International Journal of Environmental & Science Education, 2015, **10**(2), 183-200

Development and Validation of the Physics Anxiety Rating Scale

Mehmet Sahin
Dokuz Eylül University, TURKEY
Serap Caliskan
Dokuz Eylül University, TURKEY
Ufuk Dilek
Dokuz Eylül University, TURKEY

•*Received 19 September 2014*
•*Revised 17 February 2015*
•*Accepted 14 March 2015*

This study reports the development and validation process for an instrument to measure university students' anxiety in physics courses. The development of the Physics Anxiety Rating Scale (PARS) included the following steps: Generation of scale items, content validation, construct validation, and reliability calculation. The results of construct validity analysis with 495 university education students showed that the scale consisted of four components: Physics course/test anxiety, anxiety about lack of physics knowledge, mathematics anxiety, and physics laboratory anxiety. The Cronbach's alpha reliability coefficient was found as .95 for the whole scale and for the components it ranged from .83 to .92. Confirmatory factor analysis, using another sample of 864 university education students with similar characteristics as the previous sample suggested that the four factor model for the PARS is valid. Hence, each component displayed satisfactory internal consistency reliability. According to findings, the PARS may be a useful tool in identifying the anxiety of undergraduate students taking physics courses. It can be used to determine students' physics anxiety in a particular course for instructional purposes or it can be used as a pre-and post-test to determine the change in students' physics anxiety.

Keywords: factor analysis; physics anxiety; scale development and validation; science anxiety

INTRODUCTION

Research about effective teaching and learning of science has focused on two dimensions. The first is the investigation of cognitive processes, and the second is the study of the affective factors. It is pointed out that instructional strategies that regard only cognitive variables may ignore the consideration of individual's affective characteristics such as intentions, goals, experiences, and emotions (Pintrich, Marx, & Boyle, 1993; Randler et al., 2011). For instance, earlier research criticized physics

Correspondence: Mehmet Sahin, Department of Science Education, Dokuz Eylül University, İzmir, Turkey.
E-mail: mehmet.sahince@gmail.com
doi: 10.12973/ijese.2015.240a

ISSN: 1306-3065

teaching for not taking into account students' such affective characteristics (Schwedes, 1973). To help students improve their scientific thinking and abilities, instructors need to take into account both affective and cognitive factors of learning (Laukenmann et al., 2003; Mallow & Greenburg, 1983).

In studies dealing with the psychology of learning, one can identify various theoretical approaches pertaining to the role of emotions in learning. One aspect that is emphasized is the strong relationship between emotion and motivation. Another emotional dimension of the affective factors that has received increasing attention in recent decades is anxiety. Among negative emotions, anxiety has considerable significance in learning and achievement situations.

Anxiety is defined as an unpleasant emotional state of uncertainty, fear, worry, discomfort, loss of control, and expectation that something bad will happen (Sapir & Aronson, 1990; Scovel, 1991). Anxiety is an important variable that can influence the learning process (Chapin, 1989; Phillips, 1984). Anxiety-creating situations may sometimes enhance an individual's performance. Alpert and Haber (1960) identified negative and positive dimensions of anxiety which were named as debilitating achievement anxiety and facilitating achievement anxiety. Although a low level of anxiety may have a positive effect on achievement, high anxiety may severely impede it.

Science Anxiety

The term anxiety has been around for more than a century. However, the concept of "science anxiety" was coined by Mallow in 1977 at Loyola University Chicago. The first Science Anxiety Clinic was founded at Loyola University Chicago (Mallow, 1978). Researchers developed techniques in the clinic to reduce science anxiety by blending three separate approaches: (1) science skills learning, (2) changing of students' negative self-thoughts, and (3) desensitization, through muscle relaxation, to science anxiety–producing scenarios (Mallow, 1981). Several studies were carried out to assess the effectiveness of the clinic (Alvaro, 1978; Hermes, 1985). Alvaro and Hermes showed that clinic group students' anxiety was reduced significantly compared to students in control groups. The Science Anxiety Questionnaire (SAQ) was developed by Alvaro (1978) and used in numerous subsequent studies (Brownlow et al., 2000; Bryant et al., 2013; Mallow 1994, 1998; Kastrup & Mallow, 2007; Udo et al. 2001, 2004) The SAQ is a 44-item questionnaire that asks students to imagine themselves in certain situations and to rate their level of anxiety on a 5-point Likert scale: "not at all," "a little," "a fair amount," "much," or "very much." Items of the SAQ are evenly divided between science and nonscience content, with emphasis on analogues situations, such as studying for a science exam versus studying for a history exam.

Science anxiety was defined as a diffuse or vague fear which arises in science learning situations (Mallow, 1978). It is suggested that like other negative feelings, anxiety results from intervening self-messages rather than from the science learning itself. Such messages as "I can never solve these problems, I just don't have a mind of a scientist" or "If I can't pass this physics course, I'll never graduate from school" produce anxiety and reduce performance in the physics course (Mallow & Greenburg, 1983).

Science anxiety can also be related to family, school, or environment. Among the factors causing science anxiety, as well as negative thoughts, unwanted negative memories of the past and worrying plans towards the future can be mentioned. For instance, sarcastic and insulting behavior of a science teacher in the past, an unsuccessful science experiment, or parents' discouraging comments towards science learning can cause anxiety towards science (Mallow & Greenburg, 1983).

The psychological studies illustrate the significance of emotions in both learning and performance situations (e.g., Möller, 1996). Jerusalem and Pekrun (1999) reported that positive emotions were frequently related to learning and performance situations. Czerniak and Chiarelott (1984) indicted science anxiety as a factor influencing science achievement in primary school students and suggested that high science anxiety may cause low science achievement. There is a general agreement in the empirical literature that test anxiety is associated with lower academic performance (Zeidner, 1998). A meta-analysis of 562 studies from elementary school through college indicated that test anxiety reduced academic performance at every educational level (Hembree, 1988). Research showed that test anxiety is associated with lower student grade point average (GPA), but there are few large scale studies investigating the relationship between test anxiety and GPA in undergraduate students (Chapell et al., 2005). One such study reported a significant but small inverse relationship between test anxiety and GPA in both undergraduate and graduate students (Chapell et al., 2005).

Studies also showed differences between male and female students' science anxiety levels (Bryant et al., 2013; El-Anzi, 2005; Mallow, 1994, 1995; Mallow, 2006; Mallow et al., 2010; Udo, Ramsey, & Mallow, 2004; Udo, Ramsey, Reynolds-Alpert, & Mallow, 2001). Females were usually found to be more anxious than males. However, several studies reported females and males to have similar science anxiety levels in a sample of American university students (Brownlow, Jacobi, & Rogers, 2000) and Turkish pre-service elementary teachers (Bursal, 2008).

The problem of students' lack of confidence and gender differences in physics classes has long been recognized (Fuller et al., 1985). Underrepresentation of women in the so called 'hard' sciences, especially in physics-related careers continues to be the focus of many research studies (Reid & Skryabina, 2003). Girls' interest has been shown to be higher toward sciences than males in the lower grades (Labudde, Herzog, Neuenschwander, Violi, & Gerber, 2000). However, in later schooling and at the time of career decisions, women tend to avoid science-related careers. Research suggests several explanations for career choices of women (Murphy & Whitelegg, 2006). Among them are the negative attitudes (Sharma, Stewart, Wilson, & Gökalp, 2013) and anxiety they develop during school years. Science anxiety has been regarded and reported as a factor creating special obstacles for female students in both humanities and the science field (Beyer, 1991). Udo, Ramsey, Reynolds-Alpert and Mallow (2001) suggest that different pedagogies and gender role models may correlate with anxiety reduction. Astleitner (2000) describes instructional strategies that can be used to decrease negative feelings (fear, envy, and anger) and to increase positive feelings (sympathy and pleasure). It is important that instructional strategies should be put into action to reduce gender bifurcation in science anxiety.

Rationale for the Study

In the literature, there are numerous scales and questionnaires developed to screen different anxiety states. Some of these are, Science Anxiety Questionnaire (Alvaro, 1978; Mallow, 1994), Science Anxiety Scale for Primary Students (Güzeller & Doğru, 2012), Science Anxiety Survey (Bursal, 2008), Chemistry Laboratory Anxiety Instrument (Bowen, 1999), Westside Test Anxiety Scale (Driscoll, 2007), The Mathematics Anxiety Rating Scale (Richardson & Suinn, 1972), Test Anxiety Inventory (Spielberger, 1980), Cognitive Test Anxiety Scale (Cassady & Johnson, 2001), State-Trait Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), Physical Activity and Sport Anxiety Scale (Norton, Hope, & Weeks, 2004). These and the others that were not mentioned here have been used and well documented in the literature. Although physics anxiety was dealt with as part of affective variables (e.g., Gungor, Eryılmaz, & Fakıoglu, 2007), usually it was not dealt with as a separate concept in the research studies. Therefore, to the knowledge of the authors of the present study, there is no instrument to measure specifically physics anxiety of university students in physics classes. Since physics requires higher-order cognitive skills, some students may come to physics classes with their prejudiced perception of physics as very hard to cope with. Taking this possibility into account, the necessity for teachers to seek ways to minimize such perceptions and promote positive attitudes is apparent. To work for remedies of physics anxiety in our physics classes, firstly students' anxiety should be measured and determined. To do this, we need valid and reliable measuring instruments as in all other educational research areas. Therefore, the purpose of this study was to develop a valid and reliable instrument to measure "physics anxiety" of undergraduate students. As previous research (Udo et al., 2001) and the current study revealed, education students (pre-service teachers) present significantly higher levels of science anxiety. Designing research based instructional strategies according to the results of physics anxiety rating scale might prove useful in education of teachers, at least for physics components of their science courses, and in education of students in other science fields. In this article, the development process of the PARS is described in detail (Dilek, Şahin, Güler, & Eslek, 2013; Şahin, 2014; Şahin, Çalışkan, & Dilek, 2012). The PARS can be utilized to measure anxiety levels of students at any desired point during a course as well as before and after an intervention study as a pre- and posttest to determine possible shifts in anxiety levels.

METHODOLOGY

Participants

The scale was applied to a total of 495 university students enrolled in an undergraduate level introductory physics course at a public university in Turkey. There were 228 males and 267 females. Great majority of the students were from education faculty. They were pre-service teachers of physics, chemistry, biology, mathematics, elementary, elementary science, and computer education. Only approximately 8% of the participants were freshman engineering students. Due to varying department programs, some students took one general physics course during their pre-service education (e.g., elementary pre-service teachers). Some students took a general physics course in their first year, others in their second year of study (i.e., elementary mathematics and elementary pre-service teachers). The PARS was administered to students during the course time. A second set of data was collected from a similar sample of 864 pre-service teachers from the same faculty and departments during a two-semester period for further validity analyses of the PARS.

Development Process of the Physics Anxiety Rating Scale (PARS)

In the development process of the PARS, a procedure consisting of seven steps, namely, review of relevant literature, generation of scale items, establishment of face validity, construction of the draft scale, pilot testing, administration of the scale, and validity and reliability analyses were followed. Details regarding these steps are explained below.

Review of Relevant Literature

At first, an extensive literature review on studies concerning anxiety in the process of education and instruction within the fields of mathematics, chemistry and especially of science/physics was conducted. At the beginning, results of the studies concerned with the place of anxiety in education and instruction, the causes and results of its effects on an individual's physical and psychological state and on learning were revealed. Scales developed for assessing anxiety related to chemistry education (Bowen, 1999), math (Alexander & Martray, 1989; Bintaş, 2008; Fennema & Sherman, 1976; Hopko, Mahadevan, Bare, & Hunt, 2003; Richardson & Suinn, 1972; Wigfield & Meece, 1988), science education (Chiarelott & Czerniak, 1985; Mallow, 1994), and to computer and internet (Ogunkola, 2008; Wang, 2007) were examined carefully. The creation of the PARS thus heavily depends on the works of others mentioned here and in the rationale section of the paper.

Item Generation

After the literature review, items which were used in relevant studies of anxiety and which were eligible for the structure and content of a physics course (e.g., lab, exam) were selected; and these items, albeit small in number, were revised by the authors with respect to the purpose of the scale and goals of a physics course. In addition to this, new items related to anxiety which may arise from previous experiences about solving physics problems or conducting physics experiments were generated. Ultimately, a pool of 60 items covering all likely components of a physics course such as problem solving, explaining a physical phenomenon, taking exams, conducting experiments, using mathematical knowledge and asking questions, was generated.

Establishment of Face Validity

The 60 items generated were presented to a panel composed of one science education and two physics education experts. The panel was asked to examine the clarity of the items, similarity of them with each other and whether the content was sufficient to determine the anxiety levels of undergraduate students regarding physics courses and, to comment on the consistency of the items. In line with the experts' suggestions, 10 items were excluded and 2 items were revised to clarify their meaning.

Construction of the Draft Scale

The remaining 50 items were used to construct a 5-point Likert-type scale ranging from 1(strongly disagree) to 5 (strongly agree).

Pilot Testing

In order to determine the time required for administration of the scale and to pilot test it, using a convenient sample, the scale was applied to a group consisting of 14 freshman pre-service teachers from the physics education program and 12 freshman students from the science education program. The students were asked to mark the words which they did not know the meaning of and write down their suggestions or views about the items, if any existed. Upon completion of the scale, short conversations were carried out with each student and, it was concluded that the students could understand all of the items clearly and that the required administration time was 15 minutes.

Administration of the Scale

In order to assess reliability and validity, the final form of the scale composed of 50 items was administered to a total of 495 undergraduate students enrolled in a physics course. The scale was administered in the classrooms during the first 15 minutes of each class session under the supervision of the authors. The participants were asked to carefully read each item at an average speed and circle the response that best described their degree of agreement.

Validity and Reliability Analyses

To test the validity and reliability of the scale, IBM SPSS 21 and IBM AMOS 21statistics software packages were used. For reliability analysis, item-total correlations for each item were taken into account; for construct validity, exploratory factor analysis was carried out and Cronbach's Alpha reliability coefficients of the scale and subscales were calculated. Then, a 4-factor model suggested by the exploratory factor analysis was tested with a confirmatory factor analysis model using another set of data. The four components were names as, physics course/test anxiety, anxiety about lack of physics knowledge, mathematics anxiety, and physics laboratory anxiety.

Table 1. Descriptive statistics and item-total correlations for the factor analysis

	Mean	SD	Item-Total	N
Anx01	3.26	1.171	.558	495
Anx02	3.03	1.110	.569	495
Anx03	2.29	1.127	.531	495
Anx04	2.44	1.006	.324	495
Anx05	2.31	1.081	.595	495
Anx06	3.28	1.263	.614	495
Anx07	2.33	1.075	.452	495
Anx08	2.73	1.100	.518	495
Anx09	2.74	1.133	.622	495
Anx10	2.97	1.096	.590	495
Anx11	2.40	1.132	.609	495
Anx12	3.07	1.218	.681	495
Anx13	2.40	1.228	.404	495
Anx14	2.29	.974	.616	495
Anx15	3.02	1.290	.758	495
Anx16	2.82	1.366	.728	495
Anx17	3.12	1.209	.524	495
Anx18	2.38	1.086	.550	495
Anx19	2.07	1.029	.486	495
Anx20	3.01	1.138	.708	495
Anx21	2.29	1.083	.636	495
Anx22	2.11	.973	.618	495
Anx23	3.09	1.257	.629	495
Anx24	2.86	1.206	.672	495
Anx25	2.07	1.049	.506	495
Anx26	2.97	1.280	.552	495
Anx27	3.03	1.210	.749	495
Anx28	2.49	1.100	.644	495
Anx29	2.37	1.083	.600	495
Anx30	2.97	1.181	.570	495
Anx31	2.75	1.217	.585	495
Anx32	2.65	1.117	.459	495

RESULTS

The data were analyzed using IBM SPSS 21 and IBM AMOS 21 and the scale was validated via exploratory and confirmatory factor analyses. All statistical analyses were set with an alpha level of 0.05.

Exploratory Factor Analysis (EFA)

To investigate the factor structure of the PARS, an exploratory factor analysis with varimax rotation was carried out. The Bartlett's test of sphericity produced a significant result ($p< 0.001$) indicating the suitability of the factor model for the data. The Kaiser-Meyer-Olkin (KMO) Sampling Adequacy coefficient which displays the convenience of performing factor analysis for the scale (KMO>0.70) (Dalgety, Coll, & Jones, 2003) was calculated as 0.954, which can be regarded as good. All of the inter item–total correlations were found to be higher than 0.30. The data were then subjected to principle component analysis with varimax rotation. Eliminating factor cross loadings and factors whose loadings were less than 0.40 led to the exclusion of 18 items from the analyses. Using the factors whose eigenvalues were greater than 1and the scree plot test, four factors were formed including 32 items. Factor identification included several analyses steps such as observing Cronbach's Alpha values of each factor with and without including troubling items, examining scree plot in each case and rereading items for avoiding any misinterpretation while including an item into a specific factor. A 4-factor model was decided on as the best factor structure for the PARS. The final form of the scale has a maximum point of 160, and minimum point of 32. High point represents a high level of anxiety. Descriptive statistics and item–total correlations for the factor analysis are provided in Table 1.

The distribution of items in each factor and factor loadings at the end of the factor analysis are given in Table 2. As seen from Table 2, the factor loadings of the items constituting the PARS range between. 455 and .773.

The eigenvalues, percents of variance, and total percents of variance related to the four factors has been given in Table 3. The four factors accounted for 54.96 % of the total variance. In the four-factor solution, there were four items (13, 18, 20, 29), which loaded into two factors. When the meanings of these items were investigated, taking into account their factor loadings in the particular factors, they were included in one of the factors only. Some of these items were slightly revised to have the adequate meaning in the factor they belong. Actually, these items were correctly loaded into corresponding factors with a higher factor loading than the other factor.

Table 2. Factor structure and loadings of the 32 items in the PARS

Item No	F1	F2	F3	F4
Anx01	.773			
Anx15	.733			
Anx27	.733			
Anx02	.716			
Anx16	.715			
Anx10	.699			
Anx06	.692			
Anx12	.668			
Anx23	.630	.725		
Anx22		.622		
Anx19		.584		
Anx14		.581		
Anx21		.580		
Anx11		.552		
Anx25		.526		
Anx05		.468	.706	
Anx07			.691	
Anx26			.657	
Anx30			.588	
Anx24			.585	
Anx29			.486	
Anx20			.477	
Anx17			.455	
Anx13				
Anx09				.694
Anx32				.694
Anx31				.655
Anx04				.603
Anx18				.593
Anx28				.548
Anx08				.508
Anx03				

Table 3. Principle components and the corresponding eigenvalue and variance information of the PARS

Factors		Eigenvalue	Percent Variance	Total Variance
Physics course/test anxiety	Factor 1 (C/TA)	12.39	38.72	38.72
Anxiety about lack of physics knowledge	Factor 2 (LPKA)	2.39	7.47	46.18
Mathematics anxiety	Factor 3 (MA)	1.53	4.79	50.97
Physics laboratory anxiety	Factor 4 (PLA)	1.28	3.99	54.96

Factor Description

Items in the first factor are related to being anxious in a physics class or about studying for a physics exam. Therefore, this factor was named as physics course/test anxiety (C/TA). Items in factor two appear to represent anxiety about not being able to explain physics concepts to others or displaying physics content knowledge to others. This is perhaps due to a lack of basic understanding of the physics concepts. Thus, second factor was named as anxiety about lack of physics knowledge (LPKA). Factor three is about being anxious in a physics course due to a lack of mathematical knowledge required to succeed in the course, not being able to recall mathematical relationships of physical quantities, and studying a physics text full of mathematical expressions. Consequently, this factor was named as mathematics anxiety (MA). Finally, the fourth factor contains items reflecting anxiety in carrying out a physics experiment in a laboratory. In general, items such as being anxious about not being able to finish a physics experiment in time, not being able to communicate the results of a physics lab, anxiety about working with other students, setting up an experiment, and handling lab materials are included in this factor. As a result, it was called as physics laboratory anxiety (PLA).

Reliability of the Emerged Factors

Internal consistency reliability estimates of the four factors of the PARS were determined using Cronbach's Alpha reliability values for each factor and for the total instrument. Table 4 shows the names of the factors, number of items in the factors, Cronbach Alpha Reliability Coefficients, and a sample item for each factor. The physics course/test anxiety (C/TA) factor contains 9 items and its reliability value is 0.92. The second factor, anxiety about lack of physics knowledge (LPKA), consists of 8 items with an alpha value of 0.85. The mathematics anxiety (MA) factor includes 8 items producing an alpha value of 0.86. The fourth factor, physics laboratory anxiety (PLA) contains 7 items and its reliability value is 0.83. The reliability coefficient for the whole instrument, using the samples (n=495) in this analysis is 0.95. Table 4 indicates that reliability values ranged from 0.82 to 0.92 for the four factors of the PARS. The reliability of the physics course/test anxiety (C/TA) factor (0.92) is considered 'excellent' and reliabilities of 0.83, 0.85, and 0.86 are considered 'good' (George and Mallery, 2001; Tabachnick & Fidell, 2007).

Confirmatory Factor Analysis (CFA)

A confirmatory factor analysis (CFA) (Brown, 2006; Byrne, 2010) was carried out to cross check the results of the exploratory factor analysis, which is a four-factor solution for the PARS. Data were collected for a two-semester period from 864 pre-service teachers from the same faculty and departments as the sample used in EFA. Using the new set of data (n=864), the four-factor model for students' anxiety in physics courses was tested using AMOS 21 (Arbuckle, 2008). CFA assesses how well the proposed model matches the observed data. Several tests exist to determine overall model fit. The χ^2 statistics is the most common one reported. The result is usually reported as the ratio of χ^2 to degrees of freedom (χ^2/df). However, due to the sensitivity of the χ^2 statistics to sample size, it becomes difficult to retain the null hypothesis as the number of cases increases (Byrne, 2001). Therefore, when the sample size is large, the null hypothesis that the model is a good fit to the data can be easily rejected. Because of these drawbacks, many alternative fit statistics were developed (e.g., Bentler, 1990; Bentler & Bonett, 1980; Hu & Bentler, 1995, 1999; Kline, 1998; Ullman, 1996). A common way is to present four or five indices from different areas (Arbuckle & Wothke, 1999). The model in this study was evaluated using the following goodness-of-fit indices. The χ^2 to degrees of freedom (χ^2/df) ratio (CMINDF), the goodness of fit index (GFI), the comparative fit index (CFI), the Tucker–Lewis index (TLI) and the root mean square error of approximation (RMSEA). Traditionally, a non-significant χ^2 is a measure of good fit. However, χ^2 is often significant when the sample size is large and the input variables have a non-normal distribution (Hu & Bentler, 1999). A CMIN/DF value less than 3 is regarded as a good fit. The CFI compares the existing model fit with a null model, which specifies no relationship among the observed variables. The GFI is independent of sample size.

Table 4. Names of the factors, reliabilities, number of items, and sample items for the factors in the PARS

Factors	# of items	Cronbach's alpha	Sample Item
Physics course/test anxiety (C/TA)	9	0.92	I am usually very nervous when I am studying for a physics exam.
Anxiety about lack of physics knowledge (LPKA),	8	0.85	If my instructor asked me to explain a physical event from daily life, I would be worried.
Mathematics anxiety (MA)	8	0.86	When I open a physics book, seeing a page full of formulas without any explanation scares me.
Physics laboratory anxiety (PLA)	7	0.83	I am very comfortable with using lab materials.
Whole instrument	32	0.95	

The TLI measures the lack of fit of the model to a baseline model, usually the independence model, which assumes the observed variables to be uncorrelated. The CFI, GFI, and TLI values of 0 indicate no fit, whereas 1 indicates a perfect fit. A common criterion for these indices is that values >0.90 indicate a good fit (Bollen & Long 1993; Hu & Bentler, 1999). The RMSEA is relatively insensitive to sample size and corrects for the number of degrees of freedom (df) in the model. The RMSEA values less than 0.08 indicate an acceptable model fit and values less than 0.05 indicate a good model fit (Bentler & Bonett 1980, Hu & Bentler, 1999).

A CFA analysis is carried out with a sample of 864 students. The squares represent the observed variables and the ellipses show the latent variables (factors). There is also error terms associated with the observed variables indicated with the letter e. Maximum likelihood estimation method was employed to test the model. The AMOS provided the calculations of modification indices (MI), standardized residuals, covariance among error terms, standardized regression weights, and squared multiple correlations. Modification indices make suggestions about loosening certain model parameters in order to improve the overall model fit. The squared multiple correlations provide information on how much variance the common factors account for in the observed variables. All standardized regression weights were significant ($p<0.001$) and all critical ratios (C.R.) were larger than two. The standardized regression weights can be interpreted as the correlation between the observed variable and the corresponding common factor. For this four-factor model the regression weights were all significant. Correlations among the four factors ranged from 0.65 to 0.82 which indicate good values. The squared multiple correlations, R^2 statistics, ranged from 0.21 to 0.72. The R^2 values indicate that the respective factor explains a respectable portion of the variance (between 21% and 72%).

A close examination of the goodness-of-fit indices, standardized residuals and the modification indices indicate the model's misfit and hence suggest that the model could be improved. The initial results of the CFA were as follows: The χ^2 (df = 458, p = 0.000, n = 864) = 1678.73 for the model was statistically significant. CMIN/DF = 3.665, GFI = 0.887, CFI = 0.907, TLI = 0.899, and RMSEA = 0.056. The corresponding goodness-of-fit indices for the initial model and optimal values suggested for these indices are reported in Table 5.

The Model Fit

In regard to the MI, the AMOS output revealed several large covariances between error terms. Upon examining the modification indices suggested by the AMOS output, the standardized residual matrix revealed no significant violations. Standardized residuals should be less than 2 in absolute value. As indicated in the covariance matrix of the error terms, using covariances between error terms, the χ^2 value could be significantly reduced. For instance, the output revealed large covariances between Error 6 and Error 9 (MI = 159.02, EPC = 0.35). The MI also suggests adding a covariance between error terms and factors. However, this option violates the assumption that the common and the unique factors are uncorrelated. Therefore, covariances were added between the error terms only, as suggested by the MI. These modifications significantly improved the model. The corresponding path diagram for the improved model including significant standardized coefficients is presented in Figure 1. Standardized item loadings range from .60 to .87 for the C/TA factor, .49 to .69 for the LPKA factor, .44 to .78 for the MA factor, and .48 to .74 for the PLA factor. The overall model fit appears quite good with CMIN/DF < 3, RMSEA < 0.05, and CFI, GFI, and TLI > 0.90.

Table 5. Model fit statistics of the AMOS CFA solution for the four-factor model of the PARS

Index	Initial Model	Improved Model	Desired Value
χ^2 (df, p)	1678.73 (458, 0.000)*	1093.397 (445, 0.000)*	p > 0.05
CMIN/DF	3.665	2.457	CMIN/DF < 3
CFI	0.907	0.951	CFI > 0.90
GFI	0.887	0.926	GFI > 0.90
TLI	0.899	0.945	TLI > 0.90
RMSEA	0.056	0.041	RMSEA < 0.05

Table 6. Descriptive statistics, internal reliability, and factor intercorrelations for the PARS

Factor	*M*	*SD*	*α*	2	3	4
1. Physics course/test anxiety	28.42	8.63	.92	.72*	.79*	.66*
2. Anxiety about lack of physics knowledge	18.27	5.69	.82	-	.81*	.82*
3. Mathematics anxiety	22.56	6.50	.85		-	.73*
4. Physics laboratory anxiety	18.84	5.60	.83			-
Total Scale	88.08	22.45	.95			

The goodness-of-fit indices of the improved model are very close to the optimal values reported in the literature. Therefore, this model was deemed a reasonable model data fit. Although the χ^2 statistics is still significant, the other five indices provide evidence of a good fit. The χ^2 statistics was reported as problematic since its dependence on sample size (Byrne, 2001). The goodness-of-fit indices for the improved model along with the optimal values suggested for these indices are presented in Table 5.

In the final AMOS output, the regression weights of all the variables loading into their respective factors are between 0.44 and 0.87, with all critical ratios above 2 (which means that all the regressions are statistically significant at the 95% confidence level). The standardized regression weights (factor loadings) and the squared multiple correlations, (R^2), were displayed in the path diagram in Figure 1. Table 6 presents mean scores, standard deviations, and intercorrelations for each factor. Correlations among the four factors are considered moderately high and range from .66 (between the C/TA and PLA factor) to .82 (between the LPKA and the PLA factor).

Validity

The results of our analyses lend support to the use of the PARS with university students. A multivariate analysis of variance (MANOVA) was conducted to assess the effects of gender and cumulative grade point average (gpa) on physics anxiety as measured by the four subscales of the PARS. Wilks' Lambda was selected to evaluate overall significance. Results indicated a significant difference for both gender (Wilks' Lambda = .859, $F(4, 859) = 35.235$, $p < .001$, partial $\eta^2 = .141$) and grade point average (Wilks' Lambda = .920, $F(8, 1696) = 8.994$, $p < .001$, partial $\eta^2 = .041$). A follow-up analysis of variance (ANOVA) indicated that females have higher anxiety than males on all factors of the PARS. For the variable GPA, ANOVA analysis indicated a statistically significant group differences on all four factors of the PARS. A post hoc analysis using Bonferroni test indicated that students whose GPAs were above 3.00 had higher anxiety scores in C/TA ($M = 29.05$) and LPKA ($M = 18.70$) factors than students whose GPAs were between 2.00-2.99 ($M = 27.13$ for C/TA and $M = 17.40$ for LPKA). On MA factor, students whose GPAs were below 2.00 had higher anxiety scores ($M = 23.96$) than students whose GPAs were above 3.00 ($M = 22.52$) and between 2.00-2.99 ($M = 21.70$), who did not differ from each other. It is interesting to note that on the LA factor (F4), students whose GPAs were above 3.00 had higher anxiety scores ($M = 20.03$) than students whose GPAs were below 2.00 ($M = 17.89$) and between 2.00-2.99 ($M = 17.88$), who did not differ from each other.

Reliability

Using the sample of 864 students, Cronbach's alpha reliability analyses were conducted to test the internal consistency reliability of the four factors and the whole instrument. All of the item total correlations were found to be greater than 0.3. The alpha values of the four factors were as follows: The physics course/test anxiety (C/TA) (α=0.92), the anxiety about lack of physics knowledge (LPKA) (α=0.82), the mathematics anxiety (MA) (α=0.85), and the physics laboratory anxiety (PLA) (α=0.83). The alpha value of the whole instrument was 0.95. These values, which are considered 'good' and 'excellent', support the reliability of the PARS. It can be seen that, the alpha values are very similar to the alpha values of the model whose factor structure validity was tested in the EFA. Hence, it can be concluded that the PARS is a valid and reliable instrument to measure university students' physics anxiety. The PARS can be found in the appendix.

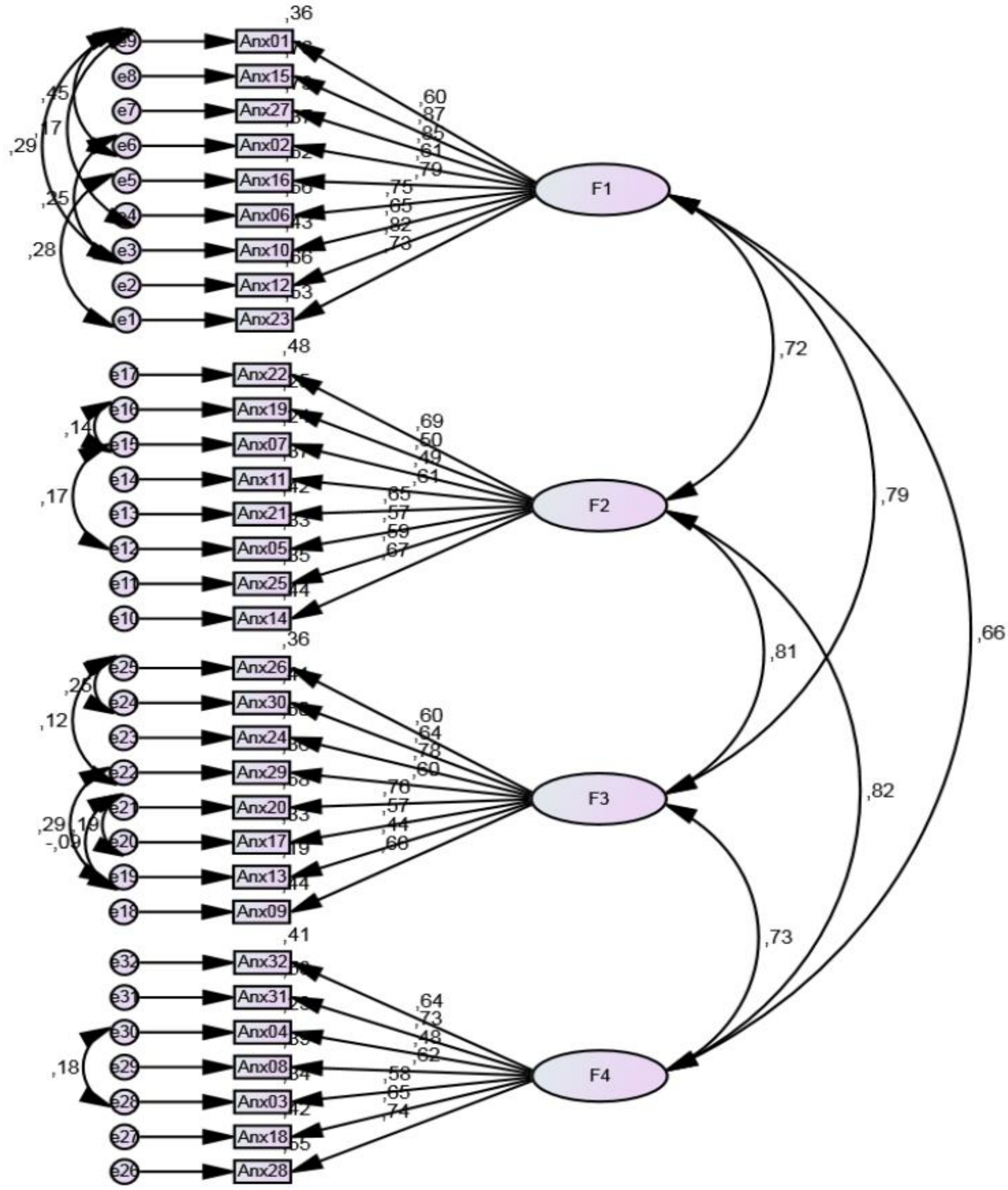

Figure 1. The path diagram of overall model fit for the four-factor solution of the PARS (where F1= physics course/test anxiety (C/TA); F2= anxiety about lack of physics knowledge (LPKA); F3= mathematics anxiety (MA); and F4= physics laboratory anxiety (PLA)).

DISCUSSION AND CONCLUSION

As a result of this study, a valid and reliable evaluation instrument, the physics anxiety rating scale (PARS) is developed by the researchers. Exploratory and confirmatory factor analyses were performed to examine the construct validity and it was concluded that the scale was composed of four subscales accounting for 54.96% of the total variance. Reliability studies showed that Cronbach's alpha reliability coefficients for the total and subscales were considerably high. Intercorrelations among the factors ranged from .66 to .82. To date, the PARS is unique in the relevant literature and is thought to bring a new and significant perspective to studies concerning physics education. Although there are a few science anxiety scales in the literature, none is specific to physics. It can be said that the PARS which has four subscales is practical and appropriate for evaluating anxiety which may arise from various teaching/learning situations in physics, and will contribute to the relevant literature.

The analyses of the data in this study revealed that there is a gender difference in anxiety and that females are more anxious than males. This finding agrees with the result of some previous research (El-Anzi, 2005; Mallow, 1994; Udo et al., 2001). The results of this study also suggested a relationship between GPA and physics anxiety. Similarly, sesearch indicated a small, significant negative correlation between GPA and test anxiety (Chapell et al., 2005). Test anxiety is one of the four factors in the PARS and the results showed that higher test anxiety and higher GPA is associated. This seemingly paradoxic pattern is also reported in Chapell et al. (2005). Test anxiety is defined as a multidimensional construct consists of many complex factors. Therefore, test anxiety should be regarded as one of the many variables effecting student grades, and many other factors need to be taken into consideration (Zeidner, 1998).

It is believed that physics anxiety, which appears to be ignored by most of the researchers, is one of the significant factors like self-efficacy, attitude and motivation which have been studied extensively in the field of physics. The results of this study suggest that the PARS will contribute to the understanding of physics anxiety phenomenon, provide physics teachers, curriculum developers, and physics education researchers with information about "anxiety" which is an important affective domain in physics education.

Since anxiety is a complex construct including many other contributing factors, relationships among the factors of physics anxiety and academic achievement need to be investigated thoroughly. Further research need to take into consideration that although anxiety has an effect on student performance, many other factors should also be accounted for, as Zeidner (1998) has indicated:

Any reasonable model of school achievement needs to consider, along with test anxiety, a wide array of cognitive, affective, motivational, somatic, and environmental factors (scholastic abilities, study habits, school attitudes, self-perceptions and self-efficacy, student health, classroom environment, opportunities for enrichment, etc.) (Zeidner, 1998, p. 235).

By considering the possibility that obligatory physics courses offered during the first and second years of the programs at the faculties of engineering, science and education may arouse different levels of anxiety in different individuals, the value of the PARS can be better understood in terms of identifying physics anxiety. In addition, for the purposes of examining the effects of particular learning experiences on physics anxiety and correlating anxiety with different cognitive, affective or psychomotor behaviors, or with different parameters (grade, gender, etc); the PARS can be used as an instrument in physics education.

IMPLICATIONS

By using the PARS, undergraduate students' anxiety levels related to physics courses can be revealed in detail. For instance, when high levels of anxiety related to exams and labs are detected, one can decide to employ a particular instructional strategy to overcome the student difficulties in these areas. In this manner, by decreasing the anxiety levels of students educators may enhance students' understanding and their chance of success in physics can be improved. Finally, further research on the validation and refinement of the physics anxiety rating scale is needed. Particularly, construct validation may be investigated across different populations and settings. In this regard, we hope other researchers use the PARS to measure physics anxiety and report their findings about validity and reliability of the scale.

ACKNOWLEDGEMENTS

We would like to thank Prof. Jeffry Mallow of the Loyola University Chicago for his constructive comments and suggestions on earlier version the manuscript.

REFERENCES

Alexander, L., & Martray, C. (1989). The development of an abbreviated version of the mathematics anxiety rating scale. *Measurement and Evaluation in Counseling and Development*, *22*(3), 143-150.

Alpert, R., & Haber, R. N. (1960). Anxiety in academic achievement situations. *Journal of Abnormal and Social Psychology*, *61*(2), 207-215. doi:10.1037/h0045464

Alvaro, R. (1978). *The effectiveness of a science-therapy program on science-anxious undergraduates* (Unpublished doctoral thesis). Loyola University, Chicago.

Arbuckle, J. L., & Wothke, W. (1999). *Amos 4.0 user's guide*. Chicago, IL: SPSS.

Arbuckle, J. L. (2008). *Amos 17.0 user's guide*. Chicago, IL: SPSS.

Astleitner, H. (2000). Designing emotionally sound instruction: The FEASP-approach. *Instructional Science, 28*(3), 169-198.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, *107*(2), 238-246. doi:10.1037/0033-2909.107.2.238

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in analysis of covariance structures. *Psychological Bulletin*, *88*(3), 588-606. doi:10.1037/0033-2909.88.3.588

Beyer, K. (1991, July). *Gender, science anxiety and learning style*. Paper presented at the meeting of the 6th GASAT Conference, Melbourne.

Bintaş, J. (2008). Motivational qualities of mathematical experiences for Turkish preservice kindergarten teachers. *International Journal of Environmental & Science Education, 3*(2), 46–52.

Bollen, K. A., & Long, J. S. (Eds.). (1993). *Testing structural equation models*. Newbury Park, CA: Sage.

Bowen, C. W. (1999). Development and score validation of a chemistry laboratory anxiety instrument (CLAI) for college chemistry students. *Educational and Psychological Measurement*, *59*(1), 171-185. doi:10.1177/0013164499591012

Brown, T. A. (2006). *Confirmatory factor analysis for applied research*. New York, NY: Guilford Press.

Brownlow, S., Jacobi, T., & Rogers, M. (2000). Science anxiety as a function of gender and experience. *Sex Roles, 42*(1-2), 119–131.

Bryant, F. B., Kastrup, H., Udo, M., Hislop, N., Shefner, R., & Mallow, J. V. (2013). Science anxiety, science attitudes, and constructivism: A binational study. *Journal of Science Education and Technology, 22*(4), 432-448.

Byrne, B. M. (2001). *Structural equation modeling with AMOS: Basic concepts*, *applications*, *and programming*. Hillsdale, NJ: Lawrence Erlbaum.

Byrne, B. M. (2010). *Structural equation modeling with AMOS: Basic concepts, applications, and programming* (2nd ed.). New York, NY: Taylor and Francis Group.Bursal, M. (2008). Changes in Turkish pre-service elementary teachers' personal teaching efficacy beliefs and science anxieties during a science method course. *Journal of Turkish Science Education*, *5*(1), 99-112.

Cassady, J., & Johnson, R. (2001). Cognitive test anxiety and academic performance. *Contemporary Educational Psychology*, *27*(2), 270-295. doi:10.1006/ceps.2001.1094

Chapell, M. S., Blanding, Z. B., Silverstein, M. E., Takahashi, M., Newman, B., Gubi, A., & McCann, N. (2005). Test anxiety and academic performance in undergraduate and graduate students. *Journal of Educational Psychology, 97*(2), 268-274. doi:10.1037/0022-0663.97.2.268

Chapin, T. J. (1989). The relationship of trait anxiety and academic performance to achievement anxiety: Student at risk. *Journal of College Student Development*, *30*(3), 229-236.

Chiarelott, L., & Czemiak, C. (1985). Science anxiety among elementary school students: An equity issue. *Journal of Educational Equity and Leadership*, *5*(4), 291-308.

Czerniak, C., & Chiarelott, L. (1984, April). *Science anxiety: An investigation of science achievement, sex and grade level factors*. Paper presented at the 68th Annual Meeting of the American Educational Research Association, New Orleans.

Dalgety, J., Coll, R. K., & Jones, A. (2003). Development of Chemistry Attitudes and Experiences Questionnaire (CAEQ). *Journal of Research in Science Teaching, 40*(7), 649–668. doi:10.1002/tea.10103Dilek, U., Şahin, M., Güler, B., & Eslek, S. (2013, February). *An investigation of university students' anxiety in physics courses*. Paper presented at the 2nd World Conference on New Trends in Science Education, Cracow, Poland.

Driscoll, R. (2007). *Westside test anxiety scale validation*. Retrieved from http://www.testanxietycontrol.com/research/sv.pdf

El-Anzi, F. O. (2005). Academic achievement and its relationship with anxiety, self-esteem, optimism, and pessimism in Kuwaiti students. *Social Behavior and Personality, 33*(1), 95-104. doi:dx.doi.org/10.2224/sbp.2005.33.1.95

Fennema, E., & Sherman, J. (1976). Fennema-Sherman mathematics attitudes scales. *JSAS Catalog of Selected Documents in Psychology*, *6*(1), 31.

Fuller, R., Agruso, S., Mallow, J., Nichols, D., Sapp, R., Strassenburg, A., & Allen, G. (1985). *Developing Student Confidence in Physics*. College Park, MD: American Association of Physics Teachers.

George, D., & Mallery, P. (2001). *SPSS for windows step by step: A simple guide and reference.* 10.0 Update (3rd ed.). Boston, MA: Allyn and Bacon.

Güzeller, C. O., & Doğru, M. (2012). Development of science anxiety scale for primary school students. *Social Indicators Research, 109*(2), 189-202.

Gungor, A., Eryılmaz, A., & Fakıoglu, T. (2007). The relationship of freshmen's physics achievement and their related affective characteristics. *Journal of Research in Science Teaching, 44*(8), 1036–1056. doi: 10.1002/tea.20200

Hembree, R. (1988). Correlates, causes, effects, and treatment of test anxiety. *Review of Educational Research, 58*(1), 47-77. doi: 10.3102/00346543058001047

Hermes, J. (1985). *The comparative effectiveness of a science anxiety group and a stress management program in the treatment of science-anxious college students.* (Unpublished doctoral thesis). Loyola University, Chicago.

Hopko, D. R., Mahadevan, R., Bare, R. L., & Hunt, M. K. (2003). The Abbreviated Math Anxiety Scale (AMAS) construction, validity, and reliability. *Assessment*, *10*(2), 178-182. doi:10.1177/1073191103010002008

Hu, L. T., & Bentler, P. M. (1995). Evaluating model fit. In R. H. Hoyle (Ed.), *Structural equation modeling: Concepts, issues, and applications.* (pp. 76-99). Thousand Oaks, CA: Sage.

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria to fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1-55.

Jerusalem, M., & Pekrun, R. (eds.). (1999). *Emotion, motivation und leistung.* Gottingen: Hogrefe.

Kastrup, H., & Mallow, J. V. (2007). Science anxiety in the Danish gymnasium. Danish Ministry of Education report

Kline, R. B. (1998). *Principles and practice of structural equation modeling*. New York, NY: Guilford.

Labudde, P., Herzog, W., Neuenschwander, M. P., Violi, E., & Gerber, C. (2000). Girls and physics: teaching and learning strategies tested by classroom interventions in grade 11. *International Journal of Science Education, 22*(2), 143-157, DOI:10.1080/095006900289921

Laukenmann, M., Bleicher, M., Fuß, S., Gläser-Zikuda, M., Mayring, P., & Rhöneck, C. (2003). An investigation on the influence of emotions on learning in physics. *International Journal of Science Education, 25*(4), 489-507.

Mallow, J. V. (1978). A science anxiety program. *American Journal of Physics, 46*, 862. doi:10.1119/1.11409

Mallow, J. V. (1981). *Science anxiety: Fear of science and how to overcome it*. New York: Van Nostrand Reinhold Company.

Mallow, J. V. (1994). Gender-related science anxiety: A first binational study. *Journal of Science Education and Technology, 3*(4), 227–238. doi:10.1007/BF01575898

Mallow, J. V. (1995). Students' confidence and teachers' styles: A binational comparison. *American Journal of Physics, 63*, 1007-1011.

Mallow, J. V. (1998). Student attitudes and enrolments in physics, withemphasis on gender, nationality, and science anxiety. In J. H. Jensen, M. Niss, & T. Wedege (eds), *Justification and enrollment problems in education involving mathematics or physics* (pp 237–258). Roskilde, DK: Roskilde University Press.

Mallow, J. V. (2006). Science anxiety: Research and action. In J. J. Mintzes, & W. H. Leonard (Eds.), *Handbook of college science teaching.* (pp. 3-14). Virginia: National Science Teachers Association.

Mallow, J. V., & Greenburg, S. L. (1983). Science anxiety and science learning. *The Physics Teacher, 21*(2), 95-99. doi:10.1119/1.2341214

Mallow, J. V., Kastrup, H., Bryant, F. B., Hislop, N., Shefner, R., & Udo, M. (2010). Science anxiety, science attitudes, and gender: Interviews from a binational study. *Journal of Science Education and Technology, 19*(4), 356-369.

Möller, J. (Ed). (1996). *Emotionen, Kognitionen und Schulleistung.* Beltz, Psychologie-Verlag-Union.

Murphy, P., & Whitelegg, E. (2006). Girls and physics: Continuing barriers to 'belonging.' *The Curriculum Journal, 17*(3), 281-305.

Norton, P., Hope, D. A., & Weeks, J. W. (2004). The Physical Activity and Sport Anxiety Scale (PASAS): Scale Development and Psychometric Analysis. *Anxiety, Stress, and Coping*, *17* (4), 363-382. doi:10.1080/10615800512331328786

Ogunkola, B. J. (2008). Computer attitude, ownership and use as predictors of computer literacy of science teachers in Nigeria. *International Journal of Environmental & Science Education, 3*(2), 53–57.

Phillips, D. (1984). The illusion of incompetence among academically competent children. *Child Development, 55*(6), 2000-2016.

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research*, *63*, 167–199. doi:10.3102/00346543063002167

Randler, C., Hummel, E., Gläser-Zikuda, M., Vollmer, C., Bogner, F. X., & Mayring, P. (2011). Reliability and validation of a short scale to measure situational emotions in science education. *International Journal of Environmental & Science Education, 6*(4), 359-370.

Reid, N., & Skryabina, E. A. (2003). Gender and physics. *International Journal of Science Education, 25*(4), 509-536. DOI: 10.1080/0950069022000017270

Richardson, F. C., & Suinn, R. M. (1972). The mathematics anxiety rating scale: Psychometric data. *Journal of Counseling Psychology*, *19*, 551-554. doi:10.1037/h0033456

Sapir, S., & Aronson, A. E. (1990). The relationship between psychopathology and speech and language disorder in neurological patients. *Journal of Speech Hearing Disorders, 55*, 503-509.

Schwedes, H. (1973.) Die rolle der affektivitat im physikunterricht. *Westermanns padagogische Beitrage, 11*, 606–609.

Scovel, T. (1991). The effect of affect on foreign language learning: A review of anxiety research. *Language Learning, 28*, 129–142. doi:10.1111/j.1467-1770.1978.tb00309.x

Sharma, M. D., Stewart, C., Wilson, R., & Gökalp, M. S. (2013). Can a syllabus change impact on students' perceptions of science? Fragmented and cohesive conceptions of physics. *Eurasia Journal of Mathematics, Science & Technology Education*, *9*(1), 33-44.

Spielberger, C. D. (1980). *Preliminary professional manual for the Test Anxiety Inventory (TAI).* Palo Alto, CA: Consulting Psychologists Press.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Şahin, M. (2014). The relationship between pre-service teachers' physics anxiety and demographic variables. *Journal of Baltic Science Education, 13*(2), 201-215.

Şahin, M., Çalışkan, S., & Dilek, U. (2012, April). *Development and validation of an instrument to measure physics anxiety*. Paper presented at the 3rd International Conference on New Trends in Education and Their Implications, Antalya, Turkey.

Tabachnick, B., & Fidell, L. (2007). *Using multivariate statistics*. Boston, MA: Allyn & Bacon.

Udo, M. K., Ramsey, G. P., & Mallow, J. V. (2004). Science anxiety and gender in studentstaking general education science courses. *Journal of Science Education and Technology*, *13*(4), 436-446.

Udo, M. K., Ramsey, G. P., Reynolds-Alpert, S., & Mallow, J.V. (2001). Does physics teaching affect gender-based science anxiety? *Journal of Science Education and Technology*, *10*(3), 237–247. doi:10.1023/A:1016686532654

Ullman, J. B. (1996). Structural equation modeling. In B. G. Tabachnick & L. S. Fidell (Eds.), *Using multivariate statistics.* (3rd ed., pp. 748-753). New York, NY: HarperCollins.

Wang, Y. S. (2007). Development and validation of a mobile computer anxiety scale*. British Journal of Educational Technology, 38*(6), 990-1009. doi:10.1111/j.1467-8535.2006.00687.x

Wigfield, A., & Meece, J. L. (1988). Math anxiety in elementary and secondary school students. *Journal of Educational Psychology*, *80*(2), 210-216. doi:10.1037/0022-0663.80.2.210

Zeidner, M. (1998). *Test anxiety: The state of the art.* New York, NY: Plenum.

◈◇◈