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# A FOUR-TIER DIAGNOSTIC TEST TO DETERMINE PRE- SERVICE SCIENCE TEACHERS' MISCONCEPTION ABOUT GLOBAL WARMING

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## Introduction

Although the factories established with industrialization, the developments in the transportation and automobile sector aimed to facilitate the lives of individuals, they brought many problems with them. Such developments have not only caused the use of huge amounts of natural resources throughout the world, but also greatly increased the use of fossil fuels, which is very harmful (Duran, 2021; Kurtuluş & Tatar, 2021). The damage caused by this situation has exceeded the capacity of nature to renew itself. In this context, many environmental problems have emerged. Especially in recent years, information about extreme weather events has been coming from many parts of the world. These are not natural weather phenomena. These natural disasters are the effects of the problems caused by the negative effects of humans on the environment, and perhaps the most serious of these problems, global warming, has been put on the agenda (Erten, 2012; Erten, 2015; Joireman et al., 2010; Pinto & Totti, 2020).

Global warming is the most negative result of human activities on nature (Al-Ghussain, 2019). It is the anthropogenic greenhouse effect that causes global warming. In other words, the amount of gases called greenhouse gases in the atmosphere as a result of human activities reaches a dangerous level. It is possible for our world to have a livable temperature with the gases in the atmosphere. However, the negative results of human activities increase the concentration of these gases in the atmosphere to abnormal levels, which causes global warming. Global warming has very serious effects that will have bad consequences for the planet and humanity. Melting of glaciers, difficulty in accessing potable water, global climate change are among the consequences of global warming that negatively affect the planet and all living things (Gürer & Sakız, 2018; Herndon, 2018; Spence, 2014).

It has been realized that global warming, which is on the world agenda, is caused by human beings and will pose a danger to the entire environment today and in the future. In this case, it has emerged that measures should be taken to solve this serious problem. There are many things to be done to reduce global warming. Renewable energy sources, green energy are some of the applications that will prevent the concentration of the gases we call greenhouse gases from increasing excessively (Shepardson et al., 2011). However, global warming is a global problem, so the measures to be taken



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**Abstract.** *Global warming is the most serious problem of our age. The most permanent measure to be taken against this problem is to ensure that individuals receive an effective and well-equipped education, free from misconceptions, which are obstacles to the efficiency of education. In this study, it is aimed to develop a four-stage diagnostic test that can reveal the misconceptions of pre-service science teachers about global warming. The sample of the study, in which the survey approach was used, consists of 401 pre-service teachers studying in the science teaching department at different universities in Turkey. The results show that the test is a valid and reliable measurement tool that can be used to determine the misconceptions, scientific knowledge, and lack of knowledge about global warming. In the study, the factor with the highest percentage of pre-service science teachers' scientific knowledge and misconceptions was the consequences of global warming, while the factor with the highest percentage of lack of knowledge was calculated as the greenhouse effect factor. It is recommended to use the test to determine the current situation regarding the level and areas where the misconceptions of individuals are concentrated to improve the missing or faulty areas in the science curriculum.*

**Keywords:** *conceptual learning, environmental misconceptions, four-tier diagnostic test, global warming*

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must be taken on a global scale as well as individually. With the understanding of the need for individual and social action to stop global warming, measures have been taken and action has been taken. Education in terms of the causes and consequences of global warming plays a key role in the fight against global warming (United Nations Environment Programme, 2003; Organisation for Economic Co-operation and Development, 2009; United Nations Framework Convention on Climate Change, 2014).

#### *Research Problem*

Environmental problems are not only the common problem of a region, but also of all living things. Even if environmental problems start in a certain region, their effects will be felt in other parts of the world over time, and they are the common problem of all living things, especially humanity. In this context, individuals play a key role in minimizing environmental problems. The only way to get rid of environmental problems is to enhance awareness of individuals about the environment (Hedefalk et al., 2014).

One of the biggest obstacles to the realization of effective learning is the misconceptions that occur in individuals. Misconceptions may arise from the personal experiences of individuals or from environmental factors such as course material and teaching environment. Misconceptions are obstacles that negatively affect individuals' current and future learning and prevent learning from taking place in a correct and holistic way (Haydari & Coştu, 2021; Kiray et al., 2015; Yin et al., 2014).

In this study, the issue of global warming was emphasized. When the literature is examined, there are many studies that detect misconceptions about global warming. The results of these studies show that individuals have misconceptions about global warming and these misconceptions make it difficult for them to reach correct information and behaviours. In this context, consciousness and awareness about global warming cannot be formed. Global warming is one of the most serious and urgent problems of our age. The most permanent measure to be taken regarding this problem is to ensure that individuals receive an effective and productive education on this issue. Only in this way can it be ensured that the knowledge, attitudes, skills, and behaviours of individuals about global warming are correct and environmentally friendly. However, thanks to individuals who grow up with this awareness, the negative effects of global warming on our planet can be minimized. In this context, teachers have a great responsibility. For this reason, it is important for teachers to graduate with the right information and to convey this information to their students and raise them with environmental awareness (Aksay et al., 2005; Prabha, 2020).

#### *Research Focus*

One of the biggest problems encountered in all fields of education, and therefore in science education, is misconceptions. Misconceptions occur as a result of misuse of concepts and incorrect learning resulting from lack of knowledge. Incorrect learning of basic concepts causes students not to be able to establish relations between concepts correctly and to understand laws and theories correctly. In this context, individuals cannot gain correct knowledge, skills, attitudes, and behaviours by establishing wrong cause-effect relationships with regard to the cases (Alkiş-Küçükaydın, 2019, Mataka ve Taibu, 2020, Taban & Kiray, 2021; Yıldırım, 2020).

Education faculties are kind of teacher schools. It has the vision and mission of graduating today's pre-service teachers to be well-equipped teachers of tomorrow. In order to raise individuals as individuals with environmentally friendly behaviours, educators in the field should be trained as individuals with environmentally friendly behaviours. An educator who does not have sensitivity towards environmental problems cannot be successful in conveying the sensitivity he does not have to his students. Pre-service teachers who receive undergraduate education in education faculties are individuals who will teach our children in the future. The students of today's education faculties are the teachers who will raise our generations. The more equipped and effective the education that pre-service teachers receive in education faculties, the more beneficial they will be to their students in their professional lives. With the quality of the education they receive, they will graduate as teachers who are equipped with awareness, knowledge, skills, values, and behaviours (Deniş & Genç, 2007; Maulana, 2016; Öztürk et al., 2015).

Science education, one of the departments within the faculties of education, has a great importance in environmental education as it trains science teachers (Derman & Gürbüz, 2018; Onbaşıllı, 2020). When the curricula of the Ministry of National Education are examined, one of the courses aimed at providing environmental education to individuals from an early age is science courses. When the science curriculum is examined, it is seen that many



concepts and acquisitions related to the cause, effect and solution of environmental problems are transferred to the students in line with the readiness of individuals at all grade levels (Gericke et al., 2020).

If we want to raise individuals who are competent and equipped on the subject of global warming, we must first make sure that the pre-service science teachers studying in education faculties have awareness and sensitivity about global warming. It should be absolutely sure that the information about the causes and consequences of global warming is correct and sufficient. When the literature is examined, there are many studies that determine the detection of misconceptions about the cause, effect and effect relationship of global warming. When these studies are examined, it is revealed that pre-service teachers have serious misconceptions (Aksan & Çeliker, 2015; Arsal, 2010; Arslan et al., 2012; Boyes & Stanistreet, 1992; Boyes et al., 1995; Boyes et al., 1998; Khalid, 1999; Khalid, 2000; Khalid, 2003).

In this context, it is of great importance that science teachers graduate with correct information free from misconceptions. However, teachers who have the right, sufficient and well-equipped knowledge can raise students with the desired behaviours and attitudes. For this reason, it is very important to determine the misconceptions of pre-service science teachers about global warming. If misconceptions are identified, necessary measures can be taken to prevent such mislearning, and existing misconceptions can be compensated for (Koray Cansüngü & Bal, 2002). In this way, teachers who graduate with correct and sufficient knowledge can contribute to the growth of future generations as environmentally friendly generations by transferring the skills they have to their students. And also the negative effects of many environmental problems, especially global warming, on the planet can be reduced.

When the literature is examined, studies aiming to determine the misconceptions about global warming are encountered. Some of these studies used a diagnostic test as a measurement tool. However, no four-tier diagnostic test developed to determine misconceptions about global warming has been found in the literature. This study is important in this respect.

#### *Research Aim and Research Questions*

In this study, it was aimed to develop a reliable and valid measurement tool to detect the misconceptions of pre-service science teachers about global warming. In this study, it was aimed to develop a four-tier misconception diagnostic test to detect misconceptions. With the developed diagnostic test, it is thought that the misconceptions of pre-service teachers about global warming and the reasons for these misconceptions can be determined. This study is important in terms of developing a measurement tool to be used to determine the misconceptions of pre-service science teachers.

The research is of great importance in terms of its role as guiding research for studies aimed at eliminating these misconceptions in the future. In line with this information, the following two questions were explored in this study.

1. Is the test developed to identify pre-service science teachers' misconceptions about global warming a valid and reliable measurement tool?
2. What are the factor-based values of pre-service science teachers' misconceptions, scientific knowledge, and lack of knowledge about global warming?

#### **Research Methodology**

##### *General Background*

In this study, it was aimed to develop a test to be used to determine the misconceptions of pre-service science teachers about global warming and determine the percentages of pre-service science teachers' misconceptions, scientific knowledge, and lack of knowledge about global warming on the basis of sub-dimensions. The study includes the development processes of the "Global Warming Misconception Diagnostic Test", which was developed to determine the misconceptions of pre-service science teachers about global warming. The study, which was carried out in the spring term of 2021-2022, covers the misconceptions, lack of knowledge and scientific knowledge of pre-service science teachers about global warming. In this study, the survey approach from the quantitative research strategy was used. The survey approach is one of the scientific research strategies used to determine the current situation. In this study, the survey approach was used because it was desired to reveal the current situation of pre-service science teachers.



### Study Group

The "Four-Tier Misconception Diagnosis Test", which was developed to determine the current misconceptions of pre-service teachers about global warming, was applied to 401 pre-service science teachers studying at 13 state universities located in different geographical regions of the Republic of Turkey for validity and reliability studies. Sekeran (1992), on the other hand, stated that a sample of 384 individuals could represent approximately 10,000,000 data. When the literature is examined, there are many studies that consider it appropriate to determine the sample size in relation to the number of items in the measurement tool. According to this view, the number of samples should be at least 5 times the number of items. Samples with 10 or more items are called perfect samples (Bryman & Cramer, 2001; Nunually, 1978). In this study, it was decided that the sample size should be at least 400 by considering all these opinions. 401 pre-service teachers participating in the study were found sufficient for the sample. The data of the study were collected in the spring semester of 2021-2022. The study group was determined by the convenience sampling method. All of the pre-service teachers who made up the study group voluntarily participated in the study. Of the pre-service teachers constituting the study group of the research, 302 (75.3 %) of them were female and 99 (24.7 %) of them were male pre-service teachers.

### Instrument and Procedures

When the literature is examined, it is seen that misconceptions are mostly determined through multi-tier diagnostic tests. Although there are several different versions of these tests, mostly two-tier tests were used before (Caleon ve Subramaniam, 2010). However, over time, it became important for researchers to determine the cause of these misconceptions as much as to identify the misconceptions. It was wondered whether the reason for wrong learning was misconception or lack of knowledge. In this context, three-tier and four-tier tests were started to be used to distinguish misconceptions from lack of knowledge. With the use of three-tier tests, it has become possible to determine whether the main reason for the student's wrong learning is misconception or lack of knowledge. However, in the three-tier tests, the confidence level presented to the student was asked both for the answer and for the reason step in which the reason for this answer was questioned. In these tests, the participant has two options: to be sure of the answer and the reason, or not. In the four-tier tests, this situation was resolved, and the confidence level was added after both the answer and the reason steps. With four-tier tests, it is possible to determine whether the student is sure of the first stage or the third stage, which the reason for the answer is questioned, with two confidence levels (Kaltakçı et al., 2015).

The first step of the four-tier test is called the content step. In this step, the information of the respondents is questioned. In the second step, it is questioned whether the respondent is sure of his answer to the content step. This step is the confidence step. The third step is called the reason step and it is the step in which the reason for the answer given by the respondent to the content step is questioned. The fourth step is the confidence level, which is similar to the second step. In this step, it is questioned whether the respondent is sure of the answer given in the reason step. Thanks to the four-tier tests created in this way, scientific knowledge, misconceptions, false positive, false negative and lack of knowledge can be determined by scoring the answers given by the respondents to these four steps. Possible decisions that can be determined as a result of the four-tier misconception diagnostic test analysis are presented in Table 1. (Kiray & Simsek, 2021).

**Table 1**  
*Finalization of Four-Tier Test Decisions*

1. Tier	2. Tier	3. Tier	4. Tier	Decision of four-tier test
True	Confident	True	Confident	SK
True	Confident	False	Confident	FP
False	Confident	True	Confident	FN
False	Confident	False	Confident	M



True	Confident	True	Not Confident	LK 1
True	Not Confident	True	Confident	LK 2
True	Not Confident	True	Not Confident	LK 3
True	Confident	False	Not Confident	LK 4
True	Not Confident	False	Confident	LK 5
True	Not Confident	False	Not Confident	LK 6
False	Confident	True	Not Confident	LK 7
False	Not Confident	True	Confident	LK 8
False	Not Confident	True	Not Confident	LK 9
False	Confident	False	Not Confident	LK 10
False	Not Confident	False	Confident	LK 11
False	Not Confident	False	Not Confident	LK 12

*SK* scientific knowledge, *LK* lack of knowledge, *M* misconception, *FP* false positive, *FN* false negative.

In this study, firstly, possible misconceptions in pre-service teachers were tried to be determined. It is thought that these possible misconceptions guide the questions and optional items in the test. For this purpose, 5 open-ended questions were prepared by the researchers, including the topics that are thought to cause misconceptions about global warming. What is meant by the subjects is; the greenhouse effect, ozone layer destruction, acid rain and climate change, which are determined to be confused with each other in terms of cause and effect relationship. In the process of determining 5 open-ended questions prepared by the researchers, literature review, interviews with pre-service teachers and observations of lecturers were used. Expert opinion was obtained from 2 science educators about 5 open-ended questions. Before applying the prepared open-ended questions to the pre-service teacher, 3 pre-service teachers, who will not be included in the study group, were given feedback about language use and whether there was any part that was not understood. Prepared open-ended questions were applied to 60 pre-service science teachers by the researcher without time limit.

Student responses to 5 open-ended questions were examined and analysed by the researchers. As a result of the analysis, the misconceptions identified in line with the answers given by the pre-service teachers to the questions were determined. After this process, the misconceptions determined as a result of the domestic and foreign literature review study, the misconceptions determined by analysing the open-ended questions, the misconceptions obtained from the interviews with the pre-service teachers and the observations of the lecturers were blended. And an item pool was created.

The questions created from the prepared item pool were converted into a multiple choice test with 3 options. In the multiple-choice test prepared, after each question, there is a section that asks them to choose the reason for choosing the above option from among the given options, and if the reason is not among the options, it allows them to present it in writing. This justification section was used in the formation of the reason step when the test was converted into four tiers. The test turned into a four-tier form by adding the confidence steps after both the content and reason steps. The questions in the prepared item pool were examined by the researchers. With the studies conducted, 14 questions were decided within the scope of the greenhouse effect, causes of global warming and consequences of global warming sub-dimensions. As a result of the examinations, a decision was made on 14 questions. These 14 questions, which were deemed appropriate by the researchers to remain in the test, were sent to three science educators working as faculty members at different universities for expert opinion. With the feedback received, the test was given its final form. Before proceeding to the data collection stage, the developed test was read to three pre-service science teachers who would not be included in the study group, and feedback was received about fluency and whether there was an incomprehensible expression in the test.



### *Data Analysis*

During the analysis of the data, the data were calculated with separate scores according to the possible consequences of scientific knowledge, misconception, false positive and false negative. During the calculations, the correct answer was coded as '1' and the incorrect answer was coded as '0' as valid for all questions. In the confidence steps where the state of being sure is questioned, the 'I am absolutely sure' and 'I am sure' options are coded as '1', and the 'I am not sure' and 'I am absolutely not sure' options are coded as '0'.

While calculating the scientific knowledge score, the calculation is made on the data coded as 1-1-1-1, that is, that the pre-service teachers answered the question correctly in all stages. When calculating the misconception score, the calculation is made on the data coded as 0-1-0-1, when the pre-service teachers gave the wrong answer to the first and third steps of the question and were sure of both confidence levels. While calculating the false positive that is the correct with wrong reasons scores, the calculation is made on the data coded as 1-1-0-1, in cases where the pre-service teachers gave the correct answer to the first step of the question and incorrectly to the third step of the question and were sure of both confidence levels. While calculating the negative mistakes, that is, the incorrect with correct reason scores the calculation is made on the data coded as 0-1-1-1, when the pre-service teachers answered the first step of the question incorrectly and the third step of the question correctly and were sure of both confidence levels.

The validity and reliability studies of the test aimed to be developed were carried out with Excel, AMOS and SPSS package programs.

## **Research Results**

### *Test Reliability*

Reliability analysis of misconception diagnostic tests is performed by calculating two different reliability coefficients. These coefficients are the reliability coefficient calculated for scientific knowledge scores and the reliability coefficient calculated for misconception scores.

#### *Reliability 1: Reliability of Scientific Knowledge*

The first type reliability coefficient of the global warming misconception diagnosis test is the coefficient calculated according to the scientific knowledge score determined according to the situation where the pre-service teachers answered the questions in the test correctly and were sure of their answers. This coefficient is the reliability coefficient to be taken as a basis when the test is used for to calculate the scientific knowledge scores of the participants. The first type reliability coefficient of the global warming misconception diagnostic test was calculated as .896 as a result of KR-20 analysis.

#### *Reliability 2: Reliability of Misconceptions*

The second type of reliability coefficient of the global warming misconception test is the coefficient calculated according to the misconception score determined according to the situation where the pre-service teachers gave wrong answers to the questions in the test and were sure of their answers. This coefficient is the reliability coefficient to be taken as a basis when the test is used for to calculate the misconception scores of the participants. The second type reliability coefficient of the global warming misconception diagnostic test was calculated as .705 as a result of KR-20 analysis.

### *Test Validity*

The validity of the misconception diagnostic tests is determined by the data obtained as a result of 4 different methods (Taban & Kiray, 2021).



*Validity 1: Factor Analysis*

Factor analysis was conducted to determine the construct validity of the test. In cases where the theoretical structure is certain, confirmatory factor analysis can be preferred among factor analyses to decide on construct validity (De Vellis, 2012).

In this study when the data obtained as a result of the literature review, open-ended question answers and the observations of the lecturers are examined, it is seen that the misconceptions emerge within the scope of three sub-dimensions; the nature of the greenhouse effect, the causes of global warming and the consequences of global warming. In this context, the items in the question pool prepared during the test development process were prepared within the framework of these three sub-dimensions.

The construct validity of the study was ensured by confirmatory factor analysis. AMOS package program was preferred for confirmatory factor analysis. Since the multivariate normality assumption was met, the Maximum Likelihood (MLR) estimation method was used for the models. For confirmatory factor analysis in the study,  $\chi^2/df$  (the value obtained by dividing the Chi-square fit statistic by the degrees of freedom), RMSEA (Root Mean Square Error of Approximation), S-RMR (Standardized Mean Square Residual), AGFI (Adjusted Goodness of Fit Index), GFI (Goodness of Fit Index), IFI (Incremental Fit Index) and TLI (Trucker Lewis Index) were examined. The fit indices used to determine whether the theoretical framework supports the data in confirmatory factor analysis are given in Table 2 (Hebebcı ve Shelley, 2018; Kline, 2005; Tabachnick ve Fidell, 2007).

**Table 2**

*Confirmatory Factor Model Fit Indices of the Four-Tier Global Warming Misconception Diagnostic Test*

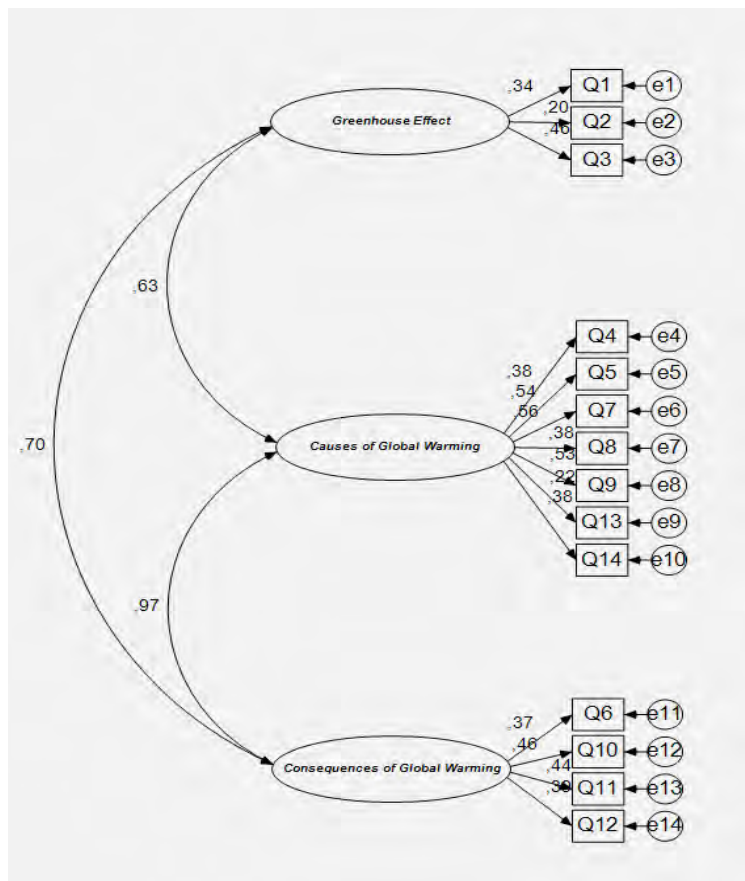
Fit Indices	Perfect Fit	Acceptable Fit	Fit Indices Observed in Test Model
$\chi^2/df$	$\chi^2/df \leq 3$	$3 < \chi^2/df < 5$	1.440
RMSA	$0 < \text{RMSA} \leq 0.05$	$0.06 < \text{RMSA} < 0.08$	0.033
S-RMR	$0 \leq \text{S-RMR} \leq 0.05$	$0.05 < \text{S-RMR} < 0.01$	0.041
GFI	$\text{GFI} \geq 0.90$	$0.85 < \text{GFI} < 0.90$	0.965
AGFI	$\text{AGFI} \geq 0.90$	$0.85 < \text{AGFI} < 0.90$	0.950
IFI	$\text{IFI} \geq 0.95$	$0.90 < \text{IFI} < 0.95$	0.933
TLI	$\text{TLI} \geq 0.95$	$0.90 < \text{TLI} < 0.94$	0.915

When the analysis results are examined, it is seen that all of the fit index coefficients calculated for the model are in the fit range. Therefore, no modification was needed in the model. The results obtained as a result of the confirmatory factor analysis show that the data support the theoretical framework. The construct validity of the scale was ensured. The path diagram for the confirmatory factor model of the four-tier global warming misconception diagnostic test is shown in Figure 1.



**Figure 1**

Path Diagram for the Confirmatory Factor Model of the Global Warming Misconception Diagnostic Test

*Validity 2: Correlation between Pre-Service Science Teachers' Correct Answer Scores and Confidence Scores*

In the study, three different correlation coefficients were calculated in order to examine the correlation between the correct answer and confidence scores of the pre-service teachers. These are:

1. Correlation between the first and second tiers (first confidence score)
2. Correlation between the third and fourth tiers (second confidence score)
3. Correlation between the first and third tiers and the second and fourth tiers (both confidence score)

The values obtained as a result of the analysis are presented in Table 3.

**Table 3***Correlation Coefficient of Global Warming Misconception Diagnostic Test*

Tier Scores	<i>r</i>	<i>p</i>
First Confidence Score	.440	< .001
Second Confidence Score	.492	< .001
Both Confidence Score	.488	< .001



As given in the table, the Pearson correlation coefficient calculated according to the answers given by the pre-service teachers to the first and second levels is .440. This coefficient indicates that there is a midlevel significant positive correlation between the answers given by the pre-service teachers to the first and second step. Another calculated correlation coefficient was calculated according to the answers given by the pre-service teachers to the third and fourth levels. This value was calculated as .492. This coefficient shows that there is a midlevel significant positive correlation between the answers given by the pre-service teachers to the third and fourth steps. The final correlation coefficient calculated is the correlation coefficient calculated according to the answers given by the pre-service teachers to the first and third step, and the second and fourth step. In other words, it is the correlation coefficient between the question steps and the confidence steps. The correlation coefficient calculated between the two confidence scores of the pre-service teachers was found to be .488. This value shows that there is a positive and significant midlevel relationship between the two confidence scores of the prospective teachers. Taban and Kiray (2021) stated that since the misconception tests are difficult tests, there should be a positive and significant relationship between the steps above, even if it is weak. Considering this criterion, it is seen that the validity criterion is met.

#### *Validity 3: False Positive and False Negative*

As a result of the misconception diagnostic tests, besides the misconceptions, scientific knowledge, and lack of knowledge of the participants, false positive and false negative averages of the participants can also be obtained. In the misconception diagnostic tests, false positive occurs when the correct answer is given to the content step, which we call the first step, while the wrong answer is given to the reason step, that is the third step, and both answers are sure. False negative occurs when the correct answer is given to the reason step which we call the third step while the wrong answer is given to the content step that is the first step and both answers are sure. In order to ensure the validity of misconception diagnostic tests, false positive and false negative averages should be below 10% (Hestenes & Halloun, 1995).

While the false positive averages calculated in the analyses made with the data obtained from the pre-service teachers within the scope of the study were 4.66%, the false negative averages were calculated as 1.65%. Both values are below 10%.

#### *Validity 4: Expert Opinions*

Expert opinion was obtained from 2 science educators for open-ended questions asked to pre-service teachers, in order to prepare questions and create an item pool.

When the question preparation and test development phase was completed, the draft test developed was sent to 3 science educators working as faculty members in different universities and expert opinion on the questions was obtained.

The results obtained from the analyses show that the four-tier misconception diagnostic test developed within the scope of the study is a valid and reliable measurement tool. One sample question in the test, whose validity and reliability studies were completed, is presented in Figure 2.



**Figure 2**

A Sample Question Regarding the Global Warming Misconception Diagnostic Test

3.1. Which of the following is true about greenhouse gases?

- a) It forms a thin layer in the atmosphere.
- b) It forms a thick layer in the atmosphere.
- c) It does not form a layer in the atmosphere.

3.2. Are you sure about your answer to the above question?

I am absolutely sure	I am sure	I am not sure	I am not absolutely sure

3.3. What is the reason of your choice for the question above?

- a) Since infrared ray cannot pass through the thick layer, it cannot spread into space.
- b) Since ultraviolet ray cannot pass through the thin layer, it cannot reach the earth.
- c) Since infrared ray cannot pass through the thin layer, it cannot reach the earth.
- d) Since ultraviolet ray cannot pass through the thin layer, it cannot spread into space.
- e) Since it is dispersed in the atmosphere, it does not form a layer.
- f) Since ultraviolet ray cannot pass through the thick layer, it cannot spread into space.
- g) Other .....

3.4. Are you sure about your answer to the above question?

I am absolutely sure	I am sure	I am not sure	I am not absolutely sure

*Percentages of Scientific Knowledge, Misconceptions and Lack of Knowledge Based on Test Items and Sub-Dimensions of Pre-Service Science Teachers*

After the validity and reliability analyses were completed, it was seen that the test was a suitable measurement tool to determine the misconceptions of pre-service science teachers about global warming. With the developed four-tier misconception diagnosis test, the percentages of scientific knowledge, misconceptions, and lack of knowledge of pre-service teachers were calculated on the basis of questions and factors. The data are presented in Table 4.

**Table 4**

Percentages of Pre-Service Science Teachers' Scientific Knowledge, Misconceptions and Lack of Knowledge (%)

Content Area	Test Items	Scientific Knowledge	Misconception	Lack of Knowledge
Category 1	1	37.9	26.1	26.6
	2	23.9	20.9	45.6
	3	27.1	21.1	48.3
Mean (%)	Factor 1	29.6	22.7	40.1
	4	36.4	18.7	31.9
Category 2	5	32.1	37.9	27.1
	7	26.1	38.9	31.4
	8	31.9	27.6	32.4
	9	45.8	24.1	24.6
	13	69.0	9.97	15.7
	14	57.6	11.7	21.1
Mean (%)	Factor 2	42.7	24.1	26.3



Content Area	Test Items	Scientific Knowledge	Misconception	Lack of Knowledge
Category 3	6	49.1	21.6	21.4
	10	29.9	41.3	23.6
	11	41.8	27.1	28.4
	12	67.0	12.7	15.9
Mean (%)	Factor 3	46.9	25.6	22.3

When the table is examined, it is seen that the average percentage of scientific knowledge of the pre-service teachers for the questions in the first factor is 29.6%, the percentage of misconceptions is 22.7% and the percentage of lack of knowledge is 40.1%. When the questions in the first factor are examined, it is seen that these questions are related to the nature and mechanism of the greenhouse effect. When the averages for the second factor are considered, the percentage of scientific knowledge is 42.7%, the percentage of misconceptions is 24.1% and the percentage of lack of knowledge is 26.3%. When the questions within the scope of the second factor are examined, it is seen that this factor includes questions about the relationship between the causes of global warming and various variables. When the third factor is examined, it is seen that the percentage of pre-service teachers' scientific knowledge is 46.9%, the percentage of misconceptions is 25.6% and the percentage of lack of knowledge is 22.3%. When the questions within the scope of the third factor are examined, it is seen that these questions are about the relationship between the consequences of global warming and various variables. When the average percentages given on the basis of factors are examined, it is seen that the highest scientific knowledge average of the pre-service teachers is in the third factor. The highest misconception average was calculated in the third factor, while the highest lack of knowledge average was calculated in the first factor.

## Discussion

Global warming is a serious problem in today's world where industrialization continues to increase day by day. The way to minimize the effects of this problem is to raise educated individuals. Individuals will continue their lives as effective and well-equipped individuals in line with the education they receive. In this respect, it is very important for the effectiveness of the education that the education they receive includes the right information. Misconceptions are one of the biggest obstacles encountered in education. When the literature is examined, it is seen that there are many different methods to detect misconceptions. Methods such as multiple choice tests, two-tier tests, three-tier tests, open-ended questions, interviews, concept maps, word association are some of them (Hestenes et al., 1992). With this research, it is aimed to develop a valid and reliable measurement tool that can be used to detect the misconceptions of pre-service science teachers about global warming. At the end of the study, the "Four-Tier Global Warming Misconception Diagnostic Test", which was analysed, was presented to the literature. With the developed test, pre-service teachers' misconceptions, lack of knowledge and scientific knowledge percentages were calculated on the basis of questions and factors.

It is seen that the average percentage of misconceptions calculated for the questions in the first factor of the pre-service teachers is 22.7%. When the questions in the first factor are examined, it is seen that these questions aim to measure the misconceptions of pre-service teachers about the nature of the greenhouse effect and the characteristics of greenhouse gases. When the literature is examined, similar to our study, there are studies in which misconceptions about these features are detected. The first of these misconceptions is the perception that the greenhouse effect is a purely anthropogenic phenomenon (Daniel et al., 2004; Karpudewan et al., 2014; Khalid, 2003). Another misconception is the perception that water vapor is not a greenhouse gas or is the primary cause of the anthropogenic greenhouse effect (McCuin, 2011; McCuin et al., 2014). Another misconception found in the literature within the scope of this factor is the perception that greenhouse gases exist as a thin or thick layer in the atmosphere (Ekborg & Areskou, 2006; Wachholz et al., 2014).

When the results of the analysis are examined, it is seen that the average of the misconception percentages of the pre-service teachers for the second factor is 24.1%. The questions in this factor are those that aim to measure the misconceptions about the causes of global warming. When the literature is examined, similar to our study, there are studies in which misconceptions about these features are detected. The most common of these misconceptions is the perception that ozone layer destruction or acid rain is the primary cause of global warming (Andersson & Wallin,



2000; Arslan et al., 2012; Khalid, 2001; Kılınç et al., 2008; Satriadi, 2019; Yazdanparast et al., 2013). Other misconceptions in the literature within the scope of this factor are the perceptions that forest fires, rotten garbage, fertilizer use, fossil fuel use do not contribute to global warming, while nuclear power plants increase global warming (Boyes & Stanisstreet, 2001; Chang & Pascua, 2015; Eroğlu & Aydoğdu, 2016; Etobro, 2020; Jafer, 2020; Mohapatra, 2009).

The average of the misconception percentages of the pre-service teachers calculated for the third factor was calculated as 25.6%. The questions in this factor are those that aim to measure the misconceptions about the consequences of global warming. When the literature is examined, similar to our study, there are studies in which misconceptions about these features are detected. One of the most common misconceptions identified in the literature regarding this issue is the perception that acid rain or ozone layer destruction is the result of global warming (Boyes et al., 1995; Daniel et al., 2004; Hebe, 2020; Khalid, 1999; Khalid, 2003; Öcal et al., 2011; Yalçın & Yalçın, 2017). Other misconceptions in the literature within the scope of this factor are that skin cancer cases and cataract cases occur as a result of global warming. Another misconception within the scope of this factor is the perception that the global average precipitation amount and the amount of oxygen in the atmosphere decrease as a result of global warming (Boyes & Stanissteeet, 2001; Darçın et al., 2006; Dikmenli, 2010; Eroğlu et al., 2016; Kılınç et al., 2008; Koulaidis & Christidou, 1993; Khalid, 1999; Khalid, 2003; Lin, 2016; Yazdanparast et al., 2013).

### Conclusions and Implications

The primary purpose of this study was to develop a valid and reliable measurement tool for detecting pre-service science teachers' misconceptions about global warming. Within the scope of the study, a four-tier misconception diagnosis test was developed as a measurement tool. The developed four-tier misconception diagnostic test has three sub-dimensions: greenhouse effect, causes of global warming and consequences of global warming. The sub-dimensions of the four-tier misconception diagnosis test consisting of 14 items were supported by confirmatory factor analysis. With factor analysis results, it was supported that the 1st, 2nd and 3rd items were compatible with the greenhouse effect sub-dimension. It was supported that the 4th, 5th, 7th, 8th, 9th, 13<sup>th</sup>, and 14th items in the test were compatible with the global warming causes sub-dimension and the 6th, 10th, 11<sup>th</sup>, and 12th items were compatible with the global warming consequences sub-dimension.

The results obtained from the analyses show that the developed misconception diagnosis test is a valid and reliable measurement tool for measuring the misconceptions of pre-service science teachers about global warming. With the test developed in the study, the percentages of pre-service teachers' misconception, scientific knowledge and lack of knowledge scores were calculated on the basis of sub-dimensions. According to this calculation, it is seen that the highest scientific knowledge average of pre-service teachers belongs to the sub-dimension of the consequences of global warming. While the highest misconception average was calculated in the consequences of global warming sub-dimension, the highest lack of information average was calculated in the greenhouse effect sub-dimension.

This scale was developed in order to detect the misconceptions of pre-service science teachers about global warming. However, similar results are expected when working with science teachers. It may be recommended to repeat validity and reliability studies in studies to be conducted with a study group other than science teachers.

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### Declaration of Interest

The authors declare no competing interest.

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