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Review article*

Construction and Validation of Problem-Solving Ability Test

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Abstract

The study focused on the construction and validation of a problem-solving ability test. The test consists of 36 multiple choice items regarding numerical and reasoning ability tested on 810 students. The preliminary instrument consists of 46 multiple choice items was tested on 352 secondary school students. After the refinement of items using different procedures, 36 items were selected. The construction and development of the test was done by expert review, preliminary draft, item analysis, selection of items, preparation of final test, norms, validity, and reliability of the test. The Cranach's (α) and split-half reliability of the test as found 0.909and 0.890 respectively with the intrinsic and criterion validity of the test was found to be 0.953and 0.781.

Keywords: Construction, Problem-solving, Students, Reliability and Validity.

Introduction

With the advancement in socio-economic and technological fields, the life of the individual is growing more and more complex fraught with a range of problems that the individual and society have to face in long run. The ability to solve problems is one of the basic skills everyone needs in order to face the increased demands in a complex life. Generally, problem-solving skills developments one of the focuses on the 21st-century educational goals (Gongden, 2016; Kivunja, 2015; Wang, *et al.,* 2018), especially in physics education (Shishigu et al. 2009; Taasoobshirazi & Farley, 2013). Apart from understanding concepts (Docktor et al.,2016; Yuliati et al. 2018), physics aim at improving the problem-solving skills of individuals (Harjono, 2012; Soetopo, 2016). Problem-solving is a cognitive process of finding means to achieve goals (Mefoh et al. 2017; OECD, 2014) which depends on the ability to compile and process information (Sujarwanto & Hidayat, 2014). The stages involved in addressing problems are often covered in physics education (Gunawan *et al.,* 2015).

Problem solving ability has played a critical role in human history (Chi & Glaser, 1985; Ohlsson, 2012). Problem solving involves people's efforts to find a solution to a problem using analytical thinking, critical thinking, creativity, reasoning, and experiences along with available information (Chi & Glaser, 1985; Schunk, 2004; Reeve, 2013). Since childhood, we actively solve problems presented by the world. We acquire information about people, objects, events, or phenomena and organize the information into the structure of knowledge that is stored in our memory. The structure of knowledge contains bodies of understanding, mental models, convictions, and beliefs, and influences how we relate our experiences together and how we solve problems that we encounter in everyday life at school, work, even at play (Resnick & Glaser, 1975; Chi & Glaser, 1985).

Problem-solving is the mental process of Assessing a Circumstance, learning what Choices are available, and then choosing the alternative which will result in the desired Result (Investigator).

Problem-solving may be defined as a process of raising a problem in the minds of students in such a way as to stimulate purposeful, reflective thinking for arriving at a rational solution Risk, (2000). Hafner and Stewart (1995) defined, "Problem Solving is a complex, multilayered skill." According to them the process of problem-solving depends on Fluidity of thinking (Guilford 1986) Generation of mental elements (Johnson-Laird 1993) and Continuous search of new ideas.

Studies Supporting Problem Solving Ability Test

Olivares et al., (2000) studied psychometric properties of the Spanish adaptation of the Social Problem-Solving Inventory-Revised (SPSI-R). The social problem-solving inventory-revised (SPSI-R) has been translated and adapted to a Spanish population. Covariance structure analysis was used to replicate the factor model for this questionnaire and to assess whether the Spanish and English versions were factorially invariant. The questionnaire was found to be only partially factorially invariant, as one of the dimensions measured by the questionnaire, impulsivity/carelessness style (ICS), appears to be measured differently across populations.

Effandi et al., (2004) reliability and construct validity of scores on the attitudes toward problem solving scale. The attitudes toward problem-solving scale (ATPSS) have received limited attention concerning its reliability and validity with a Malaysian secondary education population. Subjects were 233 secondary school students. Reliability coefficients of the three subscales and the total score were high, indicating that the scale is stable and reliable in measuring attitudes toward problem-solving. Results from factor analysis imply that the ATPSS measures more of various traits in Malaysian culture.

Behera (2009) studied the problem-solving skills in mathematics learning. The study revealed that the mean difference between high and low ability groups, between boys and girls and within each ability group is quite large. Students with high mathematical ability are far superior in mathematical problem-solving skill to their counter parts in the lower ability irrespective of their gender.

Pitma et al., (2009) studied the factors influencing mathematic problem-solving ability of sixth grade students. This study revealed that teachers‟ behaviours took both direct and indirect effects on the students‟ mathematic problem solving.

Huang and Flores (2011) exploring the validity of the problem-solving inventory with Mexican American high school students. The problem-solving inventory (PSI; Heppner & Petersen, 1982) was developed to assess perceived problem-solving abilities. Using confirmatory factor analysis, results supported a bi-level model of PSI scores with a sample of 164 Mexican American students. Findings support the cultural validity of PSI scores with Mexican Americans and enhance the generalizability with culturally diverse samples.

Dubey (2011) developed problem-solving ability test (PSAT) in 1988 and it was revised in 2011. There are 20 items in a test. The problem-solving ability has been standardized over a sample of 1640 students between the age group of 12 to 17 years. The reliability of the test is .0.78 & 0.76 (Spearman Brown & Kuder Richardson) with validity 0.85. The duration of the test is 40minutes and is available in Hindi language only.

Garg (2012) developed problem-solving ability (PSA) scale. The test contains 22 problems along with alternative answers, except item number 2 and 20, in which only one answer is correct. The reliability of the test is .683 & .791 (Spearman Brown & Kuder Richardson) on a sample of 280. The duration of the test is 30 minutes and is available in Hindi language only.

Guven and Cabakcor (2013) studied the factors influencing mathematical problem-solving achievement of seventh grade Turkish students. This study revealed that the difference between male and female students' problem-solving achievement is not statistically significant.

Kumar and Singhal (2014) conducted study of academic achievement in relation to problem solving ability. In this study a sample of 200 students from classes VI to X was taken from government schools in urban area. A problem-solving ability test was administered and academic achievements of only those students were recorded form school records. It was found that those students having better problem-solving ability were the better performers.

Beyazsacli (2016) studied relationship between problem-solving skills and academic achievement. The results of this paper indicate that the ability scores of the senior primary school students relating to problem solving does not create a significant difference at a statistical level, from the point of view of the intervening variable of gender.

Singaravelu (2017) examined problem-solving ability of higher secondary chemistry students. The result of the study reveals that the higher secondary chemistry students have low level of problem-solving ability. Teacher should give practice on problems of a huge variety to develop creative thinking in his students to increase the problem-solving ability.

Kanmani and Nagarathinam (2017) examined problem-solving ability and academic achievement of higher secondary students. The study revealed that problem-solving ability of the higher secondary students is average and there was a high positive correlation between problem solving ability and achievement in mathematics.

Teo *et al.*, (2018) psychometric properties of the problem-solving inventory in a Singapore young male adult sample. The aim of the study was to evaluate the psychometric properties of the PSI with a Southeast-Asian sample made of 342 young adult males living in Singapore. The findings showed that the PSI with a three factors solution was a valid and reliable scale for use with young male Singaporeans.

Gunawan *et al.*, (2020) improving students' problem-solving skills using inquiry learning model combined with advance organizer. Based on the result, it was found that the students in the experimental class who used a combination of inquiry learning models and advance organizer had significantly problem-solving skills 'improvement than the control class that only used inquiry learning models.

Fülöp (2021) developing problem-solving abilities by learning problem-solving strategies: An exploration of teaching intervention in authentic mathematics classes. This study presents relevant implications to practitioners and other educational designers on how to enhance problem-solving ability by focusing on teaching problems-solving strategies integrated throughout the curriculum.

Construction of Problem-solving ability Test

A good test is prepared through a systematic process. The process of test development was completed through different steps namely: test conceptualization, test construction, item scoring and analysis, reliability and validity and test standardization.

Preparation Draft for Problem-solving

After the review of literature, Problem solving ability test was prepared from the contents numerical and reasoning ability. The preliminary draft was given to experts in education, psychology, statistics and experienced mathematics teachers. After receiving their opinions, items in difficult language were modified to simple language statement and 10 items were eliminated from the draft.

Purpose of the Test

The main purpose of the test was to measure the Problem-Solving Ability of students studying at Secondary, Under Graduate and University level.

Operational Definition

Problem solving ability is a score obtained by the students in Problem-solving ability test (PSAT) against the learning and understanding of concepts of numerical and reasoning ability of given below contents.

Content areas of Problem-Solving Ability Test

It was important to identify the dimensions of Problem-Solving Test before constructing it. In this study, Problem Solving has been conceptualized in terms of broad areas of numerical and reasoning ability. These areas of test are Time, Speed, Work and Distance, Profit, Loss and Discount, Coding- Decoding, Simple and Compound interest. Averages and Percentages Ratio and Proportion, Blood Relations, Direction Sense and Problems based on Age.

The Item Pool

The researcher has adopted multiple choice items, because these items are regarded as the most valuable and most generally applicable to all test forms.

For the purpose of item pool, initially a list of '56 statements distributed over the above nine contents of numerical and reasoning ability' were prepared. Then, the draft items were given to a group of 10 select experts in the field of mathematics and reasoning and scale construction, with a request to review the statements and evaluate their content accuracy and coverage, their repetition, editorial quality with suggestions for additions, deletions and modifications of items. Based on 80% unanimity of the experts, 46 statements were included in the 'try-out form' of the scale.

Initial Try-out of the Test

The 46-items were "randomized and were provided with standard directions and administered" on a sample of 352 secondary, college and university level students of Jammu and Kashmir.

Item Analysis

Item analysis is a statistical technique which is used for selecting and rejecting the items of the test on the basis of their difficulty value and discriminated power or index. **(Investigator).** Item analysis is a technique of item validation (**Ebel, 1966**).

In the present test Item analysis was done after arranging total scores of all the students in ascending order. For the purpose of item analysis 27% subjects from highest scoring group and 27% subjects from lowest scoring group were selected. Each group consisted of 95 students.

Item Discrimination

Index of discrimination is that ability of an item on the basis of which discrimination is made between superiors and inferiors **(Blood & Bud, 1972).**

Discriminating Index was calculated for each item. Following formula was used to calculate the Discrimination Index of an item.

$$D.I = \frac{RU - RL}{NU + NL} x100$$

Difficulty Index of an Item

The difficulty value of an item may be defined as the proportion of a certain sample of subjects who actually know the answer of an item **(Frank S. Freeman).**

It was calculated using the following formula,

$$\text{Item difficulty (D.V)} = \frac{RU + RL}{NU + NL} \times 100$$

Item Selection

According to Ebel, (1966), any item having the discriminating power of above 0.30 should be considered as a reasonably good item.

In the present study, only such items have difficulty indices ranging from 30 to 60 and those items of discriminating power ranging from 0.30 to 0.45 were selected. The difficulty index and the discrimination power values are given in table 1.

Table 1. Indices of Item Difficulty and Discrimination Power of Items of Problem-Solving Ability Test

Item No.	RU	RL	D.I= $\frac{RU - RL}{NU + NL}$ x 100	D.V = $\frac{RU + RL}{NU + NL}$ x 100	Decision
1	85	20	0.34	55.26	Selected
2	82	21	0.32	54.21	Selected
3	90	45	**0.23**	**71.00**	**Rejected**
4	91	13	0.41	54.73	Selected
5	71	14	0.30	44.73	Selected
6	90	9	0.42	52.10	Selected
7	48	6	**0.22**	**28.42**	**Rejected**
8	76	15	0.32	47.89	Selected
9	70	12	0.30	43.15	Selected
10	87	7	0.42	49.47	Selected
11	85	50	**0.18**	**71.00**	**Rejected**
12	88	9	0.41	51.05	Selected
13	85	8	0.40	48.94	Selected
14	91	13	0.41	54.73	Selected
15	79	11	0.35	47.36	Selected
16	45	8	**0.19**	**27.89**	**Rejected**
17	84	8	0.40	48.42	Selected
18	91	10	0.42	53.15	Selected
19	83	10	0.38	48.94	Selected
20	81	5	0.40	45.26	Selected
21	69	10	0.31	41.57	Selected
22	90	50	**0.21**	**73.68**	**Rejected**
23	91	12	0.41	54.21	Selected
24	89	6	0.43	50.00	Selected
25	76	19	0.30	50.00	Selected
26	87	9	0.41	50.52	Selected
27	92	7	0.44	52.10	Selected

Item No.	RU	RL	D.I= RU ─ RL x 100 NU + NL	D.V = RU + RL x 100 NU + NL	Decision
28	41	9	**0.16**	**26.31**	**Rejected**
29	88	10	0.41	51.57	Selected
30	86	10	0.40	50.52	Selected
31	70	11	0.31	42.63	Selected
32	89	13	0.40	53.68	Selected
33	88	47	**0.21**	**71.05**	**Rejected**
34	73	9	0.33	43.15	Selected
35	89	7	0.43	50.52	Selected
36	72	9	0.33	42.63	Selected
37	46	9	**0.19**	**28.42**	**Rejected**
38	83	7	0.40	47.36	Selected
39	92	8	0.44	52.63	Selected
40	80	12	0.35	48.42	Selected
41	83	67	**0.08**	**78.94**	**Rejected**
42	78	17	0.32	50.00	Selected
43	87	8	0.41	50.52	Selected
44	43	8	**0.18**	**26.84**	**Rejected**
45	82	13	0.36	50.00	Selected
46	86	9	0.40	50.00	Selected

From the above table, based on Ebel **(1996),** it is evident that out of the 46 items, 10 items were eliminated which were not significant on the basis of item difficulty and item discrimination index. Hence, 36 items were included in the final form of the scale. The total 36 number of items with their serial numbers and their distribution over different areas/ dimensions in the final scale after analysis are given in the table2 below.

Table 2. Number of Items under different areas of Problem-solving ability Test

S. No	Name of the Content area	Item No.	No. of Items
A	Time, Speed, Work and Distance	4, 5, 6, 16, 24, 33, 36	7
B	Profit, Loss and Discount	2, 3, 15, 23, 31, 32	6
C	Coding- Decoding	9, 10, 19, 26	4
D	Simple and Compound interest	13, 22, 29, 35	4
E	Averages and Percentages	1, 14, 30	3
F	Ratio and Proportion	7, 17, 34	3
G	Blood Relations	11, 20, 27	3
H	Direction Sense	12, 21, 28	3
I	Problems based on Age	8, 18, 25	3
Total Number of Items			**36**

Scoring of Items

Score '1' for correct answer and '0' for incorrect answer. Total score of the respondent could range from 0 to 36 in a given test.

Standardization of the Problem-Solving Ability Test

The final manuscript with 36 items was administered to a representative sample of 810 (Secondary/ College/ University) level students of Jammu and Kashmir. The total score of the scale varied from 0 to 36 and can be inferred as higher the score higher the individual has capacity to solve numerical and reasoning problems and vice-versa. The mean age of the students participated in the development of scale was 17.5 years with 14 years as minimum and 21 years as maximum.

Reliability

The consideration of reliability of a scale viewed as essential elements for determining the quality of any standardized test. Cranach's alpha was also used for determining the internal consistency reliability of the scale.

Table 3. Descriptive statistics of Items, Scale and Cronbach's Alpha

Item No.	Descriptive statistics for item				Descriptive statistics for scale		
	Mean	Variance	SD	N	Scale Means if item Deleted	*Corrected Item-Correlation	Cronbach's Alpha if Item Deleted
1	2.17	1.08	1.04	810	78.13	.466	.906
2	2.29	1.12	1.06	810	78.00	.516	.905
3	2.11	1.27	1.13	810	78.19	.514	.905
4	2.20	1.16	1.08	810	78.10	.338	.908
5	2.28	1.10	1.05	810	78.01	.490	.906
6	1.95	1.10	1.05	810	78.35	.546	.905
7	1.88	1.29	1.14	810	78.42	.433	.907
8	2.42	1.08	1.04	810	77.88	.492	.906
9	2.26	1.21	1.10	810	78.04	.489	.906
10	2.22	1.18	1.09	810	78.07	.520	.905
11	2.31	1.16	1.08	810	77.99	.468	.906
12	1.92	1.02	1.01	810	78.38	.254	.909
13	2.19	1.06	1.03	810	78.11	.400	.907
14	2.12	1.21	1.10	810	78.18	.421	.907
15	2.39	1.18	1.09	810	77.90	.430	.907
16	2.21	1.27	1.13	810	78.09	.374	.907
17	2.34	1.10	1.05	810	77.95	.379	.907
18	1.95	1.10	1.05	810	78.35	.546	.905
19	1.88	1.29	1.14	810	78.42	.433	.907
20	2.21	1.36	1.17	810	78.09	.359	.908
21	2.40	1.23	1.11	810	77.90	.290	.909
22	2.68	.990	.955	810	77.62	.345	.908
23	2.01	1.08	1.04	810	78.29	.562	.905

Item No.	Descriptive statistics for item				Descriptive statistics for scale		
	Mean	Variance	SD	N	Scale Means if item Deleted	*Corrected Item-Correlation	Cronbach's Alpha if Item Deleted
24	2.36	1.12	1.06	810	77.94	.489	.906
25	2.21	1.36	1.17	810	78.09	.440	.906
26	2.29	1.46	1.21	810	78.00	.514	.905
27	2.31	1.14	1.07	810	77.98	.497	.906
28	2.02	1.08	1.04	810	78.27	.484	.906
29	2.30	1.14	1.07	810	78.00	.462	.906
30	2.38	1.16	1.08	810	77.91	.503	.906
31	2.17	1.08	1.04	810	78.13	.466	.906
32	2.23	.919	.959	810	78.06	.487	.906
33	2.43	1.32	1.15	810	77.86	.426	.907
34	2.22	1.02	1.01	810	78.08	.507	.906
35	2.42	1.04	1.02	810	77.88	.263	.909
36	2.39	.994	.977	810	77.91	.381	.907

** r=0.21 (p<0.001) two tailed*

Content (Face and logical) Validity

The content (Face and logical) validity of the scale was verified by number of experts and academicians. There are various methods to establish content validity of the tool. Data screening was carried out in order to overcome existence of multicollinearity and singularity in the scale. For testing multicollinearity and singularity 'Determinant' of the R-matrix was estimated and it was greater than in both cases 0.00001. Sampling adequacy was also carried out and found to be greater than 0.50as required.

Intrinsic Validity

The formula used to determine the intrinsic validity is the square root to its reliability.
Thus, the intrinsic validity of this test is

$$V = \sqrt{R} \quad V = \sqrt{0.909} \qquad V = 0.953$$

Criterion Validity

The criterion validity of the problem-solving ability test was examined by using Pearson Product Moment Correlation (zero-order) with the problem-solving ability test designed by (Dr. Roop Rekha Garg with N= 150) and was found to be 0.781 (p<0.001) two-tailed. It confirms that the criterion validity of the problem-solving ability test is excellent.

Norms

The standard score (more commonly referred to as Z-Score) is very useful statistics, as it enables us to compare scores that are from a normal distribution. Standard Scores (Z- score) were calculated by using the descriptive statistics (**Mean = 19.54, SD=8.68, N=810**).

$$Z = (X - \mu) \div \sigma$$

Where X is the raw score of the problem-solving ability scale, μ is the mean and σ is the standard deviation. On the basis of descriptive statistics, the Z -score norms have been prepared which are valid for secondary school students and shown in Table 4.

Table 4. Z-score norms for the Problem-Solving Ability Test

Mean = 19.54 SD=8.68 N=810

Raw Score	Z-Score	Raw Score	Z-Score
3	-1.905	**20**	0.052
4	-1.790	**21**	0.168
5	-1.675	**22**	0.283
6	-1.559	**23**	0.398
7	-1.444	**24**	0.513
8	-1.329	**25**	0.629
9	-1.214	**26**	0.744
10	-1.099	**27**	0.859
11	-0.983	**28**	0.974
12	-0.868	**29**	1.089
13	-0.753	**30**	1.205
14	-0.638	**31**	1.320
15	-0.523	**32**	1.435
16	-0.407	**33**	1.550
17	-0.292	**34**	1.665
18	-0.177	**35**	1.781
19	-0.062	**36**	1.896

The Z- score norms have been categorized labeled and interpreted in reference to problem-solving ability in Table 5.

Table 5. Classification of Norms for Interpretation of the Problem-solving ability on the basis of Z-Score

S. N0	Range	Level	Problem-solving ability
1	+1.50 and above	A	Extremely- High
2	+0.51 to +1.49	B	High
3	-0.50 to +0.50	C	Average
4	-1.49 to -0.51	D	Low
5	-1.50 and below	E	Extremely- Low

Conclusion

The problem-solving ability test has excellent internal consistency, split-half reliability (Guttman) and followed by the use of the Spearman-Brown prophecy formula. The face, content, intrinsic, and criterion validities were also high and are in an acceptable range. Thus, it can be concluded that the scale is highly reliable and valid for the measurement of the problem-solving ability of the 13 and above years of age group.

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