Development of Problem Solving Confidence Questionnaire: Study of validation and reliability

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Abstract

This study aimed to develop and validate a problem solving confidence questionnaire which would help teachers, instructors, and researchers to have better understanding of problem solving confidence of students. The participants of this scale were 950 undergraduate science and engineering students enrolled in the Introductory Calculus Based Physics. The development of the scale included the following three steps; item formulation, content validation and reliability calculation. The scale has 20 items allocated to two factors: (1) High Confidence; (2) Low Confidence. The scale items had a factor loading of at least .40. The results of the factor analysis revealed that the scale accounted for the 57.32% of the total variance. The alpha reliability coefficient was .92. According to these findings, the Problem Solving Confidence Questionnaire (PSCQ) is a valid and reliable instrument that can be used in the field of engineering and science education.

Keywords: Problem Solving, Problem Solving Confidence Questionnaire, Validation and Reliability.

Resumen

Este estudio tiene como objetivo desarrollar y validar un cuestionario de confianza de solución problemas que ayudan a los maestros, instructores e investigadores para tener una mejor comprensión de la confianza en la resolución de problemas de los estudiantes. Los participantes de esta escala fueron 950 estudiantes de pregrado de ciencia e ingeniería inscritos en Cálculos Introductorio Basados en Física. El desarrollo de la escala incluye los siguientes tres pasos, artículo de formulación, validación de contenido y cálculo de la fiabilidad. La escala tiene 20 temas asignados a dos factores: (1) Alta Confianza, (2) Baja Confianza. Los elementos de la escala tenían un factor de carga de al menos 0.40. Los resultados del análisis factorial revelaron que la escala representó el 57.32% de la variación total. El coeficiente de confiabilidad alfa fue 0.92. De acuerdo con estos hallazgos, el cuestionario de confianza de solución problemas (PSCQ) es un instrumento válido y fiable que puede ser utilizado en el campo de la ingeniería y la educación científica.

Palabras clave: Resolución de problemas, Resolución de Problemas Cuestionarios para la Confianza, Validación y Confiabilidad.

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I. INTRODUCTION

Problem solving is viewed as a fundamental part of learning physics [1, 2]. Most researchers working on problem solving [3] agree that a problem occurs only when someone is confronted with a difficulty for which an immediate answer is not available. However, difficulty is not an intrinsic characteristic of a problem because it depends on the solver's knowledge and experience [4]. So, a problem might be a genuine problem for one individual but might not be for another. In short, problem solving refers to the effort needed in achieving a goal or finding a solution when no automatic solution is available [5].

Research on developing an effective general instruction for physics problem solving started at least 50 years ago [4] and changed after the late 1970's with the works of [1, 6, 7]. Most of the research during this period aimed to identify the differences between experienced and inexperienced problem solvers. These studies showed that the experienced problem solvers were individuals with important knowledge, experience and training in physics, and so the process of reaching a solution was both easy and automatic for them. In contrast, the inexperienced problem solvers had less knowledge, experience and training in physics which mean that they were facing real problem.

In physics problem, inexperienced problem solvers tend to spend little time representing the problem and quickly jump into quantitative expressions [8]. Instructors have found that inexperienced problem solvers carry out problem solving techniques that include haphazard formula-seeking and solution pattern matching [1, 9]. By contrast, experienced problem solvers solve problems by interjecting another step of a qualitative analysis or a low-detail review of the problem before writing down equations [8]. This qualitative analysis used by experienced problem solvers, such as a verbal description or a picture, serves as a decision guide for planning and evaluating the solution [6]. Although this step takes extra time to complete, it facilitates the efficient completion of further solution steps and usually experienced problem solver is able to successfully complete the problem in less time than an inexperienced problem solver [8].

A. The purpose of the research

In all science courses, students are encouraged to solve various problems for enhancing learning process. Especially in physics it may be difficult to state some fundamental concepts unless students solve many problems with drawings and numerical calculations. Therefore, in physics problem solving is accepted as difficult by most of the students. Most studies mentioned in the introduction part have been performed on general problem solving and on the differences between the experienced and inexperienced problem solvers. When the studies were examined, unfortunately, the author could not find any scale constructed on problem solving confidence as of 2011. In this study, the Problem Solving Confidence Questionnaire (PSCQ) was developed to fill a gap in the literature of physical and engineering sciences.

II. METHOD

Participants

The participants selected in this study were 950 science and engineering students who enrolled in Introductory Calculus Based Physics course for Spring 2008, Fall 2008, and Spring 2009 from different departments (Physics, Physics Engineering, Chemistry, Chemistry Engineering, and Petroleum Engineering) at a public university in the northwest part of US. Of the participants, 489 students (51.4%) were female while 461 (48.5%) were male. PSCQ was given to students who completed Introductory Calculus Based Physics course successfully. The author was present to answer any queries raised by the participants. The participants took about 10min to complete the entire set of scale. Participants' involvement in this study was voluntary and their confidentiality as well as anonymity was ensured as the participants were assigned and identified by a unique code known only to the investigator.

Procedures

The open literature was reviewed to develop the basis for problem solving confidence questionnaire [10, 11]. The number of 310 students was required to write an essay about their confidences during solving a physics problem. Also, several experts in physics and physics education and forty volunteer students from three different physics courses at the university were interviewed about problem solving and confidence in problem solving. The items reported in the literature and obtained from essays and interviews were categorized to construct the items of the scale. PSCQ consisted of 20 affirmative and 11 negative statements. Respondents rated each item on a 5-point Likert scale, with the following scale anchors: 1=strongly disagree, 2=disagree, 3=undecided, 4=agree, 5=strongly agree. The validation and verification analyses were performed by giving the scale to science and engineering students. Some of the statistical analyses (Explanatory Factor Analysis "EFA", Cronbach's Alpha, etc.) were performed with SPSS 15.00 and the rest of them (Confirmatory Factor Analysis "CFA", etc.) were performed with LISREL 8.72. Validity of the scale was tested with the varimax rotation and principal component analyses. The items were selected considering the rule anticipating that the item factor load should be over .40 as a result of the varimax rotation [12]. The construct validity of the scale was obtained by Bartlett's test of sphericity. Further, as a result of the principal component analysis, the value of Kaiser-Meyer-Olkin was calculated. For reliability analysis of the scale, Cronbach's alpha was used to examine the reliability of the proposed items within each subscale of the scale. The eigenvalues for the factors, variance percentages and total variance percentages for the scale were obtained. Also, within the context of reliability analysis of the scale, Kolmogorov-Smirnov test was applied to test if the scale showed a normal distribution. Pearson product moment correlation analysis was performed between main scale and components.

III. RESULTS

The validity and reliability of the Problem Solving Confidence Questionnaire (PSCQ) were examined statistically.

The Validity Analysis

The validity analysis of the PSCQ was examined two categories which are EFA and CFA as follows.

Explanatory Factor Analysis Results of the PSCQ

The statistical analysis indicated that the result of Bartlett's test of sphericity [13] was 1735.969 for the scale ($p<.01$). The scale did not produce an identity matrix. Thus, multivariate normal distribution was accepted for factor analysis [14]. The value of .92 was obtained for KMO (KMO>.60) from the principal component analysis. KMO test was confirmed with the small partial correlations and sufficient distribution for the factor analysis. Rotation analysis was conducted with the principal component analysis and varimax method to identify the components. Two components having eigenvalues greater than 1.00 [15] were defined. The validity was confirmed with the total variance percentage greater than 41% [16].

Validity analysis enabled to include 20 items having the factor load of .40 in the scale. The items with lower factor load (<.40) were excluded. The factor distribution and factor load of these items are presented in Table I. Total item load of 20 selected items changed from .839 to .576.

The factors in the PSCQ were defined as *High Confidence and Low Confidence.* The calculated variance percentage for first factor including 14 items was 43.05. The variance percentages were obtained for second factor (6 items as 14.27). The eigenvalues for factors were 8.61 and 2.85 respectively. Also two factors accounted for 57.32% of total variance. It should be noted that *t*-values were found as significant with $p<.01$ when 27% high and 27% low group means were compared.

Confirmatory Factor Analysis Results of the PSCQ

To further assess the two-factor structure proposed by [17], a confirmatory factor analysis was conducted with LISREL 8.72 using maximum likelihood procedure as the technique for parameter estimation. The maximum likelihood procedure is among the most popular and robust methods for use in structural equation modeling [18].

The SEM (structural equation modeling) technique employs fit indices to provide estimates of how well the data fit the *a priori* hypothesized model. Because different indices reflect different aspects of model fit, multiple indices are typically reported. Also the chi-square statistic, the other fit indices selected for this study are: (a) the Goodness of Fit Index (GFI), (b) the Comparative Fit Index(CFI), (c) the Incremental Fit Index (IFI), (d) the root mean square error of approximation (RMSEA), and standardized root mean residual (SRMR).

TABLE I. The distribution of factors and factor loads of the items.

	Items	*High Confidence*	*Low Confidence*
1	I like to solve to a problem	**.839**	.109
2	I enjoy solving a problem	**.811**	5.380E-02
3	I like to solve a numeric problem	**.802**	8.377E-02
4	I do my best to be successful in problem solving	**.779**	.107
5	I am interested in problem solving	**.769**	1.461E-02
6	I like to struggle with solving problem even if I cannot solve the problem	**.761**	4.238E-02
7	I like to solve problems from different sources	**.756**	6.396E-02
8	I struggle with a problem until I find the correct answer	**.753**	-3.033E-02
9	I try too hard when I cannot solve the problem	**.744**	.113
10	I am sure that I can solve a problem	**.740**	.154
11	I am self confident in problem solving	**.740**	.272
12	I am sure that I am able to solve even a difficult problem	**.734**	.260
13	I do my best for solving the problem no matter how difficult a problem	**.699**	.276
14	I lose track of time while solving a problem	**.609**	-2.059E-02
15	I demoralize if I cannot solve a problem	-4.265E-02	**.773**
16	I am stressed while solving a problem	9.479E-02	**.766**
17	I lose self confidence if I cannot solve a problem	.136	**.735**
18	I am upset when I find incorrect answer of a problem	-.172	**.718**
19	I am afraid of making numerical mistakes	.286	**.634**
20	Preconceptions prevent me from solving a problem	.290	**.576**

TABLE II. Confirmatory factor analysis's results.

Model	χ^2	χ^2/df	*GFI*	*CFI*	*IFI*	*RMSEA*	*SRMR*
2-Factor	303.65	1.80	.90	.91	.92	.04	.02

Fig. 1 shows the path diagram for the 2-factor model for the PSCQ. As seen in Table II, there was a good fit. An examination of the modification indices in the LISREL revealed excessive co variances among the residuals of the observed variables.

The Reliability Analysis

The reliability analysis indicated the lowest and highest score as 29 and 95, respectively. The distribution of the scores was found to be normal from Kolmogorov-Smirnov test ($p<.05$). Cronbach's alpha reliability coefficient of the scale was .92. Cronbach's alpha values for high and low confidence were .94 and .91, respectively.

IV. DISCUSSION

Over the last decade, researchers in science education have identified various student attitudes, behavior, and beliefs that shape and are shaped by student classroom experience [19, 20, 21]. Several scales have been created to measure various aspects of student's beliefs, attitudes, and expectations. The three most well-known surveys for probing student beliefs about the physical sciences are the Maryland Physics Expectation Survey (MPEX) [11], the Views about Science Survey (VASS) [22], and the Colorado Learning Attitudes about Science Survey (CLASS) [10]. Each of the three has a particular focus, mainly aspects of epistemology or expectations.

When the previous studies on this subject were examined, it can be realized that most of the research has been conducted on the attitudes, beliefs, and behaviors of the students toward to the courses [10, 11, 21]. A scale hasn't been developed for revealing the state of the students while solving problem until today. It is known that students have difficulty while solving problem in engineering and physical sciences. This result was interpreted by the researchers as students insufficiently performance in problem solving. This was reported in this paper of Gok [23]. He defined the problem solving strategies of the students with the help of the problem solving strategy steps scale given in the paper. When the results of the study were examined, it was found that the students don't have any difficulty to determine the fundamental principle(s) of the problems. Although, the students could understand the related subjects easily, they couldn't solve the problems and check the results of the problems. This problem revealed the requirement of investigating the confidence of the students. This scale in this area was developed for filling this gap.

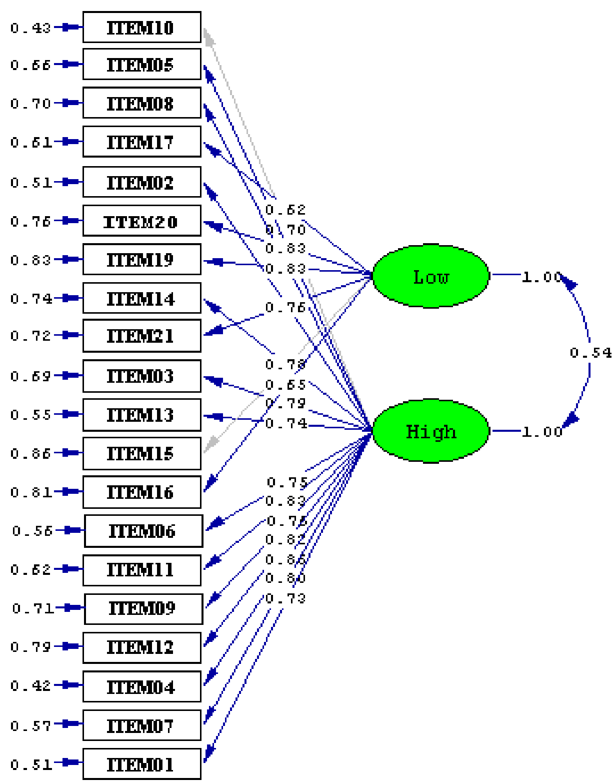

FIGURE 1. Path diagram of the two-factor model.

The author has developed and validated an instrument, the Problem Solving Confidence Questionnaire (PSCQ), which build on work done by existing scales. This scale probes the problem solving confidence of the science and engineering students while solving problem in the university level. The PSCQ was written to make the statements as clear and concise as possible and suitable for use in a wide variety of physics courses. The statements are scored overall and in two categories which are High Confidence and Low Confidence. *High Confidence*: a person's confidence is high when challenging oneself to achieve their goals through education and continuous learning. High confidence is not being a perfectionist, it's the knowledge and strength a person has. *Low Confidence*: It would be classified as a negative emotion or delusion, as it exaggerates one's limitations in capacity, quality and potential for growth.

Several design principles shaped the PSCQ and distinguish it from the previous scales. 1) It was designed to address a wider variety of issues that educators consider important aspects of solving problem. 2) The wording of each statement was carefully constructed and tested to be clear and concise and subject to only a single interpretation by both a broad population of students and a range of experts. This makes the scale suitable for use in many different courses covering a range of levels, and also allows most of the statements to be readily adapted for use in other sciences such as calculus, chemistry. 3) The expert and novice responses to each statement were unambiguous so scoring of the responses was simple and obvious. 4) The amount of time required to thoughtfully complete the scale was kept to 10 minutes or less by requiring clear and concise statements and using a simple response format. This also limits the scale to be less than about twenty statements. 5) The administration and scoring was designed to be easy. 6) The grouping of statements into categories of student confidence was subject to rigorous statistical analysis and only statistically robust categories were accepted.

The author performed a series of rigorous validation and reliability studies that involved several iterations to revise and refine the scale statements. The validation process included: interviews with and survey responses from physics faculty to establish the expert interpretation and response; interviews with students to confirm the clarity and meaning of statements; and administration of the scale to several hundred students followed by extensive statistical analysis of the responses including a detailed factor analysis to create and verify categories of statements. Revisions were made in this scale based on the results of the interviews and factor analysis and then the above validation studies were repeated with the new version of the scale.

Four experts underwent a series of interviews on the draft of the PSCQ. Their comments were used to hone the statements and remove any that could be interpreted more than one way. When this process was complete, eleven experts took the scale. Their answers confirmed the expert's point of view used in scoring. These experts were physicists who have extensive experience with teaching introductory courses and worked with thousands of students at the university. Some of these experts are involved with physics education research; others are simply practicing physicists interested in teaching. Student interviews on essays were carried out on draft by obtaining forty volunteers from different physics courses at the university. Care was taken to interview a diverse group of students by selecting from introductory courses catering to the full range of majors, having equal numbers of men and women.

Interviews consisted of first having the student take the scale with pencil and paper. Then, during the first ten minutes, students were asked about their major, course load, best/worst classes, study habits, attitude about problem solving, class attendance and future aspirations, to characterize the student and his or her interests. After this, the interviewer read the statements to the students while the student looked at a written version. The students were asked to answer each statement using the 5-point scale and then talk about whatever thoughts each statement elicited. If the student did not say anything, he/she was prompted to explain his/her choice. After the first few statements, most students no longer required prompting. If the students asked questions of the interviewer, they were not answered until the very end of the interview. Interview results showed students and experts had consistent interpretations of nearly all of the statements. Finally, these interviews provided some new insights into students' confidence in problem solving.

Statistical analyses were used to test the validity of the sub-grouping of statements into categories. In this regard, the PSCQ is different from previous scales. There is no published statistical analysis of the MPEX, VASS categories. The statistical analysis of the PSCQ revealed good validity and internal consistency reliability according to Explanatory Factor Analysis. It was possible to state that the sample data was adequate for factor analysis according to statistical results. Then, the data was analyzed with principal component analysis to explore the component structure underlying the instrument. Later, Confirmatory Factor Analysis was used to determine the ability of a predefined factor model to fit an observed set of data. According to CFA results, adequate model fit was represented by GFI, CFI, and IFI values greater than .90 [18] and RMSEA values below .05 [24]. Estimates of the internal consistency reliability of the scale were determined by calculating Cronbach's alpha reliability coefficient. This analysis aimed to determine the extent to which items within a scale measure the same construct as other items within that scale. The result of the internal consistency reliability having the value of .92 is considered to be acceptable to good. Analysis revealed that the coefficient was high enough to be considered adequate, namely, all items lead to a higher alpha coefficient for the overall scale reliability. As a result it can be said that the PSCQ consisting of 20 items is a valid and reliable instrument to assess undergraduate science and engineering student perceptions on problem solving confidence.

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