Global Environmental Problems Based on Common Knowledge Construction Model: Evaluation of “Exploring and Categorizing” Stage

Research Article

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ABSTRACT

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The aim of this study was to investigate the “exploring and categorizing” stage of global environmental problems based on Common Knowledge Construction Model (CKCM) in teaching. The CKCM consists of four stages: (1) exploring and categorizing, (2) constructing and negotiating, (3) translating and extending, and (4) reflecting and assessing. A phenomenographic research design was used. The study sample consisted of 47 seventh-grade secondary school students. Data were collected using a phenomenon form specific to global environmental issues during the exploring and categorizing stage. A total of 141 forms on global warming, acid rain, and ozone depletion within the scope of global environmental issues were analyzed. The form addresses participants' predictions and explanations concerning the phenomena before they have taken place, and their observations and explanations after they have taken place. Data were analyzed using phenomenographic analysis. Concerning the phenomenon of global warming, six categories and 11 explanations emerged in the prediction stage while four categories and 13 explanations emerged in the observation stage. Concerning the phenomenon of acid rain, three categories and 11 explanations emerged in the prediction stage while four categories and nine explanations emerged in the observation stage. Concerning the phenomenon of ozone depletion, four categories and nine explanations emerged in the prediction stage while four categories and 11 explanations emerged in the observation stage. Results were discussed with reference to literature.

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Introduction

Identifying prior knowledge and misconceptions is a prerequisite to help students to achieve meaningful learning in science. Students' prior knowledge should, therefore, be determined and then integrated with new knowledge to achieve the objectives of science education (Kartal, Öztürk & Yalvac, 2011). Otherwise, possible misconceptions prevent learning (Akbaş & Gençtürk, 2011) because misconceptions are too resistant to conceptual change to promote new information construction (Tytler, 1998). Science education, therefore, needs student-centered methods and techniques which allow for meaningful learning, active engagement (by doing-living), individual assessment, scientific predictions, and conceptual change. The Common Knowledge Construction Model (CKCM), which has become popular in recent years, may satisfy that need. As Marton (1981) puts it, the CKCM is a phenomenographic approach based on conceptual change and the prediction of information resulting from the relationship between people and real-life events. The CKCM consists of four stages: (1) exploring and categorizing, (2) constructing and negotiating, (3) translating and extending, and (4) reflecting and assessing (figure 1). The first stage involves using and making sense of knowledge of a phenomenon and presenting ideas concerning it. Students use the Predict–Explain–Observe–Explain (PEOE) approach and make predictions about the phenomenon and explain it based on those predictions and then observe the event (phenomenon) and explain it based on that observation. The objective of the PEOE strategy is to identify and categorize the topics with which students agree or disagree. The categories should be as few as possible and have a rational, clear, and hierarchical relationship with the phenomenon and express the differences in understanding it (Marton & Booth, 1997). The objective of the phenomenographic approach is to define how the individual conceptualizes a phenomenon, which is critical because the relationship between the individual and the phenomenon manifests itself in the process of self-conceptualization. This stage should also involve the identification of cognitive structures, conceptual change, and misconceptions (Ebenezer & Connor, 1998). Researchers have defined scientific knowledge and the development of learning differently and have proposed different conceptual change models to explain them. For example, Posner, Strike, Hewson, and Gertzog (1982) focused on four criteria in evaluating conceptual change, Thagard (1992) addressed the condition of replacement and/or abandonment for conceptual change, and Marton and Booth (1997) developed the variation theory of learning (phenomenography) to account for conceptual change. The second stage “constructing and negotiating” encourages students to discover valid scientific knowledge promoted by teacher-student and student-student (peer-peer) discussion/interaction moderated by the teacher (Ebenezer, Chacko, Kaya, Koya & Ebenezer, 2010). The third stage “translating and extending” enables students to use scientific ideas from the previous stage to develop socioscientific research problems, engages them in socioscientific problems, helps them develop critical thinking skills, and raises their awareness of the complex interaction between science, technology, society, and environment (Solomon & Aikenhead, 1994). The fourth stage “reflecting and assessing” encourages students to research and categorize concepts, to structure common knowledge, and to understand science concepts in socio scientific problems.

Figure 1. The common knowledge construction model (Ebenezer & Connor, 1998; Ebenezer & Haggerty, 1999).

Literature Review on Common Knowledge Construction Model

There are both national and international studies on the CKCM. For example, Ebenezer et al. (2010) divided 66 seventh grade students into two groups (experimental and control) and used a mixed method to investigate the effect of the CKCM on their academic performance and conceptual change. They concluded that the experimental group students had better academic performance and conceptual change than controls. Bakırcı, Çepni, and Yıldız (2015) divided 76 seventh grade students into two groups (experimental and control) and used a performance test on the “light and sound” unit based on a semi-experimental method in order to determine the effect of the CKCM on their academic performance. They reported that the CKCM had an effect on academic performance. Demircioğlu and Vural (2016) administered a Scale of Attitudes towards Chemistry Course to 29 eighth-grade gifted students from the science and arts center in order to determine the effect of the CKCM on their attitudes towards chemistry lesson. They concluded that the CKCM improved students' attitudes towards chemistry lesson. Bakırcı and Çepni (2016) divided 76 students into two groups (experimental and control) and used the Sound Unit Critical Thinking Test, Light and Sound Unit Achievement Test, and Light and Sound Unit Conceptual Understanding Test to investigate the effect of the CKCM on sixth-grade students' critical thinking skills and the relationship between critical thinking skills and academic performance and conceptual comprehension. They concluded that the CKCM helped students develop critical thinking skills and that critical thinking was strongly correlated with academic performance and conceptual understanding. Akgün, Duruk, and Gülmez-Güngörmez (2016) interviewed five sixth-grade students to investigate their views of the CKCM. They employed only the first two stages of the CKCM on the topic of heat dissipation. The results showed that the CKCM improved students' active engagement and learning. Bakırcı, Artun, and Şenel (2016) recruited 40 seventh-grade students and used the “Let's Learn about Celestial Bodies Conceptual Understanding Test,” “Let's Learn about Celestial Bodies Achievement Test,” and “Word Association Test” in order to compare the effect of the CKCM and 5E method on conceptual understanding. They concluded that the CKCM had a greater effect on students' conceptual understanding skills than the 5E method. Kırıyak and Çalık (2018)

recruited 25 seventh-grade students and used word association and conceptual understanding tests and conducted interviews in order to determine the effect of the CKCM on students' conceptual understanding of water pollution. They reported that the CKCM helped students have a better conceptual understanding of water pollution. Bakırcı, Artun, Şahin, and Sağdıç (2018) recruited 25 students and used a socioscientific evaluation form and conducted interviews to determine the effect of CKCM-based science education on their views of socioscientific topics. The results showed that the CKCM-based science education helped students make decisions on socio-scientific issues and solve everyday problems and develop science literacy skills. Caymaz and Aydın (2019) divided 42 seventh-grade students into two (22 experimental and 20 control) and employed the electrical energy unit conceptual understanding test to determine the effect of the CKCM on their conceptual understanding. They concluded that CKCM-based lessons helped students develop conceptual understanding skills. Studies on Predict, Observe and Explain strategies generally focus on preservice teachers (Atabey and Çiftçi, 2019; Güven, 2014; Tiftikçi, Yüksel, Koç & Çıbık, 2017) and secondary school students (Cengiz, 2018), yet address various topics.

The Significance of the Study

Unlike previous studies, this study focused on different topics and addressed the exploring and categorizing stage of the CKCM. There are some gaps in the literature with respect to the effect of the CKCM on students. This study is important for three reasons. First, it focused on three interrelated yet distinct issues concerning global environmental problems, which have been the subject of several studies. There are, however, few studies on the effect of the CKCM on students' conceptual understanding skills regarding global environmental problems. Those studies show that secondary school, high school, and university students have some misconceptions about global environmental problems. Global warming, acid rain, and ozone depletion were the issues of choice in this study because they are abstract topics which cause confusion and misconceptions. Second, most studies on the CKCM focus on achievement, attitude, conceptual understanding etc. and do not address the CKCM stages and the conceptual process. CKCM-based education, and especially the exploring and categorizing stage, may help us identify students' conceptual understanding skills and misconceptions, and the conceptual change that they go through. Most studies on CKCM focus on academic performance (Bakırcı, et al. 2015; Caymaz & Aydın, 2019) or students' views (Bakırcı, et al. 2018). This study, however, focused on the exploring and categorizing stage of the CKCM. Third, most studies use the PEOE as a whole. However, this study addressed the Predict-Explain and Observe-Explain stages separately because some studies use Predict-Observe-Explain (POE) as a strategy (Cengiz, 2018) or as a method (Güngör & Özkan, 2017; Güven, 2014; Tiftikçi, et al. 2017) and focus on preservice science teachers' views of it (Güngör & Özkan, 2017), its effect on misconceptions and achievement (Tiftikçi, et al. 2017), and conceptual understanding (Cengiz, 2018). We, therefore, believe that this study will contribute to the literature because it uses the PEOE as a technique and focuses on determining the difference between the Predict-Explain (PE) and Observe-Explain (OE) stages.

Research Objective

The aim of this study was to determine students' views of global environmental issues in the exploring and categorizing stage of the CKCM. The study sought answers to the following questions.

Research Questions

- 1- What were participants' views of the phenomena concerning the global environmental issues in the exploring and categorizing stage of the CKCM?

- a. In what way did participants predict and explain the phenomenon concerning the CKCM-based global warming issue?
- b. In what way did participants observe and explain the phenomenon concerning the CKCM-based global warming issue?
- c. In what way did participants predict and explain the phenomenon concerning the CKCM-based acid rain issue?
- d. In what way did participants observe and explain the phenomenon concerning the CKCM-based acid rain issue?
- e. In what way did participants predict and explain the phenomenon concerning the CKCM-based ozone depletion issue?
- f. In what way did participants observe and explain the phenomenon concerning the CKCM-based ozone depletion issue?

Method

Participants' PEOE forms about the global environmental issues were examined using phenomenography, which is a qualitative research methodology employed to determine different ways in which people experience, interpret, understand, and conceptualize a phenomenon (Çepni, 2007) and to systematize those different ways of understanding (Ashworth & Lucas, 1998).

Sample

The study sample consisted of 47 seventh-grade secondary school students (26 girls, 21 boys) (Table 1). The sample was a mixed group in terms of success level (lower, middle, and upper). Participation was voluntary. Participants were recruited using convenience sampling.

Table 1. Characteristics

<i>Issues</i>	<i>Female</i>	<i>%</i>	<i>Male</i>	<i>%</i>	<i>Total</i>	<i>%</i>
Global warming						
Acid rain	26	55.31	21	44.68	47	100
Ozone depletion						

Data Collection

Data were collected using a phenomenon form for the global environmental issues. The PE section of the PEOE form explores the way in which participants predict and explain how a phenomenon occurs or with what conditions/concepts it is associated. The OE section of the PEOE form explores the way in which participants observe and explain a phenomenon after it has occurred. Three events and three PEOE forms were developed for global warming, acid rain and ozone depletion. For example, as for global warming, participants were asked to predict and write in the prediction section "what happens if we put an equal amount of ice in two identical containers and leave one of the containers open and seal the other with stretch film wrap and expose both containers to the same amount of light from the same distance?" and were then asked to justify their predictions and write them on the explanation section. Afterwards, they were asked to complete the second stage of the PEOE by carefully observing the phenomenon and explaining it. The procedure was the same for acid rain and ozone depletion, but videos were used for them. The videos had visuals with no sound and text. In the prediction stage, some of the videos were played, and then, participants were asked to carefully watch them and predict the possible causes of the phenomenon and explain them. They were then asked

to write and explain what phenomena they observed. A total of 141 PEOE forms (three for each participant) were examined.

Figure 2. The PE and OP sections of the PEOE form

Data Analysis

Phenomenographic analysis involves data coding and clear categorization (Bradbeer, Healey & Kneale, 2004). Categories make complex data easy to understand. What is important is to determine the relationship between categories (Saljö, 1994; Reid & Petocz, 2002; Tözluyurt, 2008).

Results

The following Tables show participants' PEOE results concerning global warming, acid rain, and ozone depletion.

1- What were participants' views of the phenomena concerning the global environmental issues in the exploring and categorizing stage of the CKCM?

A. In what way did participants predict and explain the phenomenon concerning the CKCM-based global warming issue?

Table 2 shows the participants' predictions and explanations of the phenomenon concerning global warming. Their predictions consisted of six categories with 11 explanations (the category "heat retention" also includes those who did not provide any explanation). The correct response to this phenomenon was "heat retention," which was the first category. The participants in the other categories gave incorrect answers or had misconceptions about it. The category of heat retention consisted of 25 participants and four explanations. Most participants ($n = 10$) made an association between the film-covered container and the greenhouse effect. The explanations in this category included such concepts as heat trapping, heat retention, melting, stretch film, greenhouse effect, and air. The category of transpiration consisted of one participant and one explanation including such concepts as airless, light rays, heating, melting etc. The category of heating consisted of four students and two explanations including such concepts as stretch film, heating, melting, and open container. The category of heat convection consisted of 11 participants and three explanations with such concepts as heat transfer, airtight, heat convection, melting, stretch film, heat dissipation, expansion, temperature, and ice. Their

explanations were mostly about “the melting of ice in the containers by the heat.” The category of absorption consisted of two explanations with such concepts as light, melting, ice, stretch film, and conduction. Only two participants associated the phenomenon with depletion but provided no explanation whereas one participant made neither prediction nor explanation. The drawings and PEOE forms of some secondary school students are presented below (Figure 3).

Figure 3. The drawings and PEOE forms of some secondary school students

Table 2. Participants' PEOEs for Global Warming

Predict	<i>n</i>	Explain	<i>n</i>	Observe	<i>n</i>	Explain	<i>n</i>
Heat Retention	25	Heat is trapped in the stretch film wrapped container.	6	Correct Prediction	26	The heat melted the ice in the stretch film wrapped container more quickly.	8
		The ice in the stretch film wrapped container melts faster, and heat is retained just like the greenhouse effect.	10			The ice in the stretch film wrapped container melted quickly because it retained the heat.	2
		The stretch film wrapped container is air-tight.	4			The ice in the stretch film wrapped container melted faster, just like the melting of glaciers as a result of global warming.	11
		No explanation	5			Stretch film traps the heat.	1
Transpiration	1	Because transpiration occurs inside the airtight container, and light rays heat it faster and melt the ice in it.	1	Transpiration	2	No explanation	4
Heating	4	The stretch film heats up quickly and therefore the ice in the stretch film wrapped container melts faster.	3			The ice in the stretch film wrapped container melted faster because transpiration occurred.	2
		The open container heats up more slowly.	1			Because a plastic bag in an airless environment reflects more heat.	4
Heat convection	11	Heat spreads and melts the ice in the containers.	6	Incorrect prediction	15	Plastics such as stretch film transfer heat more quickly.	1
		Because little heat is transmitted to the ice inside the stretch film wrapped container, and so, the ice in the open container melts faster.	3			The rays passing through the stretch film were warmer.	1
		Heat dissipates in the open container, and the stretch film on the container expands and the heat goes through the stretch film and melts the ice.	2			The stretch film wrapped container drew more heat.	1
Absorption	3	The ice in it melts because it absorbs the light more.	1			Stretch film gets more heat.	2
		The ice in the stretch film wrapped container melts because it transmits the light.	2			The ice in the stretch film wrapped container melted quickly because the stretch film warmed up faster.	2
Depletion	2	-	2	Depletion	3	The stretch film wrapped container transferred the light more.	4
No response	1	-	1			No response	1

B. In what way did participants observe and explain the phenomenon concerning the CKCM-based global warming issue?

Participants' post-phenomenon observations and explanations concerning global warming differed (Table 2). There were four categories and 13 explanations about the phenomenon. The post-phenomenon observational categories were correct prediction (heat retention), transpiration, incorrect prediction, and depletion. One participant made neither observation nor explanation. During the observation stage, 26 participants made correct predictions within the scope of four explanations. Most participants (n=11) associated their phenomenon-related observations with global warming and used such concepts as heat output, stretch film, glacial depletion, melting, global warming, heat retention, and heat-trapping. Two participants used the concepts of stretch film, melting, and transpiration and came up with one explanation for transpiration, which is the second category. The category of incorrect prediction consisted of fifteen participants and seven explanations. This category had the most explanations with the concepts of airless environment, reflection, refraction, light conduction, stretch film, hot, decalescence, heat absorption, heating, and light conduction. The category of depletion had only three participants and one explanation (Table 2) with the concepts of ice and depletion. The participant who did not respond during the prediction stage did not respond during the observation stage either. In the category of heat retention, there was one more participant in the observation stage than in the prediction stage. Fifteen participants recognized their incorrect predictions.

C. In what way did participants predict and explain the phenomenon concerning the CKCM-based acid rain issue?

Participants made different predictions about the phenomenon concerning acid rain. The predictions were grouped under three categories, and four participants did not respond (Table 3). The correct response to this phenomenon was "acid rain," which was the first category. The participants in the other categories gave incorrect answers or had misconceptions about it. Thirty-two participants predicted that the phenomenon was acid rain and presented five explanations, which focused mostly on the statement "Acid rain harms the world and all living things." The explanations evolved around the concepts of oxidizer, harm, environment, world, creatures, acid. The category of increasing temperatures consisted of four participants and three explanations, focusing mostly on the statement "increasing temperatures are harmful to the forests" with the concepts of heating, world, rain, sun, drought, tree, water, drying, increasing temperatures, forest, and burning. The category of pollution consisted of seven participants and three explanations. Participants predicted that the phenomenon was pollution and used such concepts as air pollution, harm, people, wildfire, drought, hot, and burning. Four participants made neither observation nor explanation about the phenomenon.

D. In what way did participants observe and explain the phenomenon concerning the CKCM-based acid rain issue?

Participants' observations of the phenomenon concerning acid rain were grouped under the categories of correct prediction, incorrect prediction, pollution, and burning, which were associated with the concepts of oxidizer, harm, acid rain, world, harmful, forests, and depletion. Twenty-seven participants made correct predictions under six explanations, the most prevalent of which was "Acid rain harms the world" (n=10). Under the category of incorrect prediction, seventeen participants came up with two explanations associated with the concepts of chimney, smoke, factory, air, acid rain, environment, plants, living things, soil, harm, water, soil, under threat, harmful effect, reduction, thermal insulation, eco-friendly, source of energy, and public transportation (Table 3). Under each

category of pollution and burning, one participant came up with one explanation. Under the category of pollution, the participant's explanation was associated with the concepts of exhaust fumes, deodorant, environment, and harm. Under the category of burning, the participant's explanation was associated with the concepts of fossil fuels, cloud, rain, and fire. One participant made neither prediction nor explanation. There were five more participants in the prediction stage than in the observation stage under the category of acid rain while there were six more participants in the prediction stage than in the observation stage under the category of pollution. Four participants did not provide any response in the prediction stage while only one participant did not provide any response in the observation stage. Seventeen participants noticed their incorrect predictions and came up with explanations about them. The drawings and PEOE forms of some secondary school students are presented below (Figure 4).

<p>?????</p>	<p>ÇIÇILA</p>		<p>ÇIÇILA</p>
<p>TAHMİN ET</p>	<p>GÖZLE</p>		
<p>Bence bu resimde evin ve fabrika- ların ve fabrika- ların doğru görünüşü sarımsı ye- sillerin, kırmızı ve fabrika- ların gitar dumanları gitar sarımsı ye- silleri ve sarımsı ye- silleri</p>	<p>ÇÜNKÜ: Fabrikaların den ve ev- lerinden çıkan dumanlar havayı ve doğaya kötü etkiler ve sarımsı ye- silleri verir.</p>	<p>Fabrika- ların evin den doğru sarımsı ye- silleri verir. Bisikletlerin nedeniyle banyo- ken kapları olur.</p>	<p>ÇÜNKÜ: Fabrika- lardan, evlerden ve arabaların deni sarımsı ye- silleri verir. gitar dumanları dumanlar doğaya sarımsı ye- silleri verir.</p>
<p>AÇIKLA</p>		<p>AÇIKLA</p>
<p>TAHMİN ET</p>	<p>GÖZLE</p>		
<p>Sarımsın sarı re kırlığıyla Arabadan sı- kan eğme- garları, fakir kızların alın danarlar ve sar olarka Kırılan nehirler ye ottı suyu ölark Güneş Lütfen gök küde dögel ön Jahin bakışmasın Sebeap olur.</p>	<p>CÜNKÜ; resimde doğa dak fabrika- lor makineler, arabalar sarı regi kırıla- ğı için nehir- lerde kırık- dır.</p>	<p>Havadaki pris- egtoze garları havaya çıkarak kırık bir ortam Olastur yağmur yağdığında ise yer topraklı su elektirizmit amur jağar onden ya- la çıkarak ta- dığın çevrenin kırlığı ortaya çıkır.</p>	<p>CÜNKÜ; Su den- gisi deir dein yaparak abılır. ve bu kırlılık insanların yaptığ- bir çevre kırıl- ğıdır. O yzda herkes ne yapı- şına göre dikke- etmelidir.</p>

Figure 4. The drawings and PEOE forms of some secondary school students

Table 3. Participants' PEOEs for Acid Rain

<i>Predict</i>	<i>n</i>	<i>Explain</i>	<i>n</i>
Acid rain	32	Oxidizers are harmful to the environment.	5
		Because the smoke from chimneys, and deodorants and perfumes and whatnot get back at us and cause acid rain.	6
		Because it is an important factor that is harmful to the environment.	8
		Because acid rain is harmful to the world and living things.	9
		The acidic nature of acid rain causes the damage.	4
		Warming world, lack of rain, and constant sun have caused drought.	1
Increasing temperatures	4	Excess sunlight and lack of rain kill the trees.	1
		Forest fires have increased due to an increase in the global temperature.	2
		Due to pollution	4
Pollution	7	Forest fires are caused by humans.	2
		The forest is dry, and the air is polluted, so it burned because of the increase in temperature.	1
		-	-
No response	4	-	4

<i>Observe</i>	<i>n</i>	<i>Explain</i>	<i>n</i>
Correct prediction (Acid rain)	27	It is harmful because it contains oxidizers.	4
		Acid rain damages all living organisms on earth and dries out the trees.	8
		Acid rain is harmful to the world.	10
		Because acid rain is harmful	2
		Forest depletion is caused by acid rain	3
Incorrect prediction	17	The smoke from chimneys and factories is released into the air and comes back as acid rain, damaging the plants, living things, and soil around us.	12
		Things living in water and soil are under threat. We should use thermal insulation, eco-friendly energy, and public transportation to reduce the harmful effects of acid rain.	5
		Acid rain is caused by exhaust fumes, deodorant, and things like that and is harmful to the environment.	1
Burning	1	Because fossil fuels turn into clouds and so the rain sets things on fire.	1
No response	1	-	1

E. In what way did participants predict and explain the phenomenon concerning the CKCM-based ozone depletion issue?

Table 4 shows the participants' predictions and explanations of the phenomenon about ozone depletion. Their predictions were grouped under four categories; thinning, perforation, depletion, and global warming. The correct response to this phenomenon was "thinning," which was the first category. The participants in the other categories gave incorrect answers or had misconceptions about it. Under the category of thinning, seventeen participants came up with three explanations associated with the concepts of harmful rays, thinning, harmful to living things, and skin cancer. Almost all participants in this category associated the phenomenon with ozone depletion while the remaining associated it with the thinning of the ozone layer. The category of perforation consisted of 14 participants who came up with three explanations that were associated with the concepts of skin cancer, harmful rays, perforation, and harmful to living things and focused on the causes and consequences of the ozone layer. Under the category of global warming, ten participants came up with two explanations which focused on the causes of depletion of the ozone layer and were associated with the concepts of filter, harmful rays, trees, human extinction, and harmful effects. Under the last category, six participants came up with one explanation which addressed the causes of depletion of the ozone layer.

G- In what way did participants observe and explain the phenomenon concerning the CKCM-based ozone depletion issue?

Participants' observations of the phenomenon concerning ozone depletion were grouped under the categories of thinning (N=28), perforation (N=14), global warming (N=3), and depletion (N=2). Under the category of thinning, participants came up with eight explanations concentrated mostly on the statement "the ozone layer protects it from harmful rays, and the thinner it becomes, the more common the skin diseases." Six participants stated that deodorants and other harmful gases cause the thinning of the ozone layer and made a mention of chlorofluorocarbons, thinning, harmful rays, harm, deodorant, harmful gases, skin cancer, nature, unconscious use, and skin diseases. Under the category of perforation, fourteen participants came up with three explanations, one of which was associated the statement "perforation causes an increase in skin diseases" (N=10). The other two explanations (N=2) focused on the causes and consequences of depletion of the ozone layer and made associations with the concepts of deodorant, perfume, perforation, disease, skin disease, and harm. Under the category of global warming, participants came up with one explanation focusing on the consequences of depletion of the ozone layer and referred to the concepts of thinning, harmful rays, layer, and sun in that explanation. Under the category of depletion, five participants came up with only one explanation which accounted for the possible causes of depletion of the ozone layer. They also provided the same explanation under the categories of thinning (N=1), perforation, and depletion (N=2). The drawings and PEOE forms of some secondary school students are presented below (Figure 5).

Tahmin et	Açıkla	Gözle	Açıkla
Küresel ısınmayı artırır. Hastalıklar başlar. Cihazın hasatlığı sağlar.	Özen tabakası yok olduğundan güneş ışınları dünyaya ulaşır. Mavi gelir. Küresel ısınma daha çok hızlanır. Bu yüzden dünya yoktur. Güneş gibi bir çok cilt hastalıkları başlar.	Cilt kanserleri gözlemleniyor. Özen tabakasının olmadığı.	Güneş ışınları dünyaya gelmesi. Çok daha bütün hastalıklar neden olur.

Tahmin et	Açıkla	Gözle	Açıkla
Hastalıklar oluşur. Böylece insanlar zararlı ışınlar zararlı güneş ışınları insanlara zarar verir. <u>Cilt kanserlerine</u> neden olur	Güneşten gelen zararlı ışınlar insanlara zarar verir. Yüzünde herhangi bir yerinde şikâyet yaralar.	Cilt kanserleri oluşur	Ciltinde değişik şeyler çıkar. Oyundan bazı ışınlar zararlıdır.

Figure 5. The drawings and PEOE forms of some secondary school students

Table 4. Participants' PEOEs for Ozone Depletion

<i>Predict</i>	<i>n</i>	<i>Explain</i>	<i>n</i>	<i>Observe</i>	<i>n</i>	<i>Explain</i>	<i>n</i>
Thinning	17	Harmful sun rays pass through the ozone layer and harm people.	15	Correct prediction (Thinning)	28	Chlorofluorocarbons thin the ozone layer, and harmful sun rays damage the earth.	1
		The thinning of the ozone layer is harmful to all living organisms.	1			Deodorants and some harmful gases have depleted the ozone layer.	6
		Because it causes skin cancer.	1			Man-made actions that are harmful to the ozone layer	1
Perforation	14	Harmful sun rays pierce the ozone layer.	5			People lack awareness of the nature, and so, the ozone layer is damaged, and people have skin cancer.	1
		Harmful sun rays pierce the ozone layer and damage the things living close to the equator.	2			Some gases affect the ozone layer, which in return affects people. We should stay away from harmful things to prevent this from happening.	1
		Due to the perforation of the ozone layer, harmful rays reach the world and cause skin cancer.	7			The ozone layer protects the world from harmful rays. Man-made damage to it causes an increase in skin diseases.	16
Depletion	6	Human activities have depleted the ozone layer.	6			Some harmful rays that pass through the ozone layer reach the world.	1
						Human activities that deplete the ozone layer*	1
Global warming	10	Unfiltered factory chimneys cause global warming, and harmful sun rays reach the world, causing plant and human extinction.	4	Perforation	14	Refrigerators, deodorants, and perfumes cause perforation of the ozone layer, which results in many diseases.	2
						Perforation of the ozone layer causes an increase in skin diseases.	10
						Human activities that deplete the ozone layer *	2
		Human activities that deplete the ozone layer	6	Depletion	2	Human activities that deplete the ozone layer *	2
				Global warming	3	The thinned ozone layer lets harmful sun rays through, which causes global warming.	3

*In the observation stage, the categories of depletion, perforation and thinning have the same statement "Human activities that deplete the ozone layer," and hence, 11 explanations.

Conclusion, Discussion and Suggestions

Participants made different predictions, observations, and explanations about the three issues. The technique used at this stage of the CKCM showed that not all predictions, observations, and explanations were incorrect. There were quantitative and qualitative differences between the predictions and observations. For example, as for ozone depletion, the observation stage had more participants (thinning; $n = 28$) than the prediction stage. Moreover, they came up with richer and different explanations in the category of thinning in the observation stage. However, there were fewer participants in the observation stage than in the prediction stage in the categories of depletion and global warming. Some participants expressed some of their incorrect predictions that they had made in the prediction stage as correct in the observation stage or expressed some of their correct predictions that they had made in the prediction stage as incorrect in the observation stage. For example, seventeen participants correctly predicted in the prediction stage that the phenomenon concerning ozone layer was thinning while it was 28 participants who correctly predicted it in the observation stage. However, thirty-two participants correctly predicted in the prediction stage that the phenomenon was acid rain while it was 27 participants who correctly predicted it in the observation stage (Table 3). This shows that it is important to determine which concepts students focus mostly on in order to identify whether concepts are in the right category and whether they are used correctly. Therefore, such methods can be used to evaluate students individually and to determine the conceptual change process. For example, participants came up with the same explanations about ozone depletion in all three categories (perforation, thinning, and depletion) in the OE phase, but their observations differed from one another.

These results show that participants explained the phenomenon in the same way, even though they had different observations about it, which has been reported by previous studies as well (Özdemir, Köse & Bilen, 2012). PEOE-based research and thinking activities help students identify their prior knowledge and recognize their misconceptions and errors (White & Gunstone, 1992; Çetingül & Geban, 2005). Therefore, this stage of the CKCM provides students with the opportunity to identify their knowledge in detail and ensure real learning and meaningful construction. Ebenezer et al. (2010) divided 66 seventh grade students into two groups (experimental and control) and used a mixed method to investigate the effect of the CKCM on their academic performance and conceptual change. They concluded that the experimental group had better academic performance and conceptual change than controls. Kiryak and Çalik (2018) recruited 25 seventh-grade students and used word association and conceptual understanding tests and conducted interviews in order to determine the effect of the CKCM on students' conceptual understanding of water pollution. They reported that the CKCM helped students have a better conceptual understanding of water pollution. Our results showed that participants had misconceptions concerning the three issues. Research also shows that students of all levels of education have misconceptions regarding those issues. For example, students mostly think that the depletion of the ozone layer is caused by global warming.

The exploring and categorizing stage are effective in determining differences between students' predictions-explanations and observations-explanations concerning a phenomenon. The most important part of the stage lies in students' explanations because differences between students' prior knowledge are a sign of misconceptions or partial comprehension. PEOE activities at this stage can, therefore, be used to determine students' current situation. The following are recommendations drawn from the results:

- Students should have a solid grasp of the PEOE technique, which should, however, be actively used in science lectures because it takes time to master it.
- The PEOE technique should be used to encourage students to make predictions, inferences, and observations and to help them identify and develop themes concerning the nature of science.
- Future studies should address the four stages of the CKCM method separately and analyze conceptual understanding and change in students.

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