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Development of the Problem Solving Scale in Science Education (PSSSE): The Reliability and Validity Study *

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Abstract

This study aimed to develop a valid and reliable instrument measuring the 60-72 months old children's problem solving skills in preschool science education. A total of 174 children were randomly selected and included in the study to achieve the reliability and validity studies. Exploratory factor analysis, item-total correlations, mean differences of the lower and upper groups, Cronbach Alpha internal consistency coefficient, scoring consistency between the independent judges, and test-retest correlation coefficients were computed to achieve the reliability and validity. The scale had a total of 16 items on two factors as a result of the exploratory factor analysis. The Cronbach Alpha internal consistency coefficient was calculated as 0.75. The inter consistency between the independent judges was computed and no significant difference was found. The test-retest correlation coefficient was computed as 0.96 between two applications done with an interval of four weeks. As a result of the reliability and validity analysis, the Problem Solving Scale in Science Education (PSSSE) was found to be a reliable and valid scale for the implementation with preschool children between 60-72 months old.

Keywords

Science education
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Introduction

Problem is defined as a situation faced by the individuals that has not a common solution but requires a solution (Posamentier & Krulik, 1998, p.1). It is a difficulty state which has new and unknown directions for person. It could be a state of challenge requiring novice thinking ways through negotiation with others (Güven, 2005). Problem can also be defined as the restraints that are faced in the phase of reaching a goal (Bingham, 1973; Morgan, 1998).

As for children, the problems could be defined as the questions requiring their deep attention and focus in reaching to the solutions. The process of asking questions and searching for the answers is all about problem solving (Lind, 2000).

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The problem solving is a process to get rid of difficulties through a goal. The problem solving is a cognitive and behavioral process managed by the individuals themselves requiring persistence and perseverance in reaching a solution (D' Zurilla, Nezu & Maydeu-Olivers, 2004; Kneeland, 2001). Problem solving skills is defined as a skill to learn and to get (Bingham, 1973). A variety of situations such as solving puzzles, basic mathematics and science problems, cognitive, logical, social and mechanical problems (Bullock, 1988). It is a result of creative and critical thinking (Güven, 2005). It is an integral part of inquiry-based science education and is the answer to the question of what could be done when it is not known what to do (Davis & Keller, 2009). The fundamental power underlying the problem solving is cited as the curiosity, interest, and desire to solve (Lind, 2000).

When it is considered that the problem solving skills affect an individual's life, and make him happy, peaceful, satisfied and protect his psychological health; the acquisition of problem solving skills at an early age is crucial (Sonmaz, 2002). Problem solving skills help children meet their all developmental needs by providing them with the rich learning experiences. While children are involved in the process of problem solving; the research, examination, discovery, and trial processes provide them with the opportunities of coping with difficulties, feeling strong, and being happy (Britz & Richard, 1992).

One of the goals of education is children's gain of skills that may help them in solving problems encountered in their future lives. Gaining those skills could be achieved through inclusion of the problem solving skills in education programs (Lester, 1994). Therefore, current research seeks ways of determining children's problem solving skills and how to improve those skills.

Problem solving can be learned like any other skill (Aydoğan, 2004; Güneysu, Dinçer & Etikan, 1997). Starting problem solving activities from the preschool period could also ease the young child's adaptation into real life. The inclusion of problem solving skills in all preschool activities and programs help children develop their abilities of analysis, synthesis, and multi-faceted thinking (Zembat & Unutkan, 2003).

It is revealed that the preschool science, mathematics, music, language, and play activities improved children's problem solving skills (Akkaya, 2006; Akman, 2002; Aydoğdu & Yenilmez, 2012; Büyüktaşkapu, Çeliköz & Akman ,2012; Doğru, Arslan & Şeker, 2011; Gündoğdu & Izgar, 2010; Hmelo Silver, 2004; Şendurur & Akgül, 2002; Yıldırım, 2007). Hence, the problem solving skills need to be included in all of the preschool activities; besides, children need to be encouraged through those activities and multi faceted materials need to be prepared (Zembat & Unutkan, 2003).

The improvement of problem solving skills, logic, stating cause and effect relation, creative thinking can be achieved through science education (Tsung-Hui, 2001). Problem solving skills, one of the goals of science education are improved through science activities in which children could learn through experience. Through science activities, children recognize themselves, their environments and improve their problem solving skills. The science activities improve young children's problem solving skills through exploring the environment, learning the working principles of diverse materials, and establishment of cause and effect relationships (Ünal & Akman, 2006, Ünal & Aral, 2010).

During science activities in preschool years, a variety of materials including simple machines, models, technological tools and supplies, construction materials, and other related materials need to be present. While children search in such equipped environments, they can produce lots of questions and find answers to such questions through simple experiments, observations and examinations through books, discussions, and other sources (Diffily, 2001; Humphres, 2000; Ross, 2000; Worth & Grollman, 2003). This problems which is defined on studies with these materials, includes child's real life problems. Improvement of curiosity that exists in children, positive attitudes toward science, a variety of solutions to the problems of everyday life can be achieved through science activities that children face at early years (Flick, 1993; Ergin, Pekmez &Erdal, 2005; Ünal &Aral, 2010). Therefore environments must be carefully prepared to produce solutions for problems and to learn a topic with details while preparing science activities in the preschool process.

During the preparation of science education programs in preschool, the children's previous knowledge and experiences need to be known; hence the children need to learn the scientific knowledge by making connections with their previous experiences. Such an environment could help the children return back to their prior information, create problems, and provide solutions to those problems (Büyüktaşkapu, 2010; Goossen, 2002).

It is also crucial to determine the problem solving levels of children; this kind of determination could help teachers to recognize children better and improve educational programs in science education (Karataş & Güven, 2003).

Hence, there are many researches, tests, and scales aimed to measure the problem solving skills of children in the literature. Research indicated the improvement of problem solving skills through the implementation of problem solving scales and respective educational programs. The majority of those scales aim to measure the interpersonal problem solving skills of children (Aydoğan, 2004; Dinçer, 1995; D'Zurilla et al., 1996; Feldhusen et al., 1972; Frauenknecht & Black, 1995; Johnson, 2000; Shure & Spivack, 1982; Rubin, 1988; Rubin & Krasnor, 1986; Webster-Sratton, 1990). However, any test or scale aiming to measure the problem solving skills of young children in scientific problematic situations is not found in the literature. Hence, this study aimed to develop a scale measuring 60-72 months old children's problem solving skills in preschool science education and ascertain the reliability and validity of this scale.

Method

Sample

The study was conducted with 60-72 months old children attending preschools and residing at different neighborhoods representing different socioeconomic status in the city center of Malatya in line with the suggestions of school teachers and administrators. 174 children were included in the study as determined by a simple random sampling. In determining the sample the rule "the sample needs to be at least five times of the item number in the scale" was followed (Tavşancıl, 2006). There was 30 items in the scale, and at least five times of that number constituted the sample size of this study.

Data Collection Tool

Development of the Scale

The literature review revealed that there were a number of scale and test aiming to measure the problem solving skills both in the national and international literature (Dinçer, 1995; Hepner & Peterson, 1982; Kargı, 2009; Serin et al., 2010; Shure & Spivack, 1982; Webster-Stratton, 1990). Most of those scales were developed to measure the interpersonal problem solving skills. The scales were consisted of short stories and accompanied with the pictures of everyday life events (Shure, 1992; Webster-Stratton, 1990).

The literature review done for this study revealed that there was not any test or scale aiming to measure science related problem solving skills of children, especially for young children. The scale used to determine the children's problem solving skills in this study has been developed by the researchers through the stages stated below.

First a pool consisted of 92 problem situations for 60-72 months old children was created in line with the experts' suggestions from the fields of physics, chemistry, biology, child development, and preschool education. Those problem situations were grouped in life sciences, health sciences, and physical sciences which were also the subjects of preschool science education. The grouped problem situations were reviewed by the experts considering the characteristics of children's age and attention span. Some of the problem situations were excluded from the pool because of their requirement of high level cognitive skills or their relevance with more than one field. Accordingly, the number of problem situations was decreased to 30. The accompanied pictures with the 30 problem situation were drawn with software. Considering the scoring criteria of scales in the literature, the likert type scoring was determined (Shure, 1992; Webster-Stratton, 1990). The children's answers were pointed on a four point Likert type scale including zero (no answer or wrong answer), one (answer with a false focus), two (answer with no idea about the next step), and three (a full right answer). As an example to the problematic situations from the scale; “You are going on vacation with your mom and dad. There are many beautiful flowers at your home. What can you do to prevent the flowers from fading? What else can you do?”. The child gets zero if he gives no answer or says “I make sun.”; gets one point if he says “I put it in a sunny place.”; gets two point if he says “Someone could stay at home and water it.”; and gets three point if he says “I give the keys to my grandma, she can come and water the flowers.” or “I put the flowers in a bathtub full of water.” In this way, the child had a score ranging from zero to three for each problem situation, and the sum of those scores provides a total score from the Problem Solving Scale Science Education (PSSSE).

Operation

The appropriate context and construct validity study steps were followed in this study. In order to ensure the context validity, the related literature was reviewed and the problem situations provided in the scale were constructed and reviewed by the experts. The appropriateness of the data gained from the children was analyzed by the Kaiser-Meyer-Olkin (KMO) Coefficient and Bartlett Sphericity Test. Then, exploratory factor analysis (EFA), item-total correlations, and the mean differences between the lower and upper groups were computed. In order to ascertain the reliability of the Problem Solving Scale in Science Education, Cronbach's Alpha internal consistency coefficient, scoring reliability between independent judges, and test-retest correlations were computed. Hence, the reliability and validity of the Problem Solving Scale in Science Education were ascertained through achieving these steps.

Results and Discussion

Validity Studies

In order to ascertain the content validity of the Problem Solving Scale in Science Education, the problem situations and accompanied pictures were reviewed by a panel of ten experts (seven of them were from the field of preschool education, two of them were from the field of educational programs, and one was from the field of psychological counseling and guidance). The experts were required to score the problem situations and accompanied pictures on a three point scale as “appropriate”, “somewhat appropriate”, and “not appropriate” and provide written critiques to improve the problem situations. 25 of the problem situations on which ten experts had a 90% of consensus about the appropriateness were included in the scale. Five of the problem situations on which the experts had a 60-70% of consensus were reviewed in accordance with the suggestions and the necessary changes were made (Büyüköztürk, 2008). The corrected problem situations in line with the experts' suggestions were sent to another group of four preschool education experts to achieve the content validity. In accordance with the experts’ suggestions, the necessary corrections were made for the problem situations and accompanied pictures. As the result, a total of 30 problem situations and accompanied pictures were kept in the scale with a consensus of 90% between the experts. The Problem Solving Scale in Science Education consisted of 30 items was prepared for the pilot testing. The Problem Solving Scale in Science Education was applied to 20 children and there was seen no other necessary change for the problem situations or accompanied pictures. Then, the Problem Solving Scale in Science Education was applied to 174 children one by one in an appropriate environment other than the classrooms in the schools. The problem situations were presented to the children together with the accompanied pictures. The mean of application time span of the Problem Solving Scale in Science Education was 10-15 minutes per child.

In order to ascertain the construct validity of the Problem Solving Scale in Science Education, first the exploratory factor analysis was run. Prior to the factor analysis, the appropriateness of the data for factor analysis was tested with the Kaiser-Meyer-Olkin (KMO) coefficient and Bartlett's Sphericity Test (KMO=0.76, Barlett Test of Sphericity= 418.01, p= 0.000). The test items were checked for normal distribution and the 26th item was excluded due to its violation of normal distribution. Then as a result of the first factor analysis; the 1st, 7th, 13th, 16th, and 19th items were excluded from the scale due to their low levels of factorial load (below 0.40). Then, the remaining items were again included in the factor analysis and the 6th , 23rd , 24th , 25th , and 28th were excluded from the scale because of their very low levels of factorial load, and the 29th , 21st , and 27th items were excluded because of their presence in two factors. The repeated factor analysis showed that the remaining 16 items were dispersed on two factors with high factorial loads (see Table 1).

Table 1. Factor Loads and Item-Total Correlations of the PSSSE

Items	Factors		
	Science and Nature Problems (SNP)	Material Usage Problems (MUP)	
	Factor load	Factor load	Item-total Correlation Coefficients
Item 2	0.417		0.319
Item 3	0.558		0.380
Item 4	0.546		0.426
Item 5	0.501		0.364
Item 8	0.533		0.472
Item 17	0.636		0.433
Item 20	0.461		0.345
Item 22	0.602		0.423
Item 30	0.617		0.424
Item 9		0.588	0.385
Item 10		0.445	0.331
Item 11		0.548	0.324
Item 12		0.719	0.421
Item 14		0.410	0.225
Item 15		0.500	0.392
Item 18		0.518	0.302
Variance (%)	22.05	18.08	
KMO	0.76		
Barlett Test	0.00		
Df	120		
Approx Chi-Square	418.010		

Note: The items in the table have factor loads higher than 0.40

The item factor load value needs to be equal to 0.45 or higher (Büyüköztürk, 2008). In the formation of the factor structure, the factor loads between 0.30 and 0.40 could be considered as the lower cut-off points (Tavşancıl, 2006). According to Tabachnick and Fidel (2001), the factor load values equal to or higher than 0.40 could be considered as "very good"; the values equal to or higher than 0.70 could be considered as "excellent". Then the respective items were considered to have high relations with the respective factors. The items of two factors were examined and reviewed by the experts. In accordance with the experts' suggestions, the first factor was named as Science and Nature Problems (SNP) due to the content of the problem situations and the second factor was named as Material Usage Problems (MUP) due to the need of materials to solve those problem situations.

The factor analysis revealed that the SNP was consisted of nine problem situations, the items' loads were between 0.417 and 0.636; explaining 22.05% of total variance. The MUP was consisted of seven items, the items' loads were between 0.41 and 0.719; explaining 18.08% of the total variance. The two factors explained 40.13% of the variance. According to Scherer (1998), the findings about items' load values were statistically significant and the items were sufficient in terms of item discrimination. In factor analysis, the variance values between 40% and 60% are accepted as ideal (as cited in Erdoğan et al., 2007).

The construct validity of the Problem Solving Scale in Science Education has been examined via two types of item analysis. In the first one, the corrected item-total correlations were computed for the items belonging to the related factors (Table 1). The corrected item-total correlations also called as item discrimination level were 0.319-0.472 for the SNP subscale and 0.302-0.424 for the MUP subscale. Because the value of item discrimination index which is higher than 0.30 is considered to be "good", the items belonging to the two factors of the PSSSE were considered to have high item discrimination (Büyüköztürk, 2008).

The second evidence regarding the construct validity of the PSSSE was the item analysis done to determine to what extent the items measured the constructs as aimed to be measured by the subscales. To achieve that, the total scores gained from the PSSSE were ranged from low to high. Following this ranging, a total of 94 participants from the 27% of the lower and upper groups (47+47) was chosen. It was analyzed with the Mann Whitney U test whether each subscale distinguished those two groups. Because the data were not normally distributed, the Mann Whitney U Test was applied to the data gained from the children; the findings were shown in Table 2.

Table 2. The Mann Whitney U Test Results of the Item-Total Mean Scores of the Lower and Upper 27% Groups According to the Subscales and Total Scores of the PSSSE

PSSSE		$\overline{X}$	**n**	**Min.**	**Max.**	**Sd.**	**Mean Rank**	**MWU**	**p**
SNP	Lower %27	1.51	47	0.89	1.89	0.29	24	000	.000*
	Upper %27	2.73	47	2.56	3.00	0.11	71		
MUP	Lower %27	2.06	47	0.00	2.29	0.41	24	000	.000*
	Upper %27	2.73	47	2.54	3.00	0.11	71		
Toplam (SNP+MUP)	Lower %27	1.81	47	0.69	2.13	0.29	24	000	.000*
	Upper %27	2.66	47	2.56	2.88	0.08	71		

*p<0.01

It was found that the PSSSE discriminated the problem solving skills depending on the significant Mann-Whitney U values for the upper 27% and lower 27% groups' item total score differences between the SNP and MUP subscales, and total score.

Reliability Studies

The Cronbach Alpha internal consistency coefficient was computed to ascertain the reliability of the Problem Solving Scale in Science Education. The consistency of scoring was determined through internal consistency of scoring between the independent judges. Besides, to determine the consistency level of the scale, the test-retest procedure was followed with a four week interval. As the result of data analysis, the internal consistency coefficient was computed and presented in Table 3.

Table 3. The Cronbach Alpha Reliability Coefficients of the PSSSE

	Factors		
	Science and Nature Problems	Material Usage Problems	Problem Solving Scale in Science Education
Cronbach Alfa	0.72	0.61	0.75

The analysis showed that the Cronbach alpha was 0.72 for the SNP subscale, 0.61 for the MUP subscale, and 0.75 for the overall Problem Solving Scale in Science Education. The Cronbach alpha coefficient was computed as 0.78 for the Purdue Elementary Problem Solving Inventory which is developed by Feldhausen, Houtz, and Ringenbach (1972) and adapted into Turkish culture by Aydoğan (2004). A reliability coefficient computed between 0.60-0.80 for a psychological test indicates that the test is reliable (Kalaycı, 2008; Özdamar, 1997).

To ascertain the scoring reliability of the Problem Solving Scale in Science Education, the internal consistency between the judges was computed. Because the children's scores from the Problem Solving Scale in Science Education did not have a normal distribution, the Wilcoxon Signed-Rank Test was utilized to measure the internal consistency between the judges.

Table 4. The Wilcoxon Signed Rank Test Scores for the Internal Consistency between the Judges about the PSSSE

		n	%		Wilcoxon Signed Rank Test	
					Z	P
SNP	Negative	60	34.6	D1 A < D2 A	-0.616	.538
	Pozitive	66	37.9	D1 A > D2 A		
	Equal	48	27.5	D1 A = D2 A		
	Total	174	100			
MUP	Negative	60	34.6	D1 A < D2 A	-0.271	.787
	Pozitive	63	36.2	D1 A > D2 A		
	Equal	51	29.2	D1 A = D2 A		
	Total	174	100			
Total (SNP+MUP)	Negative	64	36.8	D1 A < D2 A	-0.394	.694
	Pozitive	70	40.2	D1 A > D2 A		
	Equal	40	23	D1 A = D2 A		
	Total	174	100			

As seen in Table 4, there was no significant differences (p>0.01) between the first and the second independent judges on the SNP (z: -0.616), MUP (z: -0.271) and the total scale (SNP+MUP z= -0.394). Accordingly, at the degree of significance 0.01, there was no significant difference between the independent judges for the reliability which meant that the assessment of the scale was appropriate. In developing the Preschool Interpersonel Problem Solving Scale (PIPSS), Shure (1992) indicated that there was no any significant difference between the independent judges.

Another reliability analysis determining the stability is the test-retest method. For this purpose, the PSSSE including 16 items was applied to 65 children with an interval of four weeks. The findings of this application were presented in Table 5.

Table 5. Test-Retest Correlations (n:65) of the PSSSE and Its Subscales (SNP and MUP)

PSSSE		**SNP**	**MUP**	**Total (SNP+MUP)**
SNP	r	0.962		
	p	0.000*		
	n	65		
MUP	r		0.954	
	p		0.000*	
	n		65	
Total (SNP+MUP)	r			0.962
	p			0.000*
	n			65

*p<0.01

Table 5 indicated a high correlation between two applications of the SNP, the MUP, and the total test (SNP+MUP). Accordingly, the test-retest correlation of the SNP subscale was 0.96, the MUP was 0.95, and of the total was 0.96, and all the correlations were significant (p<0.01). Similarly, the test retest correlation coefficient was computed as 0.93 for the Purdue Elementary Problem Solving

Inventory adapted into Turkish culture by Aydoğan (2004). Also, the test retest correlation was computed as 0.72 for the Preschool Interpersonal Problem Solving Scale developed by Shure (1992). The test retest correlation was computed as 0.83 for the Wally Child Social Problem Solving Detective Game Test. These high correlations indicated that the Problem Solving Scale in Science Education was a stable measurement, that is to say, the skills measured through this scale did not have a noticeable change in time (Büyüköztürk, 2008).

Conclusion and Suggestions

This research aimed to develop "Problem Solving Scale in Science Education" and ascertain its reliability and validity. The problem solving scales in the preschool education literature were mostly related to the children's interpersonal problem solving skills. The literature review revealed that there was not any problem solving scale in preschool science education. It is considered that such an instrument could help in determining the differences in problem solving skills and in developing appropriate education programs in preschool science education.

This study aimed to determine the reliability and validity of the Problem Solving Scale in Science Education. The first scale consisted of 30 problem situations was applied to 174 children and the data were studied to ascertain the reliability and validity. The last form of the scale was consisted of 16 problem situations and accompanied pictures. As a result of the reliability and validity studies, it is ascertained that the developed Problem Solving Scale in Science Education could be used to measure the problem solving skills of the 60-72 months old children in preschool science education. It is suggested that additional studies on the reliability and validity of Problem Solving Scale in Science Education could be redone with different samples and age groups. The findings of this study also revealed that the children had a hard time especially in the problem situations requiring material usage. Thus, the studies focusing on the improvement of problem solving skills in preschool science education should especially emphasize the improvement of problem solving skills requiring the usage of diverse materials.

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