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## Examination of Science Teachers' Technological Pedagogical Content Knowledge and Classroom Practices

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### Article Info

### Abstract

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The aim of this study is to investigate science teachers' technological pedagogical content knowledge and classroom practices related to the topic of global warming. The study group consists of a total of 108 science teachers working in the southeastern region of Turkey who voluntarily participated in the research. The data were collected through the Global Warming Knowledge Questionnaire, Technopedagogical Educational Competency Scale, and the Revised Teaching Observation Protocol. The findings revealed that as science teachers' knowledge levels regarding global warming increased, their technopedagogical educational competencies also improved; an increase in one area of technopedagogical competency led to a high-level increase in other competencies; teachers who perceived their school's resources as sufficient scored higher in the ethics and expertise sub-dimensions of technopedagogical competencies; teachers who always followed scientific studies and news on global warming, and consistently shared this information with students, had higher technopedagogical competencies.

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## Introduction

As a consequence of global warming, it is likely that our lives will become increasingly difficult, and we may face serious health problems. Since global environmental issues stem from human attitudes and behaviors, they are fundamentally linked to education. Through a permanent and comprehensive education, individuals can be made aware of environmental problems and acquire experience and skills to address them. Thus, education is used as a tool to raise public awareness about environmental issues. In efforts to improve the quality of education and instruction, the competencies teachers must possess and how these competencies can be acquired are constantly being discussed (Seferoğlu, 2009). Competence is defined as the qualities, attitudes, knowledge, and skills required to perform and develop a profession successfully (Şişman, 2000). Among the professional competencies emphasized in both international and national teacher standards, Pedagogical Content Knowledge (PCK) is considered as important as professional and subject-matter knowledge (Boz & Boz, 2008), and research on PCK is rapidly progressing. Furthermore, with the advancement of technology, the ability of teachers to use educational technologies (e.g., simulation software, computers, smartboards, scientific measurement tools such as probes) and integrate them into instruction has become a significant focus. Consequently, the types of knowledge teachers are expected to possess have been integrated with technological knowledge, leading to what is called Technological Pedagogical Content Knowledge (TPACK) (Koehler & Mishra, 2005).

TPACK is a model of teacher knowledge proposed by Mishra and Koehler (2006) that integrates technological knowledge into Shulman's (1987) concept of Pedagogical Content Knowledge in line with contemporary technological developments. Mishra and Koehler (2006) defined TPACK as "good teaching." TPACK is not merely the addition of technology to existing content and instruction; rather, it involves the presentation of new concepts through various instructional methods in conjunction with technology. Moreover, technology requires the integration and interaction of the three main components that constitute the TPACK framework. For teachers, technological knowledge involves the ability to utilize technology for educational purposes and to incorporate these tools effectively into the classroom (Mishra & Koehler, 2006).

Global warming is an increasingly threatening social and scientific issue that is closely related to events occurring in our environment. In order to raise environmentally conscious individuals, teachers need to possess adequate TPACK competencies and instructional skills. Only then can individuals be raised who are sensitive to environmental problems, beneficial to society, and capable of guiding others (Kaya, 2014). In addition, the competencies teachers should acquire and how these competencies can be developed are continuously discussed to enhance the quality of education (Koehler & Mishra, 2005).

When science teachers' knowledge about global warming is combined with their technological competencies and pedagogical content knowledge, it significantly influences their classroom practices and the learning experiences of students. These considerations form the foundation of the current research. Therefore, there is a need for science teachers to integrate their knowledge of global warming and TPACK with their self-efficacy beliefs and transfer this into classroom practices. This study is expected to serve as a guide for practitioners and experts working in the field. The findings of the study are anticipated to encourage various activities in science education and

contribute to both the science curriculum and the literature. Accordingly, the research problem has been defined as follows: “What are the cognitive levels of science teachers regarding global warming, their technological pedagogical content knowledge competencies, and their classroom practices?”

In line with this objective, the following research questions were posed:

1. Do science teachers’ knowledge levels on global warming and their technopedagogical educational competencies significantly differ based on their perceptions of school facilities, engagement with scientific research, frequency of following global warming news, and frequency of sharing knowledge about global warming with students?
2. Is there a significant relationship among science teachers’ scores on the Global Warming Knowledge Questionnaire, the Technopedagogical Educational Competency Scale, and the Revised Teaching Observation Protocol?
3. Do science teachers’ knowledge levels on global warming and their technopedagogical educational competencies predict their classroom practices?

## Methods

In line with the purpose of the study, the relational survey model, one of the quantitative research methods, was employed. The survey model is a research approach that aims to describe a situation that occurred in the past or currently exists, as it is. Through general survey models, either singular or relational surveys can be conducted (Karasar, 2020).

## Participants

The study group consisted of science teachers working in a province located in the southeastern region of Turkey. A two-stage approach was followed in the selection of the study group. In the first stage, the cluster sampling method was used. For cluster sampling, a list of public and private middle schools was obtained from the Provincial Directorate of National Education, and the study was conducted in the schools that agreed to participate. In the second stage, the purposive sampling method was employed. Among the schools selected through cluster sampling, science teachers who volunteered to participate in the study were chosen, and the data collection tools were administered to these teachers. In total, 108 teachers constituted the study group. Descriptive information about the study group is presented in Table 1.

Table 1. Descriptive Information About the Participants

Variable	Options	N	%
Gender	Female	57	52.8
	Male	51	47.2
Age <sup>1</sup>	22-35	65	60.2
	36-55	43	39.8

Variable	Options	N	%
Marital status	Single	36	33.3
	Married	72	66.7
Graduate education status	No	85	78.7
	Yes <sup>2</sup>	23	21.3
Duration of teaching profession <sup>3</sup>	1-5 years	37	34.3
	6-10 years	31	28.7
	11-15 years	17	15.7
	16 + years	23	21.3
Weekly working hours <sup>4</sup>	16-25 hours	70	64.8
	26-35 hours	38	35.2
Average number of students in classes teaching science <sup>5</sup>	16-25 students	26	24.1
	26-35 students	51	47.2
	36-45 students	31	28.7
Seeing the school's facilities as sufficient	Yes	36	33.3
	No	72	66.7
Status of following scientific studies	Sometimes	39	36.1
	Often	48	44.4
	Always	21	19.4
Status of following global warming news	Sometimes	27	25.0
	Often	61	56.5
	Always	20	18.5
Sharing global warming information with students	Sometimes	28	25.9
	Often	44	40.7
	Always	36	33.3

<sup>1</sup> Min. = 22 years, Max. = 55 years, Mean (M) = 34.69 years

<sup>2</sup> 20 participants hold a Master's degree, and 3 participants hold a Doctorate degree

<sup>3</sup> Min. = 1 year, Max. = 28.3 years, Mean ( $\bar{x}$ ) = 9.8 years of professional experience

<sup>4</sup> Min. = 16 hours, Max. = 35 hours, Mean ( $\bar{x}$ ) = 24.57 teaching hours per week

<sup>5</sup> Min. = 16 students, Max. = 45 students, Mean (M) = 31.77 students per class

More than half (52.8%) of the science teachers in the study group were female, while 47.2% were male. The average age of the teachers was 34.69, with the youngest being 22 and the oldest 55 years old. The majority (60.2%) were within the 22–35 age group, and 39.8% were in the 36–55 age group. Most of the teachers (66.7%) were married, while 33.3% were single. The majority (78.7%) had not pursued postgraduate education. Among the 21.3% who had, 20 held a master's degree and 3 held a doctorate degree. The average professional experience among the teachers was 9.8 years, ranging from a minimum of 1 year to a maximum of 28.3 years. Of the participants, 34.3% had 1–5 years of experience, 28.7% had 6–10 years, 21.3% had 16 years or more, and 15.7% had 11–15 years. The average weekly teaching load was 24.57 hours (ranging from 16 to 35 hours), with the

majority (64.8%) teaching 16–25 hours per week and 35.2% teaching 26–35 hours per week. The average number of students per class taught by the teachers was 31.77 (ranging from 16 to 45 students). Nearly half (47.2%) taught in classes with 26–35 students, while 28.7% taught in classes with 36–45 students and 24.1% in classes with 16–25 students. A majority of the teachers (66.7%) perceived their school's facilities as insufficient, while 33.3% considered them sufficient. Regarding the frequency of following scientific studies, 44.4% of the teachers reported doing so frequently, 36.1% sometimes, and 19.4% always. When it came to following news about global warming, most teachers (56.5%) did so frequently, 25% occasionally, and 18.5% always. In terms of sharing information about global warming with their students, 40.7% of the teachers did so frequently, 33.3% always, and 25.9% sometimes.

### **Instruments**

The research data were collected using the Global Warming Knowledge Questionnaire the Technopedagogical Educational Competency Scale, and the Revised Teaching Observation Protocol. The Global Warming Knowledge Questionnaire (GWKQ) was developed by Eroğlu and Aydoğdu (2016) to determine individuals' knowledge levels regarding global warming. The Cronbach's alpha coefficient was found to be .85. Higher scores on the questionnaire indicate a higher level of knowledge about global warming (Eroğlu & Aydoğdu, 2016).

The Technopedagogical Educational Competency Scale (TECS) was developed by Yurdakul et al. (2012) to assess technological pedagogical educational competencies. The scale consists of 33 items and four factors: Design, Application, Ethics, and Expertise. The Cronbach's alpha coefficient was calculated as .95 for the entire scale; .92 for the Design factor, .91 for Application, .86 for Ethics, and .85 for Expertise. Higher scores on the scale indicate a higher level of technopedagogical educational competency (Yurdakul et al., 2012).

The Reformed Teaching Observation Protocol (RTOP) was developed by Piburn et al. (2000) as an observation tool to assess the extent to which constructivist and collaborative approaches are implemented in mathematics and science classes. The scale consists of 25 items and 3 main factors: Lesson Design and Implementation (items 1–5), Content (items 6–15 – subdivided into Theoretical Knowledge: 6–10 and Practical Knowledge: 11–15), and Classroom Culture (items 16–25 – subdivided into Interaction and Communication: 16–20 and Student–Teacher Relationship: 21–25) (Piburn & Sawada, 2000; Piburn et al., 2002). The scale was adapted into Turkish by Türel (2008). In the current study, the reliability coefficients were calculated as follows: .95 for the overall scale, .95 for lesson design and implementation, .76 for theoretical content knowledge, .97 for practical content knowledge, .96 for classroom interaction and communication, and .94 for student–teacher relationships. Higher scores on the scale indicate a greater level of success in classroom practices (Türel, 2008).

### **Data Collection**

The necessary permissions were obtained in order to conduct the research. Three of the data collection tools — the Personal Information Form, the Global Warming Knowledge Questionnaire (GWKQ), and the Technopedagogical Educational Competency Scale (TECS) — were administered to the 108 teachers who made

up the study group. Subsequently, interviews were conducted with these teachers to observe their classroom practices. Lessons of 42 teachers who agreed to classroom observation were attended by the researcher, and classroom activities were directly observed. The evaluations of these observations were carried out using the Reformed Teaching Observation Protocol (RTOP), one of the data collection tools. To complete the RTOP, the Google Forms platform was utilized. The protocol was uploaded to Google Forms, and each teacher whose lesson was observed was assigned a protocol number. Immediately after each classroom observation, the researcher filled out the form based on the observation, including the protocol number.

### Data Analysis

The research data were tested using the SPSS program, and the statistical significance level in the study was set at  $p < .05$  or  $p < .01$ . Descriptive information about the participants was presented in tables along with frequency and percentage distributions. It was observed that the research data showed a normal distribution. Due to the normal distribution of the data: Independent Samples t-Test was used to evaluate the mean differences between two groups, One-Way ANOVA was used to evaluate the mean differences among multiple groups, Pearson Correlation Analysis was used to evaluate the relationships between variables, Multiple Regression Analysis was used to evaluate whether more than one independent variable predicts a dependent variable. The results of the normal distribution analysis of the research data are presented in Table 2.

Table 2. Results of the Normal Distribution Analysis of the Research Data

	N	M	SD	Skewness	Kurtosis
<b>Global Warming Knowledge Questionnaire</b>	<b>108</b>	<b>112.66</b>	<b>11.712</b>	<b>-.858</b>	<b>.548</b>
<b>Technopedagogical Educational Competency Scale</b>	<b>108</b>	<b>131.31</b>	<b>21.910</b>	<b>-1.436</b>	<b>1.833</b>
Design	108	39.81	6.750	-1.195	1.091
Application	108	47.86	8.442	-1.364	1.378
Ethics	108	24.44	4.560	-1.378	1.626
Expertise	108	19.21	3.777	-.976	1.497
<b>Reformed Teaching Observation Protocol (RTOP)</b>	<b>42</b>	<b>74.07</b>	<b>13.234</b>	<b>-.682</b>	<b>-.090</b>
Lesson Design and Implementation	42	13.98	4.170	-.474	-1.132
Theoretical Knowledge	42	16.02	3.212	-1.687	1.202
Practical Knowledge	42	13.74	2.687	-.775	1.187
Interaction and Communication	42	13.86	3.041	-.278	-.593
Student–Teacher Relationship	42	16.48	2.549	-.166	-1.142

Since the data showed a normal distribution and the homogeneity of variances was confirmed with  $p > .05$ , the Tukey Test, one of the Post Hoc tests, was preferred in order to determine the groups where differences occurred in the ANOVA results. For the significant results obtained from the t-Test and ANOVA, Eta squared ( $\eta^2$ ) effect size values were calculated. For the significant results obtained from the Pearson Correlation Analysis, the direction and magnitude of the correlation were examined (Şen, 2016; Köklü, Büyüköztürk & Çokluk, 2023).

## Findings

In this section, the data obtained from the research were analyzed, and the results are presented in tables along with their interpretations. The first research question was formulated as follows: “Do science teachers’ knowledge levels on global warming and their technopedagogical educational competencies significantly differ according to their perceptions of school resources, their engagement with scientific studies, their habits of following global warming news, and the extent to which they share global warming information with their students?”

Whether the mean scores from the Global Warming Knowledge Questionnaire and the Technopedagogical Educational Competency Scale differed according to teachers’ perceptions of school resources was analyzed using the Independent Samples t-Test, and the results are presented in Table 3.

Table 3. t-Test Results Regarding Teachers’ Global Warming Knowledge Levels, Technopedagogical Educational Competencies, and Self-Efficacy Based on Their Perception of School Resources

Perceiving School Resources as Adequate		N	M	SD	t	p	$\eta^2$
<b>Global Warming Knowledge Questionnaire</b>	Yes	36	112.44	12.836	-.133	.894	
	No	72	112.76	11.200			
<b>Technopedagogical Education Competency Scale</b>	Yes	36	136.06	21.699	1.602	.112	
	No	72	128.94	21.777			
Design	Yes	36	40.39	6.966	.633	.528	
	No	72	39.51	6.669			
Practice	Yes	36	49.64	8.466	1.558	.122	
	No	72	46.97	8.346			
Ethics	Yes	36	25.67	4.168	2.013	<b>.047</b>	<b>.03</b>
	No	72	23.82	4.649			
Expertise	Yes	36	20.36	3.563	2.277	<b>.025</b>	<b>.10</b>
	No	72	18.64	3.773			

When the data in Table 3 are examined, it is observed that the mean scores obtained from the Global Warming Knowledge Questionnaire, the Technopedagogical Educational Competency Scale, and the Design and Application sub-dimensions of this scale do not differ significantly based on teachers’ perceptions of school resources ( $p > .05$ ).

However, the mean scores obtained from the Ethics ( $t=2.013$ ;  $p < .05$ ) and Expertise ( $t=2.277$ ;  $p < .05$ ) sub-dimensions of the Technopedagogical Educational Competency Scale do differ significantly according to whether teachers perceive their school’s facilities as sufficient. According to this result, teachers who perceive their school’s resources as sufficient scored higher in the Ethics and Expertise sub-dimensions compared to those who perceive them as insufficient. This difference was found to have a small effect size in the Ethics sub-dimension ( $\eta^2 = .03$ ) and a moderate effect size in the Expertise sub-dimension ( $\eta^2 = .10$ ). Whether the mean scores from the

Global Warming Knowledge Questionnaire and the Technopedagogical Educational Competency Scale differ according to the teachers' status of following scientific studies was analyzed using One-Way ANOVA, and the results are presented in Table 4.

Table 4. ANOVA Results Regarding Teachers' Global Warming Knowledge Levels and Technopedagogical Educational Competencies Based on Their Status of Following Scientific Studies

Status of Following Scientific Studies		N	M	SD	F	p	$\eta^2$	Significant Difference
<b>Global Warming Knowledge Questionnaire</b>	Sometimes	39	112.97	12.049	.175	.840		
	Often	48	111.96	12.204				
	Always	21	113.67	10.273				
<b>Technopedagogical Education Competency Scale</b>	Sometimes	39	126.10	19.157	4.099	<b>.019</b>	.07	Sometimes <Always
	Often	48	130.65	23.281				
	Always	21	142.52	20.277				
Design	Sometimes	39	37.97	4.815	4.330	<b>.016</b>	.08	Sometimes <Always
	Often	48	39.81	7.756				
	Always	21	43.19	6.306				
Practice	Sometimes	39	46.28	7.907	3.169	<b>.046</b>	.06	Sometimes <Always
	Often	48	47.42	8.722				
	Always	21	51.81	7.872				
Ethics	Sometimes	39	23.64	4.428	1.859	.161		
	Often	48	24.40	4.854				
	Always	21	26.00	3.847				
Expertise	Sometimes	39	18.21	3.743	5.872	<b>.004</b>	.10	Sometimes <Always
	Often	48	19.02	3.600				
	Always	21	21.52	3.400				

When the data in Table 4 are examined, it is observed that the mean scores obtained from the Global Warming Knowledge Questionnaire and the Ethics sub-dimension of the Technopedagogical Educational Competency Scale do not differ significantly according to teachers' status of following scientific studies ( $p > .05$ ). However, the mean scores obtained from the overall Technopedagogical Educational Competency Scale ( $F = 4.099$ ;  $p < .05$ ) and its Design ( $F = 4.330$ ;  $p < .05$ ), Application ( $F = 3.169$ ;  $p < .05$ ), and Expertise ( $F = 5.872$ ;  $p < .05$ ) sub-dimensions differ significantly based on teachers' engagement with scientific research. The Tukey test, one of the Post Hoc tests, was applied to determine the groups where significant differences occurred.

According to the results, teachers who sometimes follow scientific studies scored lower on the overall Technopedagogical Educational Competency Scale and its Design, Application, and Expertise sub-dimensions compared to those who always follow such studies. This difference was found to have a moderate effect size: (TECS  $\eta^2 = .07$ ; Design  $\eta^2 = .08$ ; Application  $\eta^2 = .06$ ; and Expertise  $\eta^2 = .10$ ). Whether the mean scores from the

Global Warming Knowledge Questionnaire and the Technopedagogical Educational Competency Scale differ based on teachers' status of following news about global warming was analyzed using One-Way ANOVA, and the results are presented in Table 5.

Table 5. ANOVA Results Regarding Teachers' Global Warming Knowledge Levels and Technopedagogical Educational Competencies Based on Their Status of Following Global Warming News

Following Global Warming News		N	M	SD	F	p	$\eta^2$	Significant Difference
<b>Global Warming Knowledge Questionnaire</b>	Sometimes	27	110.41	13.929				
	Often	61	112.92	11.305	.878	.419		
	Always	20	114.90	9.520				
<b>Technopedagogical Education Competency Scale</b>	Sometimes	27	124.85	22.151				
	Often	61	130.46	21.129	4.126	.019	.07	Sometimes < Always
	Always	20	142.65	20.620				
Design	Sometimes	27	38.11	5.337				
	Often	61	39.44	7.084	3.639	.030	.07	Sometimes < Always
	Always	20	43.20	6.518				
Practice	Sometimes	27	45.70	9.003				
	Often	61	47.52	7.974	3.237	.043	.06	Sometimes < Always
	Always	20	51.80	8.141				
Ethics	Sometimes	27	22.93	5.232				
	Often	61	24.43	4.280	3.709	.028	.07	Sometimes < Always
	Always	20	26.50	3.749				
Expertise	Sometimes	27	18.11	4.126				
	Often	61	19.07	3.628	4.044	.020	.07	Sometimes < Always
	Always	20	21.15	3.117				

When the data in Table 5 are examined, it is observed that the mean scores obtained from the Global Warming Knowledge Questionnaire do not differ significantly based on teachers' status of following global warming news ( $p > .05$ ). However, the mean scores obtained from the Technopedagogical Educational Competency Scale ( $F = 4.126$ ;  $p < .05$ ) and its sub-dimensions — Design ( $F = 3.639$ ;  $p < .05$ ), Application ( $F = 3.237$ ;  $p < .05$ ), Ethics ( $F = 3.709$ ;  $p < .05$ ), and Expertise ( $F = 4.044$ ;  $p < .05$ ) — differ significantly according to teachers' frequency of following news about global warming. The Tukey test, one of the Post Hoc tests, was applied to identify the groups showing significant differences. According to the results, teachers who sometimes follow global warming news scored lower on the overall Technopedagogical Educational Competency Scale and its Design, Application, Ethics, and Expertise sub-dimensions compared to those who always follow such news. This difference was found to have a moderate effect size: (TECS  $\eta^2 = .07$ ; Design  $\eta^2 = .07$ ; Application  $\eta^2 = .06$ ; Ethics  $\eta^2 = .07$ ; and Expertise  $\eta^2 = .07$ ). Whether the mean scores from the Global Warming Knowledge Questionnaire and the Technopedagogical Educational Competency Scale differ according to teachers' status of sharing global warming

knowledge with students was analyzed using One-Way ANOVA, and the results are presented in Table 6.

Table 6. ANOVA Results Regarding Teachers' Global Warming Knowledge Levels and Technopedagogical Educational Competencies Based on Their Status of Sharing Global Warming Knowledge with Students

Sharing Global Warming Knowledge with Students		N	M	SD	F	p	$\eta^2$	Significant Difference
<b>Global Warming Knowledge Questionnaire</b>	Sometimes	28	109.79	12.691				
	Often	44	112.89	13.154	1.360	.261		
	Always	36	114.61	8.479				
<b>Technopedagogical Education Competency Scale</b>	Sometimes	28	126.18	22.626				
	Often	44	127.57	22.545	4.437	<b>.014</b>	.08	Sometimes and Often < Always
	Always	36	139.89	18.269				
Design	Sometimes	28	38.32	6.395				
	Often	44	38.64	7.539	4.212	<b>.017</b>	.07	Sometimes and Often < Always
	Always	36	42.39	5.250				
Practice	Sometimes	28	45.61	8.995				
	Often	44	46.59	8.286	4.538	<b>.013</b>	.08	Sometimes and Often < Always
	Always	36	51.17	7.331				
Ethics	Sometimes	28	23.79	4.848				
	Often	44	23.59	4.495	3.211	<b>.044</b>	.06	Sometimes and Often < Always
	Always	36	25.97	4.116				
Expertise	Sometimes	28	18.46	3.986				
	Often	44	18.75	3.767	2.622	.077		
	Always	36	20.36	3.441				

When the data in Table 6 are examined, it is observed that the mean scores obtained from the Global Warming Knowledge Questionnaire and the Expertise sub-dimension of the Technopedagogical Educational Competency Scale do not differ significantly based on teachers' status of sharing global warming knowledge with their students ( $p > .05$ ). However, the mean scores obtained from the Technopedagogical Educational Competency Scale ( $F = 4.437$ ;  $p < .05$ ) and its Design ( $F = 4.212$ ;  $p < .05$ ), Application ( $F = 4.538$ ;  $p < .05$ ), and Ethics ( $F = 3.211$ ;  $p < .05$ ) sub-dimensions differ significantly according to how frequently teachers share global warming knowledge with their students. The Tukey test, one of the Post Hoc tests, was used to determine where the significant differences occurred. According to the results, teachers who sometimes or frequently share global warming knowledge with students scored lower on the overall Technopedagogical Educational Competency Scale, as well as its Design, Application, and Ethics sub-dimensions, compared to teachers who always share such knowledge. This difference was found to have a moderate effect size: (TECS  $\eta^2 = .08$ ; Design  $\eta^2 = .07$ ; Application  $\eta^2 = .08$ ; and Ethics  $\eta^2 = .06$ ).

The second research question was formulated as follows, "Is there a significant relationship among science

teachers' scores on the Global Warming Knowledge Questionnaire, the Technopedagogical Educational Competency Scale, and the Reformed Teaching Observation Protocol?" Whether there is a significant relationship between the Global Warming Knowledge Questionnaire and the Technopedagogical Educational Competency Scale scores was evaluated using Pearson Correlation Analysis, and the results are presented in Table 7.

Table 7. Results of the Pearson Correlation Analysis Between Teachers' Global Warming Knowledge Levels and Technopedagogical Educational Competencies

Relationship between GWKQ and TECS		1	2	3	4	5	6
1. Global Warming Knowledge Questionnaire	r	1					
	p	.					
2. Technopedagogical Education Competency Scale	r	<b>.20*</b>	1				
	p	<b>.035</b>	.				
3. Design	r	<b>.19*</b>	<b>.92**</b>	1			
	p	<b>.048</b>	<b>.000</b>	.			
4. Practice	r	<b>.19*</b>	<b>.97**</b>	<b>.85**</b>	1		
	p	<b>.048</b>	<b>.000</b>	<b>.000</b>	.		
5. Ethics	r	.17	<b>.91**</b>	<b>.75**</b>	<b>.87**</b>	1	
	p	.071	<b>.000</b>	<b>.000</b>	<b>.000</b>	.	
6. Expertise	r	<b>.20*</b>	<b>.90**</b>	<b>.74**</b>	<b>.84**</b>	<b>.79**</b>	1
	p	<b>.036</b>	<b>.000</b>	<b>.000</b>	<b>.000</b>	<b>.000</b>	.

\*p<.05, \*\*p<.01 n= 108

When the data in Table 7 are examined, it is observed that there is no significant relationship between the scores from the Global Warming Knowledge Questionnaire and the Ethics sub-dimension of the Technopedagogical Educational Competency Scale ( $r = .17$ ;  $p > .05$ ). However, there is a significant, positive, and low-level relationship ( $r < .30$ ) between the Global Warming Knowledge Questionnaire and the overall Technopedagogical Educational Competency Scale ( $r = .20$ ;  $p < .05$ ), as well as its Design ( $r = .19$ ;  $p < .05$ ), Application ( $r = .19$ ;  $p < .05$ ), and Expertise ( $r = .20$ ;  $p < .05$ ) sub-dimensions.

According to this result, it can be stated that as teachers' scores on the Global Warming Knowledge Questionnaire increase, their scores on the overall Technopedagogical Educational Competency Scale and its Design, Application, and Expertise sub-dimensions also increase, albeit at a low level. It was observed that there was a significant, positive and high level ( $r = .71-.99$ ) relationship between the scores of the Technopedagogical Education Competencies Scale in general and all its sub-dimensions (Design  $r = .92$ ; Application  $r = .97$ ; Ethics  $r = .91$  and Expertise  $r = .90$ ;  $p < .01$ ); between the scores of the Design, the Application ( $r = .85$ ;  $p < .01$ ), Ethics ( $r = .75$ ;  $p < .01$ ) and Expertise ( $r = .74$ ;  $p < .01$ ); between the scores of the Application the Ethics ( $r = .87$ ;  $p < .01$ ) and Expertise ( $r = .84$ ;  $p < .01$ ); and between the scores of the Ethics sub-dimension and the Expertise sub-dimension ( $r = .79$ ;  $p < .01$ ).

According to these results, it can be concluded that an increase in one sub-dimension of the Technopedagogical Educational Competency Scale is associated with a high-level increase in the other sub-dimensions as well as in the overall scale. Whether there is a significant relationship between the Global Warming Knowledge Questionnaire and the Reformed Teaching Observation Protocol scores was evaluated using Pearson Correlation Analysis, and the results are presented in Table 8.

Table 8. Pearson Correlation Analysis Results Between Teachers' Global Warming Knowledge Levels and Their Classroom Practices

Relationship between GWKQ and RTOP		1	2	3	4	5	6	7
<b>1. Global Warming Knowledge Questionnaire</b>	r	1						
	p	.						
<b>2. Reformed Teaching Observation Protocol (RTOP)</b>	r	.19	1					
	p	.239	.					
3. Lesson Design and Implementation	r	.10	<b>.89**</b>	1				
	p	.535	<b>.000</b>	.				
4. Content: Theoretical Knowledge	r	.26	<b>.82**</b>	<b>.72**</b>	1			
	p	.098	<b>.000</b>	<b>.000</b>	.			
5. Content: Practical Knowledge	r	.30	<b>.71**</b>	<b>.71**</b>	<b>.43**</b>	1		
	p	.053	<b>.000</b>	<b>.001</b>	<b>.004</b>	.		
6. Classroom Culture: Interaction and Communication	r	.03	<b>.86**</b>	<b>.71**</b>	<b>.59**</b>	<b>.56**</b>	1	
	p	.829	<b>.000</b>	<b>.000</b>	<b>.000</b>	<b>.000</b>	<b>.000</b>	.
7. Classroom Culture: Student–Teacher Relationship	r	.12	<b>.89**</b>	<b>.81**</b>	<b>.59**</b>	<b>.55**</b>	<b>.79**</b>	1
	p	.452	<b>.000</b>	<b>.000</b>	<b>.000</b>	<b>.000</b>	<b>.000</b>	<b>.000</b>

\*\* $p < .01$   $n = 42$

When the data in Table 8 are examined, it is observed that there is no significant relationship between the Global Warming Knowledge Questionnaire and the overall Reformed Teaching Observation Protocol, as well as any of its sub-dimensions ( $p > .05$ ).

However, there is a significant, positive, and high-level relationship ( $r = .71-.99$ ) between the overall RTOP and all of its sub-dimensions: Lesson Design and Implementation ( $r = .89$ ), Content: Theoretical Knowledge ( $r = .82$ ), Content: Practical Knowledge ( $r = .71$ ), Classroom Culture: Interaction and Communication ( $r = .86$ ), and Classroom Culture: Student–Teacher Relationship ( $r = .89$ ) ( $p < .01$ ). According to this result, an increase in one of the sub-dimensions of the RTOP leads to a high-level increase in the other dimensions and in the overall protocol score. There is also a significant, positive, and high-level relationship between: Lesson Design and Implementation and: Content: Theoretical Knowledge ( $r = .72$ ;  $p < .01$ ), Content: Practical Knowledge ( $r = .69$ ;  $p < .01$ ), Interaction and Communication ( $r = .71$ ;  $p < .01$ ), Student–Teacher Relationship ( $r = .81$ ;  $p < .01$ ). In addition, a significant, positive, and high-level relationship was found between: Interaction and Communication and Student–Teacher Relationship ( $r = .79$ ;  $p < .01$ ). Furthermore, a significant, positive, and moderate-level relationship ( $r = .30-.70$ ) was determined between: Content: Theoretical Knowledge and: Content: Practical

Knowledge ( $r = .43$ ), Interaction and Communication ( $r = .59$ ), Student–Teacher Relationship ( $r = .59$ ) ( $p < .01$ ), and between: Content: Practical Knowledge and: Interaction and Communication ( $r = .56$ ), Student–Teacher Relationship ( $r = .55$ ) ( $p < .01$ ). Whether there is a significant relationship between the Technopedagogical Educational Competency Scale and the Reformed Teaching Observation Protocol was evaluated using Pearson Correlation Analysis, and the results are presented in Table 9.

Table 9. Pearson Correlation Analysis Results Between Teachers' Technopedagogical Educational Competencies and Their Classroom Practices

Relationship between TECS and RTOP		TECS	Design	Application	Ethic	Expertise
Reformed Teaching Observation Protocol	r	.17	.15	.15	.16	.22
	p	.281	.340	.359	.315	.171
Lesson Design and Implementation	r	.22	.19	.19	.20	.27
	p	.168	.227	.235	.195	.085
Content: Theoretical Knowledge	r	.24	.19	.24	.23	.28
	p	.120	.237	.129	.135	.073
Content: Practical Knowledge	r	-.01	.00	-.03	.01	.01
	p	.950	.995	.831	.948	.974
Classroom Culture: Interaction and Communication	r	.15	.17	.12	.11	.16
	p	.358	.290	.459	.489	.302
Classroom Culture: Student–Teacher Relationship	r	.06	.04	.04	.05	.12
	p	.706	.815	.783	.733	.436
n= 42						

When the data in Table 9 are examined, it is observed that there is no significant relationship between the overall Technopedagogical Educational Competency Scale and all of its sub-dimensions, and the overall Reformed Teaching Observation Protocol and all of its sub-dimensions ( $p > .05$ ). The third research question was formulated as follows, “Do science teachers' global warming knowledge levels and technopedagogical educational competencies predict their classroom practices?” Whether the Global Warming Knowledge Questionnaire and Technopedagogical Educational Competency Scale scores significantly predict teachers' classroom practices was evaluated using Multiple Regression Analysis, and the results are presented in Table 10.

Table 10. Results of the Multiple Regression Analysis on the Prediction of Teachers' Classroom Practices by Their Global Warming Knowledge Levels and Technopedagogical Educational Competencies

	M	SD	B	Std. H	$\beta$	t	p	T	VIF
Constant			48.733	19.207		2.537	.015		
Global Warming Knowledge Questionnaire	112.76	13.87	.159	.154	.167	1.032	.308	.949	1.054

	M	SD	B	Std. H	$\beta$	t	p	T	VIF
Technopedagogical Education Competency Scale	129.79	25.86	.097	.117	.189	.829	.412	.478	2.092

n= 42

p&lt;.05

R= .237

R<sup>2</sup>= .056Revised R<sup>2</sup>= .018

F= .752

p= .528 (p&gt;.05)

Independent variables: Global warming knowledge levels, technopedagogical educational competencies

Dependent variable: Classroom practices

In the multiple regression analysis, it was determined that the necessary assumptions for conducting the analysis were met. Accordingly, the data showed normal distribution, the independent and dependent variables were continuous and measured on equal intervals, and there were linear relationships between the variables. The correlations among independent variables were below .80 (GWKQ and TECS = .18; GWKQ and RTOP = .19; TECS and RTOP = .17;  $r < .80$ ), and no outliers were found in the observed values (Std. R.= Min. -2.32 / Max. 1.32; within the acceptable range of -3.29 to +3.29). The residuals of the predictions were normally distributed (Cook's Distance Max. = .41; acceptable if  $< +1.0$ ) and homoscedasticity (equal variances) was ensured.

In the analysis, the Durbin-Watson (DW) statistic was found to be .653, which, being between 0 and 2, indicates positive autocorrelation — meaning that the residuals are not independent of each other. Although a value between 1 and 3, especially closer to 2, is preferred to indicate no autocorrelation, the fulfillment of the other seven assumptions was considered sufficient to proceed with the regression analysis. In this multiple regression analysis, the independent variables were defined as science teachers' global warming knowledge levels and technopedagogical educational competencies, while the dependent variable was defined as their classroom practices. When the data in Table 13 are examined, it is observed that science teachers' global warming knowledge levels and technopedagogical educational competencies do not significantly or positively predict their classroom practices ( $R = .237$ ;  $R^2 = .056$ ; Adjusted  $R^2 = .018$ ;  $p > .05$ ). Accordingly, the independent variables (science teachers' global warming knowledge levels and technopedagogical educational competencies) explain only 1.8% of the total variance in the dependent variable (science teachers' classroom practices). This indicates that there is no meaningful relationship between the dependent and independent variables, and that the regression model is not statistically significant.

## Discussion and Conclusion

In this study, science teachers' global warming knowledge levels did not significantly differ based on variables such as perceiving school resources as sufficient, following scientific studies, following global warming news, and sharing global warming knowledge with students. Kaya et al. (2013) reported that pre-service science teachers were inadequate in explaining the relationship between global warming and environmental issues, and that most of them could not clearly articulate the purpose of teaching global warming or the difficulties middle school students face regarding the subject.

The study found no significant relationship between science teachers' global warming knowledge levels and the

ethics sub-dimension of technopedagogical educational competencies. However, there was a positive and low-level relationship between global warming knowledge levels and the overall technopedagogical educational competencies, as well as the design, application, and expertise sub-dimensions. Accordingly, as teachers' global warming knowledge levels increased, their technopedagogical competencies in these areas also increased at a low level.

Furthermore, no significant relationship was found between science teachers' global warming knowledge levels and the classroom management or instructional strategies sub-dimensions of teacher self-efficacy. However, a positive and low-level relationship was observed between global warming knowledge levels and both the overall teacher self-efficacy and its student engagement sub-dimension. This suggests that as teachers' global warming knowledge increases, their overall teacher self-efficacy and student engagement also increase at a low level. Similarly, Karakaya (2012) found a significant relationship between science teacher candidates' global warming knowledge and both subject matter knowledge (SMK) and pedagogical content knowledge (PCK); however, no significant relationship was found between SMK and technopedagogical content knowledge (TPACK). Kaya et al. (2013) also identified a significant relationship between SMK and PCK among science teacher candidates in the context of global warming.

In this study, science teachers' overall technopedagogical educational competencies, as well as the design and application sub-dimensions, did not significantly differ according to their perceptions of school resources. Likewise, the ethics sub-dimension did not show a significant difference based on teachers' status of following scientific studies, and the expertise sub-dimension did not differ according to whether they shared global warming knowledge with students.

However, science teachers' ethics and expertise scores did differ significantly based on their perceptions of school resources. Teachers who perceived their school resources as sufficient scored higher in both sub-dimensions compared to those who perceived them as insufficient. This difference had a low effect size for the ethics dimension and a moderate effect size for the expertise dimension. According to the variable of following scientific studies, significant differences were found in the overall technopedagogical competencies and the application, design, and expertise sub-dimensions. Teachers who followed scientific studies "sometimes" had lower mean scores than those who followed them "always," and this difference had a moderate effect size.

Regarding the status of following global warming news, significant differences were observed in the overall technopedagogical competencies and all sub-dimensions (design, application, expertise, and ethics). Teachers who followed global warming news only "sometimes" had lower mean scores in all sub-dimensions compared to those who followed the news "always," and the effect sizes were moderate. Based on the status of sharing global warming knowledge with students, significant differences were found in the overall technopedagogical competencies and the design, application, and ethics sub-dimensions. Teachers who shared such knowledge "sometimes" or "frequently" scored lower than those who "always" shared it with their students. This difference was also found to have a moderate effect size.

The study also revealed significant, positive, and high-level correlations between the overall technopedagogical educational competencies and all of its sub-dimensions (design, application, ethics, and expertise); between design and the other sub-dimensions; between application and both ethics and expertise; and between ethics and expertise. These results suggest that an increase in one dimension is associated with high-level increases in the others. Karakaya (2013) reported that chemistry teachers did not keep up with innovations in educational technologies, and that there was a positive correlation between content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK) and years of experience, while a negative correlation was found between technological knowledge (TK), technological content knowledge (TCK), technological pedagogical knowledge (TPK) and years of experience.

Burmabıyık (2014) concluded that there was a low and positive correlation between teachers' level of technology use and their TPK, TCK, and TPACK competencies; a moderate and positive correlation with TK; and no significant relationship with CK, PK, or PCK. Kaya et al. (2013) reported that pre-service teachers lacked sufficient content knowledge and had inadequate knowledge regarding the purpose of technology integration into teaching. Tamir (1988) and Bozkurt & Kaya (2008) similarly identified deficiencies in teachers' content knowledge and the presence of conceptual misconceptions.

The literature (Tamir, 1988; Bozkurt & Kaya, 2008; Kaya, 2009; Kaya et al., 2013) suggests that insufficient conceptual knowledge is the most negatively influential type of knowledge on the development of TPACK. In his study, Sarı (2018) found that science teachers' self-efficacy levels differed in relation to CK, PK, PCK, TK, TCK, TPK, and TPACK. It was also found that teachers were partially confident in their content and technological knowledge, but had difficulties integrating technology with pedagogy during instruction. Some teachers who perceived themselves as competent in TPACK did not show the same level of performance in classroom practices.

There are also studies in the literature that examine the relationship between science teachers' technopedagogical educational competencies and their teacher self-efficacy (Karakaya, 2012; Karakaya, 2013; Lin et al., 2013; Sarı, 2018; Kırındı & Durmuş, 2019). In his study, Sarı (2018) concluded that teachers' self-efficacy levels varied across CK, TK, PK, PCK, TPK, TCK, and TPACK, and teachers had only partial confidence in their content and technological knowledge. Karakaya (2012) reported that while pre-service teachers had adequate knowledge of technologies used in science education, they were only partially competent in creating technology-enriched learning environments. Karakaya (2013) found that chemistry teachers' TPACK self-efficacy was not sufficiently high.

Kırındı & Durmuş (2019) observed that integrating technological innovations into lessons enhanced teachers' self-efficacy beliefs. Lin et al. (2013) found that science teachers who had self-efficacy in technology, pedagogy, and content knowledge also demonstrated self-efficacy in emerging knowledge domains such as TCK, TPK, and TK. Mahler et al. (2017) revealed that self-efficacy and topic-specific interest were positively associated with pedagogical content knowledge.

In this study, a significant, positive, and high-level relationship was found between overall classroom practices

and each of its sub-dimensions, including lesson design and implementation, content (theoretical and practical knowledge), and classroom culture (interaction–communication and student–teacher relationship). Accordingly, it can be stated that an increase in one aspect of classroom practices is associated with a high-level increase in the others. Significant, positive, and high-level relationships were also observed between lesson design and implementation and the sub-dimensions of content (theoretical and practical knowledge) and classroom culture (interaction–communication and student–teacher relationship), as well as between the interaction–communication and student–teacher relationship sub-dimensions. In addition, moderate-level, positive relationships were found between theoretical content knowledge and the other sub-dimensions (practical knowledge, interaction–communication, and student–teacher relationship), and between practical content knowledge and the two classroom culture sub-dimensions. However, no significant relationship was found between science teachers' global warming knowledge levels and overall classroom practices, including all sub-dimensions (lesson design and implementation, theoretical and practical content knowledge, classroom culture: interaction–communication and student–teacher relationship). In contrast to this finding, Karakaya (2012) found a significant relationship between science teacher candidates' global warming knowledge and their classroom practices. Kaya et al. (2013) reported that science teacher candidates were approximately 65% successful in implementing global warming-related content in classroom settings and attributed this limited success to inadequate and insufficient experience in practice schools. Moreover, this study found no significant relationship between science teachers' overall technopedagogical educational competencies and their classroom practices, including all respective sub-dimensions (application, design, expertise, ethics and lesson design and implementation, content, and classroom culture). In contrast, Sarı (2018) found a significant relationship between technological pedagogical content knowledge (TPACK) and classroom practices. While science teachers perceived themselves as competent in TPACK and its sub-dimensions, they were unable to fully integrate their knowledge of technology and pedagogy during lessons, and some failed to demonstrate sufficient performance in classroom applications. Kılıç et al. (2019) showed that TPACK-based instructional environments contributed positively to teacher candidates' classroom practices. Kaya et al. (2013) also found significant relationships between content knowledge (CK) and classroom practices, pedagogical content knowledge (PCK) and TPACK, and between TPACK and classroom practices, though no significant relationships were reported between CK and TPACK, or PCK and classroom practices.

Similarly, no significant relationships were found in this study between teachers' self-efficacy beliefs (overall and in the sub-dimensions of student engagement, classroom management, and instructional strategies) and their classroom practices. In contrast, Bayraktar and Çelik (2021) found significant differences in teachers' classroom management skills based on total years of service, gender, and subject area, but not based on educational level, professional seniority, or in-service training. They also found a moderate, positive relationship between teachers' self-efficacy and classroom management skills.

This study also revealed that science teachers' global warming knowledge levels and technopedagogical educational competencies do not significantly or positively predict their classroom practices. These independent variables accounted for only 1.8% of the variance in classroom practices, indicating no meaningful relationship between the variables and an insignificant regression model. In contrast to these results, Kılıç et al. (2019)

emphasized that TPACK-based learning environments had a significant effect on improving the classroom practices of science teacher candidates. Kaya et al. (2013) also stated that global warming knowledge levels positively influenced classroom practices. In the study conducted by Keller et al. (2017), teachers' pedagogical content knowledge and motivation in classroom practices moderately influenced students' interest in the subject and their academic success.

## Suggestions

In addition to quantitative studies, it is recommended that qualitative research and experimental studies also be conducted, as these would contribute to the diversification of studies on this topic. Furthermore, qualitative studies would enable science teachers to express their thoughts, feelings, and behaviors in a more detailed and authentic manner. Considering that many environmental problems—including global warming—are thought to be human-induced, and given the influence teachers have on students, lifelong environmental education is known to be the most effective solution to these problems. Therefore, it is of great importance to train teachers who are competent in environmental issues. Activities such as in-service training, seminars, and courses can be organized—or existing ones improved—in order to enhance teachers' competencies in the subject of global warming.

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