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Developing a Holistic Measurement on Nuclear Issues for Preservice Science Teachers

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ABSTRACT

In this study, a conceptual understanding test and a knowledge test were developed to investigate the conceptual understanding and knowledge levels of pre-service science teachers about a socio-scientific topic, nuclear energy and nuclear plants. The study addresses the reliability and validity of these developed tests. While the 34-question knowledge test was administered to 441 pre-service science teachers, the 15-question conceptual understanding test was administered to 223 pre-service science teachers. In the test development process, to establish the validity expert opinions were sought, item analyses and factor analyses were conducted and reliability computations were performed. At the end of the editing, after the correction and elimination of some problematic questions, the final form of the knowledge test emerged with 30 questions and the conceptual understanding test emerged with 13 questions. As a result of the analyses, it was found that the knowledge test consists of four factors and explains 56.98% of the total variance while the conceptual understanding test is made up of three factors and accounts for 46.35% of the total variance. Furthermore, the Cronbach's alpha coefficient of the conceptual understanding test was found to be 0.77 and KR-20 and two-tier reliability coefficients of the knowledge level test were calculated to be 0.86 and 0.85 respectively.

Keywords: Pre-service Science Teachers; Nuclear Energy; Nuclear Plant; Validity; Reliability.

INTRODUCTION

Energy has become an indispensible part of modern life. Throughout the last two centuries, the main component in the developments in many fields of industry, [1]modern life, science and technology has been energy. However, with the rapid growth of the world population, many countries are now confronted with energy-induced challenges. In order to be able to deal with such problems, some countries have been engaged in the search for sources of energy as alternative to fossil fuels and one of these alternatives is nuclear energy. While some developed countries such as the USA, France and Japan are still making full use of nuclear energy, some other countries adopt approaches against nuclear energy. In Turkey, discussions about nuclear energy date back to the 1960s and during that period, attempts were

[*] Franklin says; "If you would not be forgotten as soon as you are dead, either write something worth reading or do things worth writing." In memory of Hilal Küçük (1986 - ∞)…

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made to establish nuclear plants but all these attempts failed due to various reasons. At present, there are two nuclear plants in the process of construction in the Turkish cities of Sinop and Mersin. Preliminary research is being conducted for the construction of a nuclear plant in the Trakya-İğneada region of Turkey.

Lack of agreement on the use of nuclear energy among countries has led to some disputes on the generation and use of nuclear energy. The public is informed about these disputes on nuclear energy and construction of nuclear plants by the media. It is seen that there are two extreme sides to these disputes in the media. On one hand, some media adopting the view of *Nuclear Renaissance* argue that the cleanest way of saving the world from the nightmare of global warming is nuclear energy as it does not emit greenhouse gases, it does not yield waste ashes and it is a more efficient means of energy production when compared to its alternatives. On the other hand, some other media adopting the view of a *Nuclear Nightmare* argue that nuclear energy poses great security risks and waste-disposal challenges; they refer to the Chernobyl accident in 1986 and the Fukusima accident in 2011 (Kaya, 2012) as examples.

Though the media serves the function of informing the public on the issue, some misleading news, animations, speculations and quotations on television, newspapers and the Internet result in members of the public experiencing a dilemma about nuclear energy and nuclear plants. As a result, the public can be either too indifferent or too sensitive to risky situations. Moreover, due to lack of information the concept of nuclear energy and radiation can be perceived more negatively and be more confusing. It is widely observed that individuals having negative or positive perceptions of the issue cannot justify their position and have some problems. The opinions expressed by lay-people about the issue mostly stem from unquestioned social learning rather than scientific inferences based on scientific reading and research. People not reading about or researching the issue may turn out to be indifferent to the problem of nuclear energy and view it like a science fiction scenario not much related to their daily lives. As some other people think that this is the problem of scholars, they may not be willing to be involved in decision-making processes even if they have the right to do so. However, when the relevant literature is investigated, it is seen that there is a great lack of information in society and they cannot evaluate the up-to-date nuclear energy-related problems and issues critically (Cohen, 1998; Matsuura and Iırı, 2002; Yalcin and Kilic, 2005). Hence, it is of great importance to educate individuals to be able to question and evaluate the issue of the generation of nuclear energy and construction of nuclear plants with critical and scientific rationality.

It can be easily argued that for a society to be an information society, teachers are of vital importance. Teachers may exert great influence on the development of critical thinking, problem solving and scientific thinking skills of their students (Ralph and Wayne, 1967). However, to do so, first, teachers should be educated well. According to Gultekin (2002), the only way of training qualified teachers is to get pre-service teachers to undergo a quality teacher training program.

Besides this, it is clear that the teachers who introduce students to nuclear issues should be science teachers. In this respect, when the pre-service science teacher training programs are analyzed, it is seen that nuclear issues are only taught in a few courses. During the observation performed by the researchers in these courses, it was seen that the pre-service science teachers had great difficulties in discussing this highly popular socio-scientific issue. This may be because of the lack of information or misconceptions possessed by the pre-service teachers. Some other research has also revealed that teachers and students have difficulties in discussing the issue of nuclear energy and plants due to deficiency in knowledge or misinformation (Atila, 2004; Ozdemir and Cobanoglu, 2008).

When the literature on nuclear energy and nuclear plants is investigated, it is seen that it mostly focuses on the evaluation of the attitudes and interest of students from different grade levels and teachers from different subject areas. In some of the related studies, university students' attitudes and interests in nuclear energy and wastes (Berberoglu and Tosunoglu, 1995; Karagoz, 2007; Larsen, 1993; Ozdemir and Cobanoglu, 2008; Taskin, 2004) or elementary students' opinions and feelings about the use, effects, benefits and harmful effects of nuclear energy and construction of nuclear plants (Kilinc, Boyes and Stanisstreet, 2013; Maharaj-Sharma, 2011) were investigated. It can be argued that the pre-requisite of making correct inferences and developing appropriate attitudes is based on prior knowledge. Given the fact that interests and attitudes develop depending on prior knowledge, it becomes clear that the determination of individuals' knowledge and conceptual understanding through reliable tests can be of great importance as well. In this regard, together with the scales of attitude and interest on nuclear issues, tests to understand what pre-service science teachers know about nuclear issues can fill the gap in the literature to some extent.

In order to be able to critically approach any issue, the related basic concepts should be understood and internalized. In this regard, the basic concepts of nuclear energy and nuclear plants should be accurately taught and learned, correctly interpreted and thus, by forming the right knowledge, the advantages and disadvantages of nuclear energy and nuclear plants should be appropriately evaluated. Hence, the importance of a holistic measurement which covers the conceptual understanding of the basic concepts and knowledge of pre-service science teachers on nuclear issues is important.

Based on the belief that this problem may be possessed by many pre-service science teachers, the purpose of the present study is to develop a holistic measurement to comprehensively understand what pre-service science teachers know about nuclear issues. Accordingly a conceptual understanding test which includes the basic concepts on nuclear issues, determining the attitudes that influence the decision-making processes and a knowledge test to understand the basic knowledge level of the pre-service science teachers were be developed. We believe that it would be easier to accurately determine the sources of the level of misunderstanding of pre-service science teachers on nuclear issues through these two tests together.

METHODOLOGY

In this section, the characteristics of the study groups in which the reliability and validity of the two tests were established will be discussed.

a) Conceptual Understanding Test of the Concepts of Nuclear Energy and Nuclear Plants

The first test consists of 15 questions. During the development process of the questions, first, a concept map was constructed by reviewing some books written in this field. After seeking the opinions of experts in the field of chemistry about this concept map, concepts such as *strong nucleus force, instability, radioactive decay, radiation, ionized radiation, non-ionized radiation, half-life, fission* and *fusion* were included within the concept map. Then, concept analysis including scientific definitions and misconceptions reported in the literature was conducted for each concept and the test questions were developed based on these concept analyses. The conceptual understanding test includes conceptual and phenomenological questions that can be answered by the students who internalized these concepts. The questions developed by using all the concepts may be categorised under three main concepts: *Radioactivity, environmental effects* and *nuclear reactions*.

When the relevant literature is examined, it is seen that the concepts of knowledge level and conceptual understanding may mean different things. It is known that knowledge level can be improved through recall and exercise (Stephanou, 1999). However, in a science course, it is widely observed that even the most successful students provide memorized answers to questions. When questions requiring deep analysis are asked, it is seen that students have in fact some misconceptions about the issues that they seem to know only superficially (Unal Coban, 2009). In this regard, the concept called conceptual understanding can become really difficult to evaluate by means of classical methods including multiple-choice, false or correct and short answer questions and they may not be adequate to claim that students deeply internalized the concepts. Hence, such measurement instruments should include questions requiring students to transfer their knowledge into different settings so that they can use their knowledge. In a similar manner, Demirelli (2003) states that for learning to occur at the understanding and comprehension levels, the questions of “Why” and “How” should be answered. Thus, whether a student has the conceptual understanding or not can be evaluated through a test including these types of questions.

In order to determine whether students have reached a conceptual understanding level, there are many different types of evaluation techniques that have been developed. Among these, the effective ones are those including open-ended questions to define students’ opinions. Through tests including such questions, students’ opinions can be more comprehensively evaluated and the reasons for their opinions can be well understood (Kabapinar, 2003). Driver and Erickson (1983) argue that there are two dimensions involved in the elicitation of students’ opinions for such tests. These are conceptual and phenomenological dimensions. At the conceptual level, students are asked to give explanations about the concept, and use or define the concept in a context. At this level, while collecting the data, techniques such as conceptual associations, free writing and concept maps can be used. At the phenomenological dimension, on the other hand, an incident is presented and students are asked to make predictions about the incident and then they are asked to provide explanations about their predictions (Driver and Erickson, 1983; Kucukozer, 2004). Within the framework of the present study, by taking these factors into consideration, the conceptual understanding test was planned to contain such open-ended questions.

If we examine the questions of the conceptual understanding test that was prepared, it could be said that the first, second and third questions of the conceptual understanding test are phenomenological questions that can be answered by using the information of the fundamental forces in nature such as strong nuclear force, electromagnetic force, weak nuclear force and the force of gravity. The fourth and fifth questions in the test are conceptual questions for which students are expected to provide explanations in their own words about the concepts in question. In order to be able to answer the sixth and seventh phenomenological questions of the test, students have to know the concepts of radiation and nucleus stability. The eighth question can be answered based on the fact that radioactive substances cannot be changed by physical factors as long as radioactive substances do not affect the nucleus. The ninth question of the test is a phenomenological question that can be answered by knowing the ionization effect of radiation. The tenth question requires knowing that radioactive decays are exothermic reactions. The eleventh question of the test is phenomenological and requires information about the types of radioactive decay and their areas of influence. In order to be able to answer the twelfth question of the test, students must know that radioactive wastes are produced as a result of radioactive decay of radioisotopes; after decay, these wastes go on emitting radiation at gradually decreasing amounts. When exposed to such wastes, students need to know about the types of radiation that are produced and the effects of exposure to them. The thirteenth question of the test is a conceptual question measuring three different basic concepts. The fourteenth question is a phenomenological question that requires students to know the difference between the concepts of fission and fusion. The last phenomenological question requires knowing the effects of ionized radiation on the human body.

b) Knowledge Test on Nuclear Energy and Nuclear Plants

In order to measure the pre-service science teachers' knowledge level about nuclear energy and nuclear plants, a knowledge test was developed by the researchers. Before developing the test, the sub-headings and scopes of the topic of nuclear energy and plants were determined by considering the grade levels of the pre-service science teachers. Then the opinions of three science education experts in their fields were sought. In light of their opinions, the sub-headings of the topic were determined to be *nuclear force*, *radioactive substance*, *radioactive isotope*, *half-life*, *radioactive decay*, *radiation*, *fission* and *fusion*, *the state of nuclear plants in the world*, *working principles of nuclear plants*, *advantages* and *disadvantages of nuclear plants* and *the effects of nuclear plants on human health and the environment*.

A question pool including multiple-choice questions about each sub-heading of the topic of nuclear energy and plants was constructed. During the construction of this question pool, various sources including achievement tests reported in the relevant literature, question pools including these sub-headings, test worksheets and chemistry textbooks were referred to. Moreover, by developing additional multiple-choice questions, the researchers contributed to the existing question pool. The questions in the pool were classified according to cognitive domains of Bloom's taxonomy. In the final form of the test there were 34 multiple-choice questions that were suitable for 3rd and 4th-year pre-service science teachers to answer.

FINDINGS

In this section, the findings related to validity and reliability of the conceptual understanding test and knowledge test that were developed to evaluate the students' information about nuclear energy and nuclear plants are discussed. These findings are related to item analyses, content, face and construct validity and reliability of the test questions.

Findings related to Conceptual Understanding Test of Nuclear Energy and Nuclear Plants

Validity is one of the important characteristics to be considered while developing an evaluation tool. The validity of an evaluation tool involves what this tool aims to measure and how well it fulfils this goal (Anastasi and Urbina, 1997; Tavsancil, 2006). In the literature, validity is generally discussed under three headings (Sencan, 2005). The first is related to whether the evaluation tool used is suitable for the feature to be evaluated. The second is related to whether evaluation is performed in compliance with the rules of evaluation. The third is related to whether the data obtained are actually reflecting the characteristic intended to be evaluated. In relation to these headings, validity can be classified under different categories. Some of these are content validity, construct validity, predictive validity and face validity. In the present study, in order to test the content and face validity of the test, the concept analyses of the conceptual understanding test together with the expert opinions form developed by the researchers were scrutinised by five instructor experts in their fields. The instructors analyzed each question in terms of scientific suitability, suitability for student level and comprehensibility. In order to evaluate the consistency between the experts' responses about the test questions, agreement values were calculated through agreement an percentage formula (Miles and Huberman, 1994).

According to agreement results, some corrections were made to questions 1, 3, 7, 9, 11 and 15. No question was discarded from the test. After undergoing the scrutiny of the experts, the questions were administered to 223 pre-service science teachers studying at Muğla Sıtkı Koçman University in Turkey. Of these students 16.6% (n=37) are senior students, and 83.4% (n=186) are third-year students. The reason for the selection of the students for the administration of the test is that they have already completed a course related to nuclear issues.

In the analysis of the responses to the conceptual understanding test of the present study the data were coded according to a quintet coding scheme developed by Abraham, Williamson and Westbrook (1994) (Table 1). The same scheme was also used in other studies (Abraham, Gryzbowski, Renner and Marek, 1992; Haidar and Abraham, 1991; Simpson and Marek, 1988; Westbrook and Marek, 1991, 1992).

Table 1. *Conceptual Understanding Evaluation Scheme*

Degree of conceptual understanding	Criteria for scoring
0 – No understanding (NU)	Blank, repeats question, irrelevant or unclear response, no explanation given for choice of answer
1 – Specific misconception (SM)	Scientifically incorrect responses
2– Partial understanding with a specific misconception (PU/SM)	Responses that show understanding of the concept, but that also contain a misconception
3 – Partial understanding (PU)	Responses that contain a part of the scientifically accepted concept
4 – Sound understanding (SU)	Responses that contain all parts of the scientifically accepted concept

The existence of such a coding system allows the calculation of item difficulty and discrimination indices and conducting reliability and construct validity for a conceptual understanding test. After coding, item difficulty and discrimination indices were calculated for each question. According to Ozguven (1994), the item difficulty is the percentage of participants correctly responding to the question. When item difficulty converges to 0.00, it means that the question is very difficult and when it converges to 1.00, it means the question is very easy. The item difficulties of the test questions were determined through item analysis. The questions having item difficulty values ranging from 0.30 to 0.70 were retained in the final form of the test. In addition to item difficulty, the discrimination value of each question was also calculated. The questions having discrimination values higher than 0.30 were included in the test.

According to the item analysis results, it was decided to discard questions 8a, 8b, 8c, 10a and 10b so as not to distort the conceptual structure of the test. After the exclusion of these questions from the test, exploratory factor analysis was conducted using SPSS 14 and the factor structure of the test was investigated to check the construct validity. Construct validity is useful to explain what the analysis results are related to. Construct validity is a process of inquiry of what the measurement scale and scores obtained from it mean (Ozguven, 1994). Factor analysis is a technique used to transform associated data structures into fewer new data structures independent from each other, to reveal common factors by grouping the variables assumed to explain a formation or an event and to group the variables affecting a formation (Ozdamar, 2002). That is, it is a technique providing an empirical basis for acquiring fewer independent variables by combining moderately or highly related variables. In this way, it can be possible to reduce many variables to a few groups or dimensions. And each of these groups or dimensions is called factor (Balci, 2009).

According to exploratory factor analysis, the Keiser-Meyer-Olkin (KMO) test result was found to be .814. The Bartlett coefficient was significant at the .000 level. A significant

Bartlett result shows that the data have multi-variable normal distribution and accordingly, it shows that the other assumptions of the factor analysis are also met. According to the analysis results, while four-factor construct explains 53.865% of the total variance, if three-factor construct is selected, it can explain 46.358% of the total variance. Given that while developing the conceptual understanding test, the concepts determined through expert opinions were collected under three main headings, it can be said that three-factor construct is more suitable for the test. Factor loadings of the questions according to three-factor construct are given in Table 2.

Table 2. *The Factor Structure of the Conceptual Understanding Test*

Questions	Factor Loadings of the Factors		
	Radioactivity (1st factor)	***Environmental effects (2nd factor)***	***Nuclear reactions (3rd factor)***
1-2-3-4-5-6	0.407-747		
7-9-11-12-15		0.357-0.749	
13-14			0.745-0.708
Variance explained	19.289%	15.469%	11.599%
	Total variance : 46.358%		

Exploratory factor analyses were conducted on this three-factor structure. This three-factor structure was justified by the confirmatory factor analysis. The confirmatory factor analysis was carried out using Lisrel 8.7.

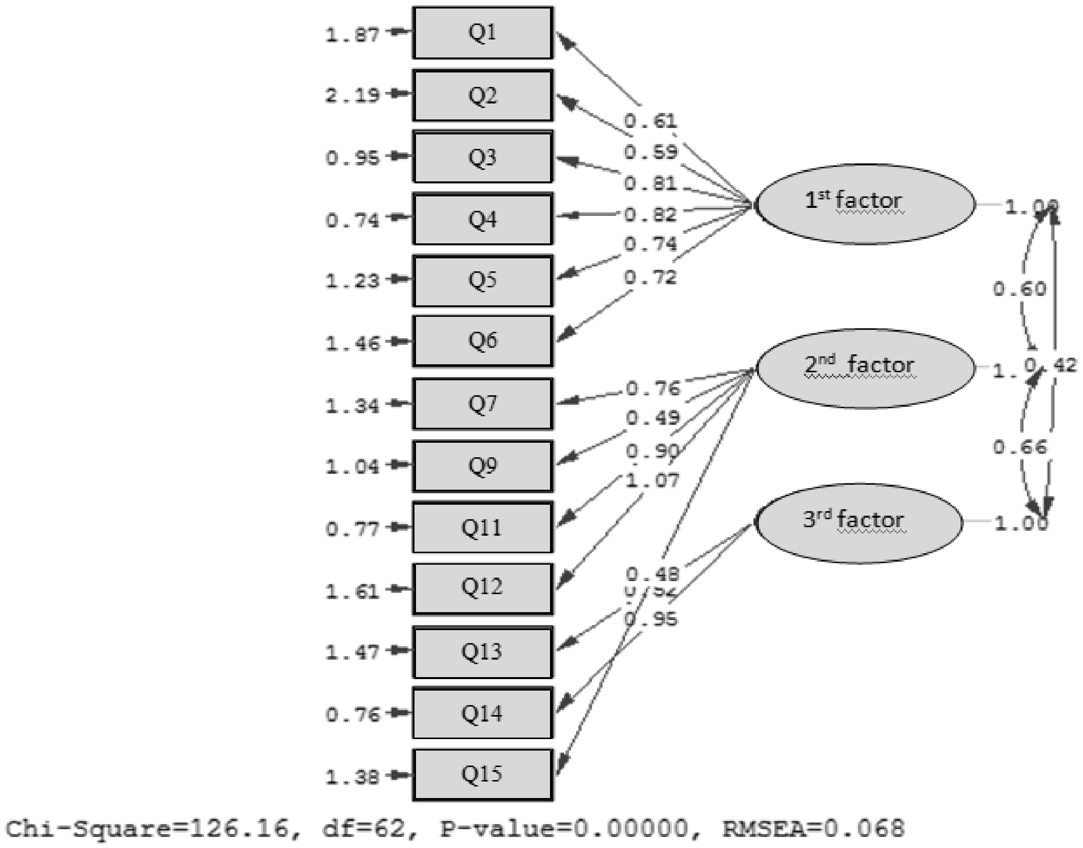

Figure 1. *The Results of the Confirmatory Factor Analysis of the Conceptual Understanding Test*

In light of the data presented in Figure 1, it can be argued that fit indices of the conceptual understanding test consisting of 13 questions are significant (X^2=126.16, sd=62, p=.000, X^2/sd=2.035). In addition to this, fit indices are RMSEA=.068, GFI=.92, AGFI=.88, CFI=.94, NNFI=.92 and IFI=.94. Based on these results, the model can be claimed to have a good fit; hence, no modification was made to the questions. Within the context of the reliability analyses of the conceptual understanding test, the Cronbach's alpha (α) coefficient was calculated and reliability coefficient for the whole of the test was found to be .775. According to Cepni (2007), reliability means consistency shown by the measurement scale when more than one measurement of the same feature is made.

Findings related to Knowledge Test of Nuclear Energy and Nuclear Plants

During the development process of the test, required applications were performed with the questions were administered to 441 senior and third-year pre-service science teachers from the science teaching programs of Muğla Sıtkı Koçman University, Dokuz Eylül University and Celal Bayar University in the 2013-2014 academic years. Of the participants, 38.7% (n=171) are third-year students and 61.3% (n=270) are senior students.

Item difficulty index and item discrimination index were calculated for the knowledge test and questions with difficulty value below or above 0.50 and discrimination indices lower than 0.30 were discarded from the test. The questions having low values were modified or discarded from the test in line with the opinions of experts. In this regard, questions 20 and 21 were modified and four questions were excluded from the test. While doing this, the content validity of the test was ensured. As a result, the number of questions in the test was reduced to 30. The distribution of the questions in the final form of the knowledge test according to cognitive domains is presented in Table 3.

Table 3. *Distribution of the Questions in the Knowledge Test according to Cognitive Domains*

Content	Information	Understanding	Analysis	Synthesis
Nuclear force	1			
Radioactive substances	2	3, 4 ,5		
Radioactive isotopes		7	6	
Half-life	8	9		
Radioactive decay	11	10	12	
Radiation	13, 14			
Fission and fusion	15, 16, 18, 19	17		
Nuclear plants in the world and in Turkey	20, 21			22
Working principle of nuclear plants	23	24, 28		27
Advantages and disadvantages of nuclear plants		25, 30		
Effects of nuclear plants on human health and nature		26		29
Total number of questions	13	12	2	3
Percentile	43	40	7	10

First, the exploratory factor analysis (EFA) was conducted to establish the construct validity of the knowledge test. While determining the questions to be kept in the test as a result of the EFA, the following criteria were observed. Eigenvalues should be at least 1, loading values should be at least .30 (Martin and Newel, 2004), questions' should be located in one factor and there should be at least .10 difference between the factors located in two factors (Buyukozturk, 2007). Moreover, Orthogonal Varimax was used in EFA. In social sciences, this method is preferred in factor rotation (Cokluk, Sekercioglu and Buyukozturk, 2010). As a result of the EFA, the KMO was found to be .902 and the Barlett test was found to be significant at the level of $p < .001$. As a result of the EFA, a four-factor construct explaining 56.985% of the total variance was obtained.

Table 4. *The Factor Structure of the Knowledge Test*

Questions	Factors and Factor Loadings			
	Radioactivity (1st Factor)	Nuclear energy (2nd Factor)	Working principle of a nuclear plant (3rd Factor)	Effects on human health and nature (4th Factor)
1-2-3-4-5-6-7-8-9-10-11-12	0.59 - 0.74			
13-14-15-16-17-18-19		0.36- 0.77		
23-24-27-28			0.43- 0.68	
20-21-22-25-26-29-30				0.31-0.82
Total variance	18.523%	13.142%	12.804%	12.516%
	Total variance : 56.985%			

As can be seen in Table 4, there is a four-factor construct explaining 56.985% of the total variance. In multi-factor designs, when the variance explained is between 40% and 60%, it is considered to be sufficient (Tavsancil, 2006).

Model fitness of the question-factor construct obtained from EFA analysis was tested through confirmatory factor analysis (CFA). There are several fit indices used to justify the adequacy of the model tested through CFA. In the present study, the DFA, Chi-Square Goodness, GFI (Goodness of Fit Index), AGFI (Adjusted Goodness of Fit Index), CFI (Comparative Fit Index), NNFI (Non-Normed Fit Index), IFI (Incremental Fit Index) and RMSEA (Root Mean Square Error of Approximation) fitness indices were investigated. A fitness value of 0.90 is considered to be acceptable for GFI, AGFI, CFI, NNFI and IFI indices and a perfect fitness value is considered to be 0.95 (Simsek, 2009). For RMSEA, 0.08 is set to be acceptable fitness and 0.05 is set to be perfect fitness value (Thompson, 2004). In CFA, fitness indices of the four-factor model were investigated. The data for CFA are shown in Figure 2.

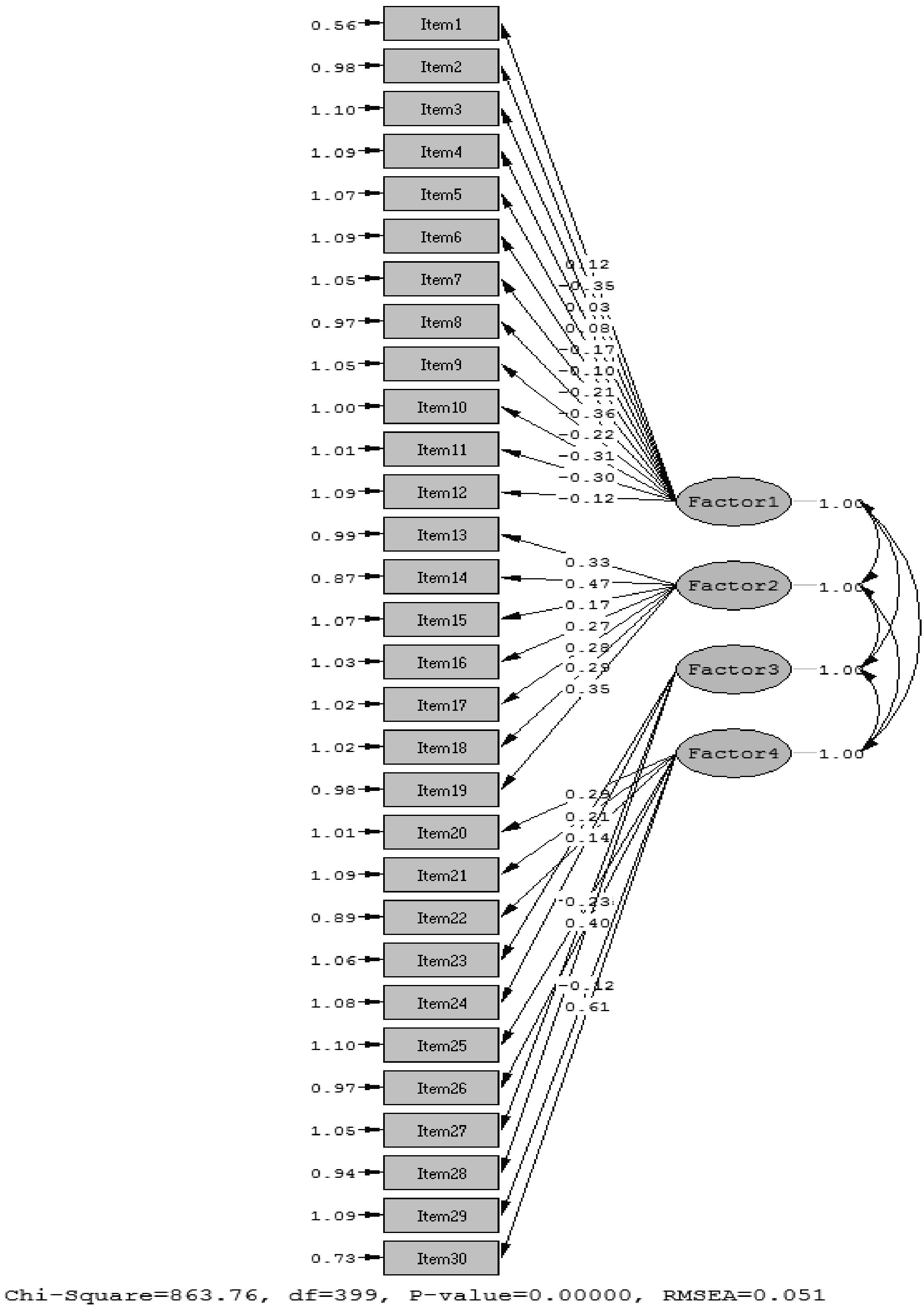

Figure 2. *The Results of the Confirmatory Factor Analysis of the Knowledge Test*

When Figure 2 is examined, it is seen that the fit indices of the knowledge test consisting of 30 questions and 4 factors are significant (X^2=863.76, sd=399, p = .000, X^2/sd=2.16). Fitness index values were found to be as follows: RMSEA= .051, GFI= .93, AGFI= .89, CFI= .97, NNFI= .96, and IFI= .95. As CFA analysis shows that the model has a good fitness, no modification was made to the questions. Therefore, it can be argued that four factors revealed by the exploratory factor analysis (*Radioactivity, nuclear energy, working principle of a nuclear plant and effects on human health and nature*) were justified through the confirmatory factor analysis.

Within the context of the reliability of the test, the Kuder-Richardson 20 (KR-20) and two-tier reliability calculation method were employed (Table 5).

Table 5. *Internal Consistency Reliability Coefficients of the Knowledge Test*

Internal consistency (Reliability)	*Radioactivity* (1st Factor)	*Nuclear energy* (2nd factor)	*Working principle of a plant* (3rd Factor)	*Effects on human health and nature* (4th Factor)
KR-20	.92	.86	.81	.87
Two-tier reliability	.90	.85	.83	.87

KR-20 and two-tier reliability coefficients found for the knowledge test are .86 and .85, respectively. These values show that the knowledge test has a highly reliable construct (Ozdamar, 2002).

DISCUSSION and CONCLUSİONS

In the present study, a conceptual understanding test and knowledge test on nuclear issues, especially on nuclear energy and nuclear plants were developed for the pre-service science teachers. The conceptual understanding test evaluates basic concepts that can be used in socio-scientific discussions and interpretations about nuclear energy and nuclear plants by the pre-service science teachers. The knowledge test, on the other hand, includes questions to evaluate the knowledge about nuclear energy and nuclear plants possessed by the pre-service teachers.

In order to develop the conceptual understanding test, 15 questions were developed for the first draft of the test and then corrections were made on the questions based on expert opinions. Then the test was administered to pre-service science teachers, and based on the data obtained from this piloting, item analyses were conducted. In line with the obtained item discrimination and difficulty indices, questions having low indices were discarded from the test. Then, exploratory factor analysis was conducted to check the construct validity and factor structures of the test. According to the results of this analysis, a three-factor construct explained 46.358% of the total variance. Hence, the conceptual structure was subsumed under three headings: *Radioactivity*, *environmental impacts* and *nuclear reactions*. The factor structure of the conceptual understanding test was tested by confirmatory factor analysis. The fit indices obtained through the confirmatory factor analysis were found to be significant and the model showed a good fit. Within the framework of the reliability analyses of the conceptual understanding test, the Cronbach's alpha (α) coefficient was found to be .775 for the whole test.

The first draft of the knowledge test was developed to include 34 questions and after item analyses and expert opinions were considered, some questions were corrected or discarded from the test. Following this, exploratory factor analysis of the test was conducted and sub-factors were determined. Thus, it was found that the knowledge test has a four-factor structure explaining 56.985% of the total variance. The structure obtained by exploratory factor analysis was tested in terms of fitness through confirmatory factor analysis. As a result of the exploratory and confirmatory factor analyses, the test model including 30 questions that can be grouped under four factors was found to be statistically suitable. These sub-factors are *radioactivity, nuclear energy, working principle of a nuclear plant* and *effects on human health and nature*. The KR-20 and two-tier reliability coefficients calculated for the reliability of the knowledge test were found to be .86 and .85, respectively.

In conclusion, it can be argued that the conceptual understanding test and the knowledge test developed in the present study to ensure that pre-service science teachers' conceptual understanding and knowledge level about nuclear issues are sufficiently reliable and valid. Therefore, it is believed that these tests can be used to evaluate the conceptual understanding and knowledge level of pre-service science teachers about nuclear energy and nuclear plants and they can yield reliable and valid results. Moreover, based on data obtained from a pre-test, instruction can be planned to reduce or eliminate the misconceptions and knowledge deficiencies of students. Critical evaluation of any knowledge requires understanding and internalization of the related basic concepts. Therefore, a holistic measurement that covers a conceptual understanding test and a knowledge test could be helpful to completely understand what the pre-service science teachers know about nuclear issues.

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