers might follow instructions to create a critical thinking environment. Therefore, the findings can serve as a starting point for enhancing curricula or designing interventions to support students' CT growth. Hence, CT-4MAT instruction in this research might help teachers expand their students' critical thinking skills for biodiversity with their brain-based understandings.

This study is limited to the biodiversity subject and students aged 13-14 years. Further research can involve other subjects in the science curriculum and different age groups. Given that one of the main objectives of education is to raise individuals who can produce logical ideas in adaptable environment democratically, it is of growing importance to integrate critical thinking dispositions into curricula. In this regard, the acquisitions covered in updated curricula can be designed based on CT strategies. The 4MAT integrated with CT should be known by educators and generalized to every field as it takes into account individual differences and addresses the brain and education relationship that has recently increased in importance.

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Appendix A

Examples of CT-4MAT Instruction's Fifth Section and Worksheet Questions

Step 5: At this step, the process of production and adaptation has not yet begun for students. Students must acquire sufficient skills before they can develop new ideas, inventions, and activities that allow them to collaborate and offer practical activities using the information provided in the previous step.

Figure 5

The Sample Of The Worksheet Given To The Students In The Fifth Step

5-Which of the following activities is not one of the human activities that threaten biodiversity?
a) Overgrazing of grasslands and pastures
b) Transition to mechanical agriculture
c) Establishment of dams
d) Separation of continents

6-In England, John Worlidge, agronomist in agriculture published in 1668 a book entitled "The Agricultural System" where he indicated the actions to be put in place against against pests in the field of agriculture.Therefore, to reach high yields in agriculture:
- **All frogs and their eggs must be exterminated in February**
- **Worms must be picked up in April**
- **Ants must be destroyed in June**
- **In July, wasps and flies should be killed.**

Given the functioning of ecosystems and their effects on each other, what agricultural problems are not faced by the farmers of the period who applied these defective methods in England?
a) The elimination of insect-fed frogs has increased the number of other agricultural pests not mentioned and has caused extensive damage to crops.
b) Destruction of ants and worms in the soil adversely affected soil aeration and decreased yield.
c) The killing of wasps and flies had an adverse effect on plant fertilization and pollen transport and reduced agricultural yield.
d) The elimination of ants and worms has increased the need for irrigation and increased the costs of agricultural production.

7- Does the high number of living beings in an ecosystem mean that biodiversity in this ecosystem is also high? Explain your answer.
....
....
....

8- Write the causes and explain the two most important threats to biodiversity.
....
....
....

9- Is biodiversity greater in "Culture Park" or greater in "Botanical Park"? Explain your answer.
....
....
....

Figure 6

The Sample of the Student's Responses Related to the Fifth Step

8-Biyo-çeşitliliği tehdit eden faktörlerden size göre en önemli olan 2 tanesini nedeniyle birlikte yazıp, açıklayınız.
Asit Yağmuru: Çünkü bütün canlılar hayatını yitirebilir. Nükleer kirlilik: Fazla radyasyon yayar ve canlıların yaşamını tehdit eder.
9-Yakınızda bulunan kültür Parkta mı biyoçeşitlilik daha fazladır ? Botanik parkta mı daha fazladır? Açıklayınız.
Botanik parkta çünkü fazla sayıda bitki çeşidi ve hayvan çeşidi vardır.

8-Write the causes and explain the two most important threats to biodiversity. Acid rain. *Because all living things can die. Nuclear pollution. It emits excessive radiation and threatens the life of living things.*
9- Is biodiversity greater in "Culture Park" or greater in "Botanical Park"? Explain your answer.
In the botanical park. Because there are many plant and animal varieties.