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Research Article

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Measurement Tool for The Determination of Misconceptions About Change of State

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Abstract

Misconceptions are one of the most serious obstacles to education. Chemistry is one of the sub-disciplines of science. Failure to learn basic chemistry concepts accurately and completely may appear as misconceptions. The focus of the study is on state change. The aim of this study is to develop a valid and reliable measurement tool that can be used to determine the misconceptions of pre-service science teachers about change of state. The research is a quantitative study. The study data were obtained using the survey method. Within the scope of the study, a four-tier diagnostic test was developed by the researchers as a measurement tool. The participant group of the study consisted of pre-service science teachers from all grade levels continuing their undergraduate education in the science teaching department of a faculty of education in the Central Anatolia region. A total of 221 pre-service science teachers, who were selected using the convenience sampling method, constitute the study group of the research. Through the analysis of the data, it was determined that the four-tier change of state misconception diagnostic test developed by completing the validity and reliability studies within the scope of the research was a valid and reliable measurement tool.

Key Words

Science education • Change of state • Misconceptions

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Concepts

The basis of learning is built on making sense of and associating new information with the existing knowledge of the individual. According to many researchers, including Ausebel, one of the most substantial factors affecting learning is the existing knowledge of individuals, that is, their prior knowledge (Brod, 2021; Hailikari et al., 2008). In this context, in order for learning to take place fully and accurately, the individual's prior knowledge, that is, the existing knowledge, should be purified from false learning (Agra et al., 2019; Potvin et al., 2015). Knowledge acquired in daily life can sometimes lead to unscientific mislearning and misconceptions (Khalid & Embong, 2019). Misconceptions are a serious problem encountered in the teaching of all branches of science. Pose significant obstacles to healthy and accurate learning processes. In order for learning to take place correctly and error-free, concepts must be learned and understood correctly and error-free. When concepts are learned incompletely or incorrectly for some reasons, it causes future learning to be structured incorrectly and incorrect learning to be realized. Misconceptions are very resistant structures and if they are not detected and corrected in the individual, they will affect all other learning throughout his/her life and cause him/her to be equipped with inaccurate and unscientific knowledge (Kurtulus & Tatar, 2021; Mataka & Taibu, 2020; Taylor & Kowalski, 2014).

Science is an active and living field. All the disciplines it includes are directly related to life. Science is a complex discipline that includes many sub-disciplines. In other words, it is a multidisciplinary science (Morillo et al., 2003). Chemistry is one of the sub-disciplines within science. Like other disciplines of science, chemistry is a science that is highly related to daily life (Gilbert, 2006; Icoz, 2015). Chemical science contains many abstract concepts due to its complex structure. Due to the difficulties experienced in the process of structuring and making sense of these abstract concepts in the individual, difficulties or mislearning may occur in learning. In this context, chemistry is one of the branches of science in which misconceptions are frequently encountered (Nahum et al., 2004). When the literature is perused, there are numerous studies focused on misconceptions in chemistry science subjects (Al-Balushi et al., 2012). For example; chemical bonds (Coll & Treagust, 2001; Dhindsa & Treagust, 2009), atomic structure (Park & Light, 2009; Stefani & Tsaparlis, 2009), oxidation and reduction (Barke et al., 2009), electrochemistry (Ahtee et al., 2002; Lin, et al., 2002) acids and bases (Cetingul & Geban, 2005; Lin & Chiu, 2007; Yasa & Kocak, 2022) and chemical equilibrium (Bilgin, 2006). Upon examination of the studies, it is observed that different researchers aimed to determine the misconceptions in the subjects of chemistry science with different methods. Misconceptions can be identified with many different methods. Each method has advantages and disadvantages. Interview, open-ended questions, multiple-choice tests and tiered diagnostic tests can be given as examples. Recently, tiered diagnostic tests have been widely used (Maharani et al., 2019; Putri et al., 2021).

Rationale and Purpose of the Study

The subject of change of state is among the basic topics of chemistry. In this context, the complete and accurate teaching of this subject is important in order to prevent the formation of misconceptions related to chemistry science in individuals. It is important that science teachers, who introduce chemistry-related topics to young age groups, do not have misconceptions about their sub-disciplines in order to prevent future generations from having misconceptions. Pre-service teachers should graduate from the faculties of education with complete and accurate information. In fact, teachers transfer the information that they think is correct to students. If there are misconceptions in this information, these misconceptions will also be transferred to future generations. When the literature is examined, there is no specific measurement tool developed for the determination of misconceptions about change of state. In this regard, the purpose of this study is to develop a valid and reliable measurement tool for the subject of change of state and present it to the literature. As the measurement tool to be developed, a four-tier misconception diagnostic test specific to the subject of change of state was preferred. Four-tier diagnostic tests provide data not only on misconceptions but also on the prior knowledge that causes these misconceptions. Four-tier diagnostic tests were preferred because of their ability to provide data on individuals' lack of knowledge, scientific knowledge, misconceptions, false positives and false negatives. It is thought that the misconceptions of pre-service science teachers can be determined with the phased diagnostic test developed within the scope of the study. In this context, the areas where misconceptions are present can be identified and the elimination studies can be focused on these areas.

Method

This quantitative study aimed to develop a valid and reliable measurement tool for identifying misconceptions among pre-service science teachers regarding changes in state.

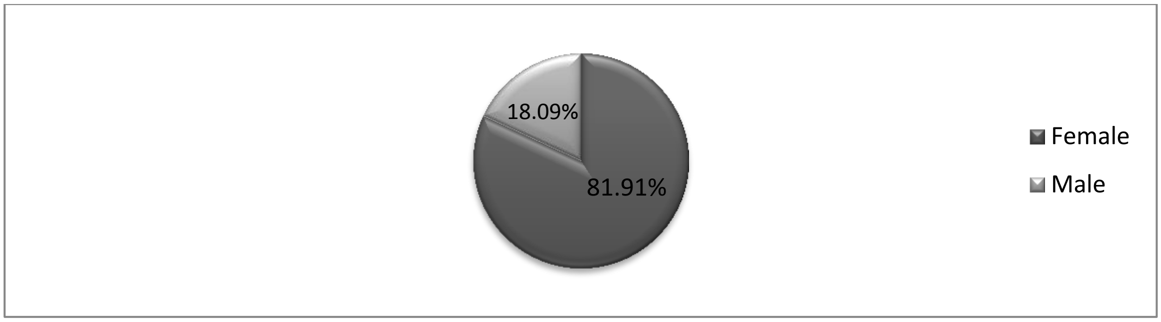
Research Design

This research, which was conducted to develop a valid and reliable tiered diagnostic test that can be utilized to determine the misconceptions of pre-service science teachers about change of state, is a quantitative research. The data of the study were gathered by survey method. The survey method used to diagnose the current situation is one of the scientific research method. The survey method is a scientific research method that aims to describe a past or present situation as it is (Groves et al., 2009).

Study Group

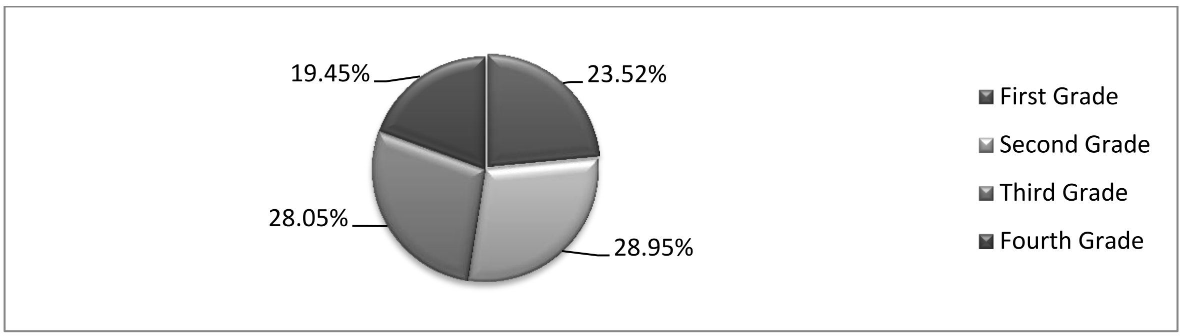
The participant group of the study comprised 221 pre-service science teachers. The participant group of the study consisted of pre-service teachers from each grade level continuing their undergraduate education in the science teaching department of a state university in Türkiye. The convenience sampling method was utilized to determine the participant group. This approach, commonly referred to as convenience sampling, involves selecting samples from readily available and applicable units due to constraints such as time, budget, and available workforce (Kılıc, 2013). The study data were gathered in the spring semester of the 2023-2024 academic year.

The study group of the research consisted of 181 (81.91%) female and 40 (18.09%) male pre-service teachers (Graph 1).



Graph 1. Gender distribution of pre-service science teachers

The participant group consisted of 52 first-year (23.52%), 64 second-year (28.95%), 62 third-year (28.05%) and 43 fourth-year (19.45%) pre-service teachers (Graph 2).



Graph 2. Distribution of pre-service science teachers according to grade level

Research Instruments and Processes

The research is a test development study. In the study, a four-tier misconception diagnostic test was developed for the subject of change of state. The test was developed by the researchers within the extent of the study. The misconception diagnostic test comprising four tiers, developed as part of the study consists of eight questions in its draft form. Each question in the test consists of four stages in total. During the test development process, instructor observations and misconceptions in the literature were taken as the basis for the preparation of questions and options. Question patterns and options were prepared by blending the misconceptions that the researchers decided existed in the students with the findings of the studies in the literature through informal observations during theoretical and practical lessons. An item pool was created with the prepared questions. The item pool was analyzed by the researchers and eight questions which is thought to contain all of the possible misconceptions on this subject were decided. The eight questions were converted into multiple-choice format. With the addition of reason and trust steps to the multiple-choice test format, it was transformed into a four-tier diagnostic test. The developed draft test was sent to three field experts and expert opinions were obtained. The test was finalized by making the necessary arrangements with the feedback from the expert opinions. The multiple-choice test was administered to the pre-service science teachers who constituted the participant group of the study for validity and reliability studies.

After the validity and reliability analyses, the test developed to determine misconceptions about the subject of change of state was finalized with seven four-tier questions. The researchers personally conducted the data collection process. The data were collected at one time. All pre-service teachers who participated in the study answered the questions voluntarily.

Data Analysis

Data were analyzed with Excel and SPSS package programs. In the data analysis phase, the data were calculated separately according to the possible outcomes of the four-tier misconception diagnostic test. These possible outcomes are scientific knowledge, misconceptions, false positives and false negatives. The data remaining after these calculations represent the lack of knowledge rates of individuals. Throughout the calculations, a coding system was employed where the correct answers were represented as '1,' and the incorrect answers as '0' for all questions. In the step where the question of being sure or not in the confidence steps was questioned, the options of absolutely sure and sure were coded as '1', and the options of not sure and absolutely not sure were coded as '0'. When computing the scientific knowledge score, the calculation was derived from data coded as 1-1-1-1, indicating that pre-service teachers answered all components of the question correctly. When computing the misconception score, the calculation was performed using data coded as 0-1-0-1, signifying that pre-service teachers provided incorrect responses to the first and third components of the question while expressing confidence in both confidence steps. When calculating the false positives, i.e. correct scores with incorrect reasons, the calculation was made over the data coded as 1-1-0-1, i.e. the cases where the pre-service teachers answered the first step of the question correctly, the third step incorrectly and were sure of both confidence levels. When computing false negatives, denoting incorrect scores with correct reasoning, the calculation used data coded as 0-1-1-1. This one represents instances where pre-service teachers answered the first step of the question incorrectly, the third step correctly, and expressed confidence in both confidence levels.

Before proceeding to the validity and reliability analyses, four pre-service science teachers (one from each grade level) who were not included in the research study group were asked to read the test and it was determined whether the overall test had any problems in terms of expression and fluency.

Results

Before starting the validity and reliability studies, the reliability coefficient was calculated for the draft test consisting of eight questions as a preliminary study. The coefficients were calculated separately for scientific knowledge and misconception scores and KR-20 analysis was used. The sample for the preliminary study was determined to be 40. Considering that the test consisted of eight questions, five times the number of participants was sufficient for the pretest (Tavşancıl, 2002). The reliability coefficient of the pretest with 40 participants was calculated as KR-20; ,598 for misconception scores and KR-20; ,613 for scientific knowledge scores. Both numbers indicate that the reliability of an 8-item test was achieved. When interpreting the reliability coefficient for tests containing less than fifteen items, the coefficients calculated as 0.50 and above are interpreted as sufficient reliability (Kehoe, 1994).

The four-tier misconception diagnostic test for change of state was administered to 221 pre-service science teachers to complete the validity and reliability studies. The validity and reliability studies were developed using the data collected from pre-service science teachers.

Validity Analysis Findings of the Test

Validity analyses in four-tier diagnostic tests are completed in four steps. To decide that the four-tier tests are valid, the findings of these four steps are evaluated and conclusions are reached. The four items are listed as expert opinion, factor analysis, positive and negative false rates, and the correlation coefficient calculated between certain stages (Taban & Kiray, 2021).

Validity Analysis 1; Expert Opinion

When the questions were prepared, creating the item pool, and selecting the questions were completed, the draft test was sent to two science and one chemistry educators working as faculty members in different universities. Expert opinions were obtained about the questions, and the test was reorganized in line with the expert opinions. The test was reorganized in line with the expert opinions. Thus, the test was ready for data collection for validity and reliability studies.

Validity Analysis 2; Factor Analysis

In order to ascertain the construct validity of the four-tier diagnostic test developed to determine pre-service science teachers' misconceptions about change of state, it was decided to conduct exploratory factor analysis. Before the factor analysis, Kaiser-Meyer-Olkin (KMO) values and Barlett Sphericity test results were examined to determine the adequacy of the sample size. As a result of the analysis, the KMO value of the test was calculated as ,675. The Barlett Sphericity test result was significant ($p< .005$). Both values indicate that the data are appropriate for factor analysis (Kaiser, 1970; Shrestha, 2021).

After deciding on the adequacy of the sample, factor analysis was performed. As a consequence of the factor analysis, it was determined that the factor load of the third item was below 0.4 and it was decided to remove from the scale. After the third item was removed from the scale, the factor analysis was repeated. The test consisting of seven questions showed a three-factor structure. The items and factor loads are presented in Table 1.

Table 1

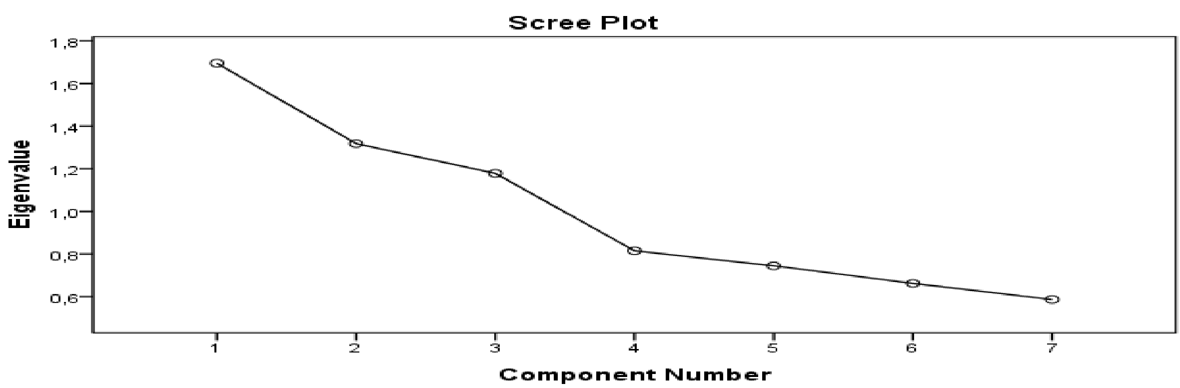
Exploratory factor analysis results of the four-tier change of state misconception test

Test Questions	**Factor 1**	**Factor 2**	**Factor 3**
Question 7	,803		
Question 3	,802		
Question 1		,852	
Question 5		,692	
Question 4		,512	
Question 6			,738
Question 2			,692

It was observed that the factor loadings of all questions were higher than "0.4". Among the items that make up the test, items 7 and 3 were under the first factor, items 1, 5, and 4 were under the second factor, and items 6 and 2 were under the third factor. When the items under the first factor were analyzed, it was found appropriate to name this factor as "external factors". The second factor consisting of items 1, 5 and 4 was named "states of matter" and the factor consisting of questions 2 and 6 was named "boiling". When the factor variances were analyzed, it was observed that the first factor named external factors explains 22.047% of the total variance, the second factor named states of matter explains 19.925% of the total variance and the last factor named boiling explains 17.911% of the total variance. All factor eigenvalues were greater than "1" and the three factors explain 59.883% of the total variance. The eigenvalue graph of the identified factors is given in Figure 1. It was seen that there are three factors with eigenvalues greater than 1 and 1 and that the slope continues to decrease continuously after the third factor and the graph moves horizontally.

Figure 1

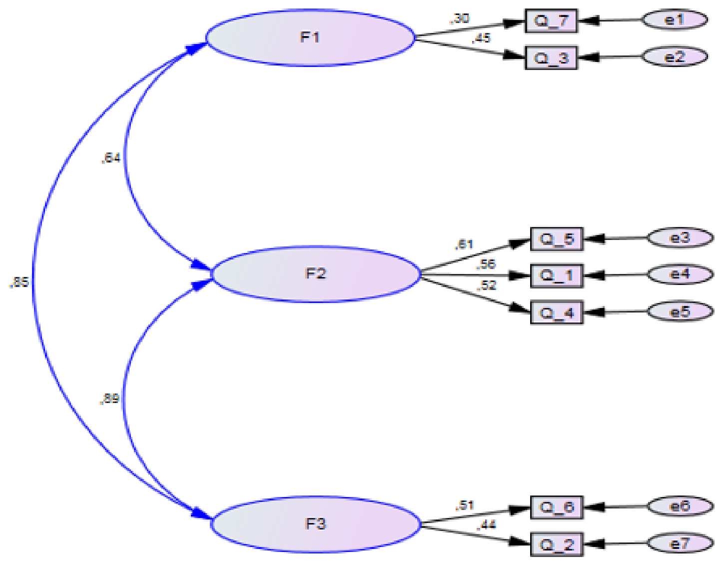
Factor eigenvalue graph obtained as a result of exploratory factor analysis of the four-tier change of state misconception diagnostic test



The three-factor structure identified in the exploratory factor analysis was confirmed through confirmatory factor analysis. For confirmatory factor analysis, data obtained from 215 pre-service science teachers from each grade level who were not included in the main study group of the research were used. AMOS program was preferred for confirmatory factor analysis. The path diagram obtained as a result of the analysis is presented in Figure 2.

Figure 2

Path diagram obtained as a result of confirmatory factor analysis



The factor loadings of the first factor, external factors, are between 0.30-0.45, the factor loadings of the second factor, states of matter, are between 0.52-0.61, and the factor loadings of the last factor, boiling, are between 0.44-0.51. According to the results of the confirmatory factor analysis, strong relationships were found between the first factor and the second factor at a positive level of 0.64, between the second factor and the third factor at a positive level of 0.89, and finally between the first factor and the third factor at a positive level of 0.85.

Since the multivariate normality assumption is met for the analysis data, the Maximum Likelihood (MLR) estimation method is used for the models. For confirmatory factor analysis in the study, x^2/df the result of 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), CFI (Comperative Fıt 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. (Hebebci & Shelley, 2018; Kline, 2005; Tabachnick & Fidell, 2007).

Table 2

Confirmatory factor model fit ındices of the four-tier change of state misconception diagnostic test

Fit Indices	**Perfect Fit**	**Acceptable Fit**	**Fit Indices Observed in Test Model**
x^2/df	$x^2/df \leq 3$	$3 < x^2/df < 5$	1,50
RMSA	0< RMSA ≤ 0,05	0,06 <RMSA ≤ 0,08	,035
S-RMR	0≤ S-RMR ≤ 0,05	0,05< S-RMR< 0,08	,030
GFI	GFI ≥ 0,90	0,85 < GFI <0,90	,988
AGFI	AGFI ≥ 0,90	0,85 < AGFI <0,90	,970
IFI	IFI ≥ 0,95	0,90 < IFI < 0,95	,979
TLI	TLI ≥ 0,95	0,90 < TLI < 0,95	,957
CFI	CFI ≥ 0,97	0,95 ≤ CFI < 0,97	,978

When the results of the analysis were examined, it was seen that all of the fit index coefficients calculated for the model are within the fit range. The results of the confirmatory factor analysis support the three-factor structure obtained from the exploratory factor analysis. The construct validity of the four-tier state change diagnostic test was ensured by both factor analyses.

Validity Analysis 3; False Positive and False Negative Rates

The four-tier diagnostic tests present factors such as participants' scientific knowledge, misconceptions and lack of knowledge, as well as their false positive and false negative rates. False positives are the results of individuals reaching the right conclusion with the wrong reason while answering a question. In other words, the individual answered the question correctly, but reached the correct answer with a wrong reason. However, the individual is sure of both his/her answer and the accuracy of the knowledge that is the reason for this answer. In this context, another name for these constructs is false reasoned truths. As a result of the analysis, the researchers' false positive average for the overall test was calculated as 4.20%.

Another construct that can be calculated with four-tier diagnostic tests is the construct we call false negatives. False negatives are when individuals arrive at the wrong answer to the content step with a correct reason. In other words, the individual give a wrong answer with a reason that is correct information. However, the individual is sure of the accuracy of the information given in both the content and reason steps. In this context, these constructs are also known as errors with correct reasons. As a outcome of the analysis, the average false negatives rate of the researchers for the overall test was calculated as 4.13%. In order to guarantee the validity of the four-tier misconception diagnostic tests, false positives and false negatives should be below 10% (Hestenes & Halloun, 1995). When the calculated values were analyzed, it was seen that both values were below 10%.

Validity Analysis 4; Correlation

One of the validity analyses of the four-tier diagnostic tests is the correlation coefficient calculated between the participants' step-by-step answers. The validity of this step in four-tier diagnostic tests is decided by calculating and evaluating 3 different correlation coefficients. These coefficients are;

1. Correlation calculated between the first (content) and second step (confidence) (First confidence score)

2. Correlation calculated between the third (reason) and fourth step (confidence) (Second confidence score)

3. Correlation calculated between the first (content) and third steps (reason) and between the second and fourth steps (both confidence scores).

The values acquired as a result of the analysis of the data obtained from the science teachers' candidates are presented in Table 3.

Table 3

Correlation between the scores of pre-service teachers

Confidence Scores	**Pearson Correlation**	**Sig. (2-tailed)**
First Confidence Score	.336	.000
Second Confidence Score	.340	.000
Both Confidence Scores	.385	.000

Before the correlation analysis, normality tests of the data groups were performed. Pearson product-moment correlation (simple linear correlation) was applied after the data were found to be normally distributed. As can be seen in the table, the Pearson correlation coefficient calculated between the answers of the pre-service science teachers to the first and second steps of the questions in the four-tier change of state misconception diagnostic test was calculated as .336. Another correlation coefficient calculated in the analyses was the Pearson correlation coefficient between the answers given by the pre-service teachers to the third and fourth steps of the test questions. This number was calculated as .340. The last coefficient required to complete the validity analysis is the Pearson correlation coefficient calculated for the participants' answers to the first and third steps and the second and fourth steps of the test. This coefficient was calculated as .385. All three Pearson correlation coefficients show that there is a positive and significant relationship between the data groups analyzed in the correlation analysis. In their study, according to Taban and Kiray (2021), given that misconception tests are inherently challenging, there should exist a positive and statistically significant correlation among the mentioned steps, even if it's modest. Evaluating based on this standard, it's evident that the validity criterion is satisfied.

It was seen that the four-tier change of state misconception diagnostic test developed with the results of this step in accordance with the literature is a valid measurement tool.

Reliability Analysis Results of the Test

Reliability analyses of misconception diagnostic tests are performed by evaluating two different coefficients. These coefficients are the reliability coefficients calculated according to the scientific knowledge and misconception scores of the participants.

First Type Reliability: Scientific Knowledge Reliability Coefficient;

This coefficient was calculated based on the scientific knowledge scores of the pre-service teachers from the misconception of change of state diagnostic test. The first type reliability coefficient of the change of state misconception diagnostic test is the reliability coefficient to be taken as a basis when it was used to calculate the scientific knowledge scores of the participants of the study. As a result of KR-20 analysis, this coefficient was calculated as .741.

Second Type Reliability: Misconception Reliability Coefficient;

This coefficient was calculated based on the misconception scores of the pre-service teachers from the misconception of change of state diagnostic test. The second type of reliability coefficient of the change of state misconception diagnostic test is the reliability coefficient to be taken as a basis when it was used to calculate the misconception scores of the participants of the study. As a result of KR-20 analysis, this coefficient was calculated as .521. When the reliability analyses were examined, the KR-20 value calculated for the scientific knowledge scores of the participants in the test was calculated as .741, while the KR-20 reliability coefficient value calculated for the misconception scores was calculated as .521. When interpreting the reliability coefficient for tests containing less than fifteen items, the coefficients calculated as .50 and above are interpreted as sufficient reliability (Kehoe, 1994). Considering that the developed four-tier misconception diagnostic test consists of seven items, the calculated coefficients showed that the test is reliable in both categories.

Figure 3

Four-tier change of state misconception diagnosis test sample question

5.1. A quantity of water at 10°C is cooled down to 0°C for freezing. Which of the following events occurs during this process?

a) Due to the freezing of water molecules, ice molecules become smaller.

b) Due to the freezing of water molecules, ice molecules do not move at all.

c) Due to the freezing of water molecules, the spaces between ice molecules increases, causing an increase in volume.

5.2. Are you sure about your answer the previous question?

a) Absolutely sure

b) Sure

c) Not sure

d) Absolutely not sure

5.3. Which of the following is your reason for selecting the above option?

a) Since water expands when it freezes, water molecules decrease in size.

b) The size of water molecules is smallest in the solid phase and largest in the liquid phase because during the transition from solid to liquid and from liquid to gas, the volume of molecules increases.

c) As the temperature decreases during the freezing of water, the temperature of the molecules also decreases, so the molecules freeze and their volume decreases.

d) Since water freezes and becomes solid, its molecules do not move.

e) Due to the hexagonal molecular arrangement in ice, there are more spaces between molecules compared to those in the liquid phase, resulting in an increase in volume.

f) Other...

5.4. Are you sure about your answer the previous question?

a) Absolutely sure

b) Sure

c) Not sure

d) Absolutely not sure

The results of the validity and reliability analyses showed that the four-tier change of state misconception diagnostic test is a valid and reliable measurement tool for determining the current misconceptions of pre-service science teachers about state change. A sample question belonging to the "Four-tier Change of State Misconception Diagnostic Test" whose validity and reliability analyses were completed is given in Figure 3.

With the Four-Tier Change of State Misconception Diagnosis Test, the question and factor-based scientific knowledge, misconception, false positive, false negative and lack of knowledge ratios of pre-service teachers were determined. The findings are presented in Table 4.

Table 4

Rates of pre-service teachers' scientific knowledge, misconceptions, false positive, false negative and lack of knowledge

	Test Items	**Scientific Knowledge**	**Misconceptions**	**False Positive**	**False Negative**	**Lack of Knowledge**
Factor 1; External Factors	3	21.71%	7.69%	4.97%	18.55%	47.08%
	7	69.23%	3.61%	3.61%	4.07%	19.48%
Mean (%)	Factor 1	45.47%	5.65%	4.29%	11.31%	33.28%
Factor 2; States of Matter	1	74.66%	8.14%	0.45%	0.90%	15.85%
	4	25.33%	16.74%	3.61%	0%	54.32%
	5	40.27%	17.19%	6.78%	5.42%	30.34%
Mean (%)	Factor 2	45.75%	14.02%	3.61%	3.16%	33.46%
Factor 3; Boiling	2	80.09%	4.97%	1.35%	0%	13.59%
	6	32.12%	4.07%	8.59%	0%	55.22%
Mean (%)	Factor 3	56.10%	4.52%	4.97%	0%	34.41%

The question with the highest level of scientific knowledge is question number 2. 80.09% of the pre-service teachers answered this question correctly by being sure about the content and reason step. The lowest level of scientific knowledge belongs to question number 3. 21.71% of the pre-service teachers answered this question correctly by being sure about the content and reason step. When the results on factor basis were analyzed, the highest average scientific knowledge rate belongs to Factor 3. The average scientific knowledge of this factor is 56.10%. Factor 3 is followed by Factor 2 with an average of 45.75% and Factor 1 with an average of 45.47%.

The question with the highest rate of misconceptions among pre-service science teachers is question number 5. 17.19% of the pre-service science teachers answered the content and reason steps of this question incorrectly, confidently. The question with the lowest rate of misconceptions is question number 7. 3.61% of the pre-service teachers answered the content and reason steps of this question incorrectly with confidence. When the factor-based results were analyzed, the highest misconception average belongs to Factor 2. The misconception average of this factor is 14.02%. The average misconception value of Factor 1 is 5.65% and the average misconception value of Factor 3 is 4.52%.

When the false positive rates of the questions in the test were analyzed, it was seen that the highest rate belongs to question number 6. The false positive rate of this question is 8.59%. In other words, 8.59% of the pre-service science teachers in the participant group answered the content step of this question correctly but the reason step incorrectly. The question with the lowest false positive rate among the questions in the test is question number 1. 0.45% of the pre-service teachers, which corresponds to 1 person, confidently answered the content step of this question correctly but the reason step incorrectly. When we look at the results on factor basis, Factor 3 (4.97%), Factor 1 (4.29%) and Factor 2 (3.61%) are listed respectively.

When Table 4 was analyzed, it was observed that the question with the highest false negative average of the pre-service science teachers is question number 3 with a rate of 18.55%. 18.55% of the pre-service science teachers answered the content step of this question incorrectly and the reason step correctly. Among the questions in the test, questions numbered 2, 6 and 4 have the lowest false negative rate. The average false negative rate of all three questions is 0%. In these questions, no false negatives are found in any of the pre-service teachers. When the results on factor basis are analyzed, Factor 1 (11.31%), Factor 2 (3.16%) and Factor 3 (0%) are listed respectively.

As mentioned before, four-tier diagnostic tests reveal individuals' scientific knowledge, misconceptions, false positives and negatives, and lack of knowledge about the relevant topic. Test answers were calculated based on the probability of these five situations. In this context, when Table 4 was examined, the percentages of pre-service teachers' lack of knowledge are presented on the basis of questions and factors. When the knowledge deficit percentages of pre-service science teachers were analyzed, a general high level can be mentioned. The lack of knowledge is revealed when the pre-service teachers answer "I am not sure" to at least one of the confidence steps of the content and reason step of the questions in the four-step diagnostic tests. When the table was analyzed, it was seen that the highest percentage of lack of knowledge is calculated for the sixth question. 55.22% of the pre-service teachers are not sure about at least one of their answers to the sixth question. The lowest percentage belongs to the second question (13.59%). 13.59% of the pre-service teachers are not sure about at least one of their answers to the second question. When the rates of lack of knowledge was analyzed on a factor basis, they are listed as Factor 3 (34.41%), Factor 2 (33.46%) and Factor 1 (33.28%), respectively.

Discussion, Conclusion & Suggestions

This research was carried out to develop a valid and reliable measurement tool that can be used to determine the misconceptions of pre-service science teachers about change of state.

Within the scope of the study, a four-tier misconception diagnostic test was developed by the researchers and the validity and reliability analyses of this test were conducted. As a result of the factor analysis, which was the first validity step, it was decided that the third question in the test was insufficient in terms of factor loading and it was found appropriate to remove it from the test. Expert opinions were obtained from two science and one chemistry educators during the question preparation and draft development stages of the test. The false positive and false negative averages of the developed test were calculated below 10% as it should be. Correlation analysis, one of the validity analyses of the four-tier diagnostic tests, was conducted. Moderate and significant correlations were observed in all data groups analyzed. For reliability analysis, two different reliability coefficients were calculated.

These coefficients are KR-20 reliability coefficients calculated according to scientific knowledge and misconception scores. Both coefficients show that the test is a reliable measurement tool. The four-tier misconception diagnostic test for change of state consists of 7 questions. As a result of the analysis, the test showed a three-factor structure named external factors, states of matter and boiling. With the completion of validity and reliability analyses, the test showed that it is a valid and reliable measurement tool.

The focus of the research is change of state. Although change of state is a subject area of chemistry, it is an interdisciplinary subject. Students' incorrect or incomplete formation of the basic concepts of science in their minds leads to the formation of misconceptions. Misconceptions manifest themselves in change of state as in every field of education (Osborne & Cosgrove, 1983). When the literature was reviewed, it was seen that different researchers have studied misconceptions about change of state. For example; Morgil et al. (2009) investigated the misconceptions of students about the concept of melting and boiling and the effect of question and answer technique on the elimination of these misconceptions. The researchers reported that the question-answer technique was an effective method in eliminating students' misconceptions about the concepts of melting and dissolution. Paik (2015) examined the role of examples in 4th grade textbooks used as textbooks in Korea on students' perceptions of the concepts of evaporation and boiling. In the study conducted with fourth, fifth and sixth grade students, it was revealed that many students thought that evaporation events under heating conditions were boiling, while the same events without an obvious heating source were evaporation. Koomson & Owusu-Fordjour (2018) examined students' misconceptions about the water cycle and evaporation in a high school in Ghana. The researchers managed the data collection process through interviews and water cycle drawings requested from the students. As a result of the study, misconceptions were identified in about 25% of the students. Suhandi et al. (2020) examined the effectiveness of conceptual change laboratories on students' misconceptions about the concept of boiling. In the study conducted with 40 high school students, five-stage laboratory activities for conceptual change were used. As a result of the study, they stated that conceptual change laboratories were effective in eliminating high school students' misconceptions. As another example, Husnah et al. (2020) aimed to determine the misconceptions of eleventh grade (K-11) natural science students about the concept of boiling and the reasons for these misconceptions in one of the public high schools in Bandung Barat Regency. In the study conducted with 92 students, misconceptions were reported by 60%, scientific concepts by 13% and lack of knowledge by 27%. Among the misconceptions, the most misconceptions occur in the analysis of the effects of pressure at the boiling point with 65%.

When the literature was reviewed, it was seen that although there are studies in which misconceptions are detected with many different methods, the popular method for the detection of misconceptions recently is tiered diagnostic tests. Among the tiered diagnostic tests, four-tier diagnostic tests are more preferred because they can also present the causes of misconceptions in individuals. Four-tier diagnostic tests outperform both other methods and two- and three-tier diagnostic tests in terms of detecting false positives, false negatives, lack of knowledge, misconceptions and scientific knowledge. When the literature was reviewed, no four-tier diagnostic test was found for the topic of change of state. In this context, it is thought that the four-tier change of state misconception diagnostic test developed in this study can fill this gap in the literature. With the developed test, the points where the misconceptions of pre-service science teachers about change of state are concentrated can be identified, the reasons can be analyzed and correction studies can be carried out. Experimental studies can be designed with the developed test and the effectiveness of the methods or tools on misconceptions can be determined.

Ethic

Ethical approval was obtained from Necmettin Erbakan University, Social Sciences and Humanities Scientific Research Ethics Committee with protocol number of 2023/556.

Author Contributions

This article was written with the equal contributions of all authors.

Conflict of Interest

The authors declare no conflict of interest in the research.

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