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Developing a Science Process Skills Test for Secondary Students: Validity and Reliability Study*

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Abstract

Science process skills are claimed to enable an individual to improve their own life visions and give a scientific view/literacy as a standard of their understanding about the nature of science. The main purpose of this study was to develop a test for measuring a valid, reliable and practical test for Science Process Skills (SPS) in secondary education at basic and integrated levels. The test was developed according to the renewed 9th and 10th and 11th grades chemistry curriculum acquisitions of "content", "chemistry-technology-society-environment", "communication", "attitude" "value" Participants of this study are 222 students from a vocational high school and the Anatolian school of Izmir, Turkey. The test consisted of 30 multiple-choice questions and the KR20 reliability coefficient of this test was calculated as 0, 83. The test consisted of sub-dimensions as , observing, classifying, measuring, communicating, inferring, predicting, formulating hypotheses, identifying variables, designing investigations, acquiring data, organizing data, and interpreting it. The test is compatible with a model which consists of observing, measuring, acquiring data, formulating problems, designing investigations, organizing data, interpreting factors of literature. The results of the confirmatory factor analysis supported validity and reliability of the test.

Key Words

Science Process Skills, Chemistry-Technology-Public-Environment Gains, Secondary Education, Test Development.

One of the most important purposes of science is to improve the understanding of the students about the nature of science. The nature of science is identified as scientific data, scientific behaviours and the gathering of information (Köseoğlu, Tümay, & Budak, 2008). The most important dimension of the nature of science is the ways to achieve (gather) information and the phases of the scientific method (Millar, 1991; Toplis, 2012; Ünal-Çoban, 2009). The ways of gathering scientific data and the phases of scientific method are technical processes. The researchers, who want to experience this process, must have some skills such as science process skills (Gültekin, 2009; Kanlı, 2007; National Research Council [NRC], 1996). Science process skills (SPS) consist of observation, classification, measurement, setting correlations of numbers and space, predicting, organizing data, formulating models, interpreting, identifying of variables, formulating hypotheses and finally experimenting (Ergin, Şahin-Pekmez, & Öngel-Erdal, 2005; Feyzioğlu, 2009; Gabel, 1992; Rezba, Fiel, & Funk, 1995; Smith, 1994; Kuhn & Franklin, 2006; Lancour, 2005; Talim Terbiye Kurulu Başkanlığı [TTKB], 2007; Valentino, 2000; Wilkening & Sodian, 2005). Zimmerman (2007) put forward the idea that SPS could be done by scientific understanding and conceptual change. According to Koslowski (1996), SPS is an application

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of the methods and principles for reasoning about the problem situations. Colvill and Pattie (2002) postulated that the activities, which consist of basic and integrated process skills, are the key factor of scientific/science literacy and the key dimension of scientific/science literacy. Bağcı-Kılıç (2006) and Padilla (1990) also classified these skills as basic and integrated scientific skills due to their usage according to students' progressional phases. Science process skills constitute the basis of scientific investigation. Scientific searching and thinking should not be confined to just scientists (Bozkurt & Olgun, 2005). These skills enable an individual to improve their own life visions and give a scientific view/literacy as a standard of their understanding about the nature of science (Bozkurt & Olgun; Williams, Papierno, Makel, & Ceci, 2004). Science process skills (Gott & Dugan, 1994) are named in literature as intellectual familiarity (A.A.A.S., 1993) and scientific searching skills (NRC, 2000).

Zimmerman (2000; 2007) classified science process skills as specific for a field, or general process skills, and also argued that knowing the scientific terms of the issue must be achieved in order to solve any problems about one issue. For example, Pauen (1996) declared that students need to understand the relationship between forces, in order to explain the physical movement, by using weights and for doing this they need to know the gravity concept. Bozkurt and Olgun (2005) also argued that science process skills are relative to learning issues and so cannot be evaluated in isolation. Students' motivation and interest are very important for the evaluation of these skills and, because of these, they postulated that students' scientific skills should not be evaluated about the issues which they don't know.

Zimmerman (2000) stated that general process skills are used for correlation between the cause/result of reasoning ability and non-specific situations. Koslowski (1996), Kuhn, Garcia-Mila, Zohar, and Anderson (1995) agree with Zimmerman. They remarked that multiple methods must be used for searching the relationship between theory and evidence about the improvement of science process skills and field knowledge is not required for this situation. Kuhn, Amsel, and O'Loughin (1988) and Koslowski (1996) declared that, while this approach is evaluated through evidences due to hypothetical scenarios, these skills will be used by interpreting the cause-result relationships and evaluations of different evidence (cited in Williams et al., 2004).

SPS is similar to skills which we use for solving the daily problems we meet (Taşar, Temiz, & Tan, 2002). Chemistry is an experimental discipline and so SPS should be gained by students in laboratories. During the laboratory work students are supposed to improve their science process and problem solving skills. Therefore, science process and problem solving skills should be measured during the laboratory phase, not just their understanding (Ayas, Çepni, & Akdeniz, 1994; Cartier, Rudolph, & Stewart, 2001; Lei, 2006).

The best way to measure the SPS of students is laboratory reports, oral presentations and observation (Lavinghousez, 1973). In order to determine the change of the students' SPS, we should asses to what extend the students understood the topic and their using of SPS in novel learning situation (Buck, Bretz, & Towns, 2008; Öztürk, Tezel, & Acat, 2010; Pyle, 2008; Souchek & Meier, 1997). Harlen and Jelly (1997) developed observation criterias for each skill in order to determine the improvement of students' SPS. Educators can perform evaluations with a gradational scaling method by finding different questions and criteria for other process skills (Bozkurt & Olgun, 2005). This is not an easy way for educators and researchers to observe the changes in students' scientific skills. In order to use this, or similar methods, teachers should collect the evidence about skill improvements and should make students always focus on lessons. Students need evaluation methods in which they can show their scientific skills and join the processes (Bozkurt & Olgun). In order to use as pre-test and post-test, researchers need valid, reliable and discriminatory measurement tools (Buck et al., 2008; Lavinghousez, 1973).

When the literature is investigated; national measurements and international comparisons of SPS are being performed by the International Education Success Evaluation Institution and the International Educational Improvement Evaluation Institution (IEA-1970, 1984) through International Mathematics and Science Studies (TIMSS-1999, 2003, 2007, 2011). Evaluations are performed though surveys and multiple-choice test (Burns, Okey, & Wise, 1985; Butzow & Sewell, 1972; Dillashaw & Okey, 1980; Enger & Yager, 1998; Lavinghousez, 1973; Molitor & George, 1976; Smith, 1994; Tannenbaum, 1971; Tobin & Capie, 1982).

In our country, test for SPS, which were developed in other countries, were initially used. Then our researchers developed their own appropriate tests. The test, which were developed by Burns et al. (1985) in accordance with 8th grade and adopted by Geban, Aşkar, and Özkan (1992), includes skills about defining variables, formulating hypothesis, defining variables operationally, designing investigations, organizing data and interpreting it. This test consists from 36 questions, each of them having 4 choices, and it was designed for science process skills at 8thgrade. It was performed on many levels of learners, including pre service teachers (Aktamış, 2007; Aydoğdu, 2006; Gültekin, 2009; Kula, 2009; Sevinç, 2008; Tavukçu, 2008; Ünal-Çoban, 2009).

Though the study issues and work fields differed from each other in literature there are many other examples in which the same test were used (Akar, 2005; Dana, 2001; Gedik, Ertepınar, & Geban, 2002; Kadayıfçı, 2001; Kanlı & Yağbasan, 2008; Sökmen & Bayram, 1999; Tezcan & Salmaz, 2005; Ünal, Bayram, & Sökmen, 2002; Yılmaz, Erdem, & Morgil, 2002; Yürük, Şahin-Yanpar, & Bozkurt, 2000). The usage of the test, which was prepared for 8thgrade, in accordance with both different levels. The way in which there is no appropriateness with the information which Zimmerman (2000; 2007) expressed, is a discussion topic. In addition to the test of Geban et al. (1992), many other tests were developed and applied in literature. However these tests include general process skills rather than specific science process skills (Anagün & Yaşar, 2009; Arslan, 1995; Azar, 2008; Birinci, 2008; Duran & Özdemir, 2010; Erdoğan, 2005; Karaöz, 2008; Korucuoğlu, 2008; Öztürk, 2008; Şenyüz, 2008). It was seen that the test, which was developed by Öztürk for evaluation of the effects of the 5E model on science process skills, about geography education, consists of both specific and general science process skills.

Though the tests, documented in the literature, measure the basic science process skills they are implemented with sample groups which are supposed to be at an advanced level. This situation stimulates discussion. This is because there is some incompatibility between the purpose and implementations of the tests. The development of the tests, which are suitable for secondary education students and also measure both basic and integrated level SPS is very important.

Purpose of the Study

The aim of this study is to develop science process skill tests for secondary education classes. The tests contain chemistry fundamentals with appropriate levels of cognitive content and can be applied to resolving problems in everyday life. The acquisitions of "Chemistry" and "chemistry-technology-society-environment" relationship are considered in the basic and integrated science process skills.

Method

The test that measures the science process skills of high school students is referred to as the 'science process skill test' (SPST).

Procedure

To determine the content of science process skill test, the outcomes of renewed 9th and 10th and 11th grade Chemistry Curriculum (TTKB, 2007), science process skills, chemistry-technology-society-environment and communication, attitudes and values are used. The test consists of a problem situation including outcomes of the chemistry curriculum that compatible with chemistry-technology-society- environment outcomes. This situation is given in successive events in the test. To write the test questions, other tests of science process skills were rewieved and the kind of skills measured by the questions were analyzed (A.A.A.S., 1990; Ergin, et al., 2005; Gabel, 1992; Lancour, 2005; Rezba et al., 1995; Smith, 1994; Valentino, 2000; YÖK/World Bank National Development Project, 1997).

The data used in writing items are prepared by utilizing similar studies with similar problem scenarios. Fifty two (52) questions were written containing at least three questions with five multiple choices for each skill. The skills mentioned in the literature showed common skills were noticed in whole classifications such as observing, measuring, classifying/organizing data, relationship between numbers and space, predicting, identifying of variables, formulating hypothesis, designing investigations, acquiring data, organizing data, analyzing investigations, concluding and decision making. In addition, science process skills are classified as; basic science process skills and integrated science process skills, by some field experts (A.A.A.S., 1990; Ramig, Bailer, & Ramsey, 1995; Rezba et al., 1995).

Sampling

In order to determine whether the test is valid for measuring science process skills the study was carried out with groups which have SPS and have not. In the academic year 2010-2011, the working group comprised a total of 222 students which are in 9th grade from the Anatolian High School and the Industrial Vocation High School, Izmir. 74% of participants are from the Industrial Vocation High School and rest from the Anatolian High School.

Findings

The scope, content and face-validities, in the preparation phase of the test, were determined by professionals of measurement and program development in addition to domain experts. Besides, the test was examined by a Turkish language education expert and applied to 30 9th grade students (15 Anatolian High School students and 15 Vocational High School students) in order to determine the sufficiency of the understandability of the test. Necessary corrections were made, in accordance with the views and suggestions of the experts, and 7 questions that either correspond to each other or are hard to comprehend or contain scientific mistakes were dismissed. This resulted in a final test consisting of 45 questions.

The discrimination of items that compose the test was determined by 'item-total correlations'. 14 questions were dismissed because of having an item-total correlation of less than 0.20 and 1 question for misspelling before seeking evidence of reliability and validity of the test. The analysis was conducted with the remaining 30 questions. In order to determine how difficult were the items for the study group, item difficulty indices for each item were calculated. The item discrimination is calculated via bi-serial item total correlation (Magnusson, 1966, p. 202). As the analyses were examined, it was seen that the all of the questions had discrimination values higher than 0. 30. It was also seen that the item difficulty indices were between 0.06 and 0.84. Accordingly, the test was considered as an achievement test that had mediocre difficulty and contained questions with various difficulty levels.

Validity

It was observed that there were several different suggestions for SPS in the literature regarding number of dimensions. One of these suggestions was the 11 factor model that pointed out in work done by YÖK and the World Bank (1997). Another suggestion was the 5 factor SPS model of Ergin et al. (2005). Confirmatory factor analyses were done for both models for determining which developed items would produce a more favorable measurement for each factor model. The goodness of fit indices of these two models were compared in order to determine which factor model would fit better. According to YÖK-the World Bank model, it was determined that the 2nd and 3rd items were in observing, 4th, 5th and 35th items were in classifying, 7th and 24th items were in measuring, 21st, 22nd and 23rd items were in communicating, 6th, 31st and 36th items were in inferring, 9th, 14th, 30th and 33rd items were in predicting, 15th item was in hypothesizing, 10th, 32nd and 40th items were in acquiring data and organizing data, 17th, 18th and 19th items were in interpreting factors.

As a result of the confirmatory factor analyses, for determining the 'better fit' factor structure, the goodness of fit indices were examined with Structural Equation Modeling (SEM). In order to determine this, the fitness rate obtained from the dividing of the $\chi 2$ to its own degrees of freedom. The significance test between values of $\chi 2$ and GFI, AGFI, RMSEA and CFI values were taken into account (Byrne, 1998; Kelloway, 1998). The rate of $\chi 2$ value to its own degree of freedom is an important statistic. Having a rate of 3 or more than 3 shows that the fitness is very good (Loehlin, 2004).

When the fitness indices in factor structures were put to examination, it was seen that the 11 factor model had perfect goodness of fit. While the RMSEA value was 0.024, CFI value was 0.97. Also, the $\chi 2$/sd rate was 1.04. This rate is another evidence that indicates good fit.

It was seen that the 5 factor model also had very good fit. The RMSEA value was 0.034 and the CFI value was 0.94. While the low values of RMSEA show that this model also has good fit, GFI and AGFI values point out that this model has a similar goodness of fit to the 11 factor model. Also, the $\chi 2$/sd rate was 1.24.

The significance test of the difference between this model's $\chi 2$ value and the 11 factor model's $\chi 2$ value shows that the $\chi 2$ difference between two models was not statistically significant. However, since the chi-square values were affected by sample size this was not interpreted in this study. In order to determine the better fitting model, the differences of RMSEA and CFI values (Cheung & Rensvold, 2002) were examined. While the difference of RMSEA values was 0.01, the difference of CFI values was 0.03. According to this, the fitness of the 11 factor model is better than the 5 factor model. Yet, one must take note that the both of the models have good degrees of fitness.

One may state that both of the models have goodness of fit indices, yet the 11 factor model has a better fit according to the findings stated above. In the subsequent applications of the test, the 11 factor model might be used as well as the 5 factor model. It could be argued that researchers should consider that the 11 factor model has a better fit.

Since the test under development is an achievement test each item is graded as 1 or 0. Because of this it should be understood that, as the grade achieved in test increases, the science process skill increases and as the grade achieved in test decreases the science process skill decreases accordingly. This is valid for all sub-dimensions and for the whole test.

Use of the t test concluded that if there was a statistical significant difference between SPS test grades that it is in accordance with the factor structure YÖK-the World Bank (1997) and Ergin et al. (2005) of students seen sufficient or insufficient for SPS. In other words, if there was a relevance of the SPS test in terms of the SPS difference determination. As a result of the t test, there was a statistically meaningful difference between the two high schools according to the grades obtained from factor structure for both YÖK-the World Bank model and Ergin et al. model. The factor structure agrees with YÖK-that is, that the World Bank model can discriminate the BSB structure effectively according to this.

Reliability

The KR20 reliability coefficient that was calculated for finding out the internal consistency of the 30 items that make up the Science Process Skills test was found as 0.83. This value is an important proof for the reliability of the test as it shows that the questions are consistent with each other.

Discussion and Conclusion

Science educators have been emphasizing the importance of the activities that are based on questioning at secondary education level since 1960s. They have mentioned importance of problem solving and scientific thinking skills in science programs. There are many studies the literature regarding the science process skills of teachers and students, the factors affecting these processes, the effect of the education methods being used in the science processes and the relationship between success and process skills (Laçin-Şimşek, 2010). The evaluations of the improvement of skills are not performed with ordinary methods. A relevant measurement tool that can determine the main lines of the questioning should measure the skills. At the same time this tool should provide feedback with regard to the effect of the education activities of the teachers and program developers and their role in the development of questioning skills. The relationship of test sets with relevant test, scientific thought or questioning should be allowed to be used as pre-test and post-test and should document the improvement of the students in this field (Butzow & Sewell, 1972; Tannenbaum, 1971).

In the literature, especially in science education studies, the researchers working on the subjects related to science process skills have a requirement for measurement tools, which are suitable to the student level, in order to measure the science process skills of the students before or after application. However, it is seen that they cannot manifest such tools (Temiz, 2007). Also in the literature, it is stated that the student should make a presentation of his/her understanding and his/her extent of application of the subject in order to explain the science process ability changes of students in the field (Buck et al., 2008; Öztürk et al., 2010; Pyle, 2008; Souchek & Meier, 1997; Temiz, 2007; Zimmerman, 2000). Evaluations might also be done with graduated scaling method by finding different questions and criteria for the general process skills (Zimmerman, 2000, 2007). Yet, observing the improvement of the students in this form might not be suitable for the teachers and researchers. It might be suitable to use observation, survey, etc. techniques with test for observing/determining the improvement of science process skills.

In this study, the "Science process Skills" test focusing on field with high validity, relevance and distinctiveness was developed. In the development of the test, chemistry-technology-society-environment gains were used as emphasized by the renewed course program. The aim of the test was to allow the students to understand the methods of scientists in the scientific research process and to allow the individuals to use these processes to solve their daily life problems (TTKB, 2007).

The science process skills test consists of 30 multiple choice questions. The KR20 relevance coefficient of the test is calculated as 0.83. The test, designed by the use of literature and factor analysis, was done according to this design. As the result of the analyses, it was seen that the test was suitable both for the11 factor model of YÖK and the World Bank (1997) and the 5 factor SPS model of Ergin et al. (2005). The confirmatory factor analysis shows that the model suggested by YÖK and the World Bank was more suitable than the model of Ergin et al. (2005). The test includes expressions of chemistry curriculum acquisitions but it does not cover the experimentation phase of the process skills. The number of items of the developed test was not sufficient for a relevance analysis. More proof should be collected to establish the relevance by increasing the number of items in the sub-dimensions in subsequent studies of this subject.

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