JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

DEVELOPMENT AND EVALUATION OF AN INSTRUMENT MEASURING ANXIETY TOWARD PHYSICS LABORATORY CLASSES AMONG UNIVERSITY STUDENTS

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Abstract. *The learning in the physics laboratory is related to several non-cognitive variables such as anxiety which has a significant role in teaching and learning process. Therefore, university students may have different thoughts and anxiety levels towards physics laboratory class. The aim of this research was to develop a measurement tool assessing the anxiety levels of university students in a physics laboratory class. In this research the Physics Laboratory Anxiety Scale (P-LAS) consisting of 18 items was developed, and its validity and reliability were analysed. The sample consisted of 557 university students (295 female and 262 male) who take physics and/or physics laboratory classes at three different Faculties of Education. Validity of the scale was first assessed by expert review. Exploratory factor analysis was performed to assess structural validity, and revealed a one-dimensional structure. The loading values of all 18 items varied between 0.58 and 0.80, and explained 52% of the total variance. Cronbach's alpha coefficient of internal consistency was calculated as 0.94 and the split-half test correlation was 0.76. These results showed that P-LAS can be used as a valid and reliable instrument in physics education.*

Keywords: *physics education, physics laboratory anxiety, scale validity and reliability, university students.*

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Introduction

Introductory physics is a required course for many science fields such as engineering, chemistry, and mathematics. Also, introductory physics is taught in many academic programs such as chemistry, biology, medicine, dentistry, pharmacology, environmental sciences, engineering, and architecture as a compulsory course at high school and university level. Physics education in Turkey starts in the fourth grade as science courses and it continues all through secondary and university education.

Students traditionally have difficulty in physics course (Byun, Ha, & Lee, 2008; Raw, 1999). As a result, many students change their major after failing physics several times (Tuminaro & Redish, 2004). Introductory physics requires a laboratory to accompany the lecture sequence. There are a variety of reforms (Hake, 1998; Sokoloff, Laws, & Thornton, 1995) designed for introductory physics laboratories that show promise for improving student learning.

Laboratory works have always been important components for the reinforcement and understanding of physics concepts in high schools and universities. Millar (2004) emphasizes the important role of practical work in helping students to make links between the domain of objects and observable properties and events, and domain of ideas. Therefore, laboratory application should be considered seriously to make learning in physics lessons reach higher cognitive levels than just knowledge and comprehension. Laboratory activities have long had a distinctive and central role in the science curriculum and thus science educators have suggested that many benefits accrue from engaging students in science laboratory activities (Hofstein & Lunetta, 1982, 2004; Lunetta, 1998; Tobin, 1990). More specifically, it has been suggested that inquiry-centred laboratories have the potential to enhance students' meaningful learning, conceptual understanding, and their understanding of the nature of science (Taitelbaum, Mamlok-Naaman, Carmeli, & Hofstein, 2008).

Laboratory experiences that use hands-on inquiry have been considered as one of the most effective methods for learning science and developing the higher-order thinking skills necessary to "do" science (Escalada & Zollman, 1997). According to Hershey (1990), laboratory experiences provide students with the important experience of meeting "nature as it is, rather than in idealized form" and (Hoffer, Radke, & Lord, 1992; Shymansky, Kyle, & Alport, 1983) the opportunity to develop skills in scientific investigation and inquiry. Moreover, the laboratory provides support for high-order learning skills that include observing, planning an experiment, asking relevant questions, hypothesizing, and analyzing experimental results (Bybee 2000; Hofstein, Shore, & Kipnis, 2004).

The learning in the physics laboratory is related to several non-cognitive variables such as anxiety which has a significant role in teaching and learning process. Science anxiety was firstly introduced by Mallow (1978) as involving feelings of tension and anxiety that interfere with the manipulation of scientific equipment in a wide variety of ordinary life and academic situations. Science anxiety can also be described as a state of discomfort which occurs in response to situations involving scientific tasks which are perceived as threatening to self-esteem. Such feelings have been shown to lead to panic, tension, helplessness, fear, distress, shame, inability to cope, sweaty palms, nervous stomach, difficulty in breathing, and loss of ability to concentrate (Seligman, Walker, & Rossenhan, 2001).

The causes of science anxiety are many, including past bad experiences in science classes, exposure to anxious science teachers who are teaching science in secondary schools, lack of positive role models, gender and racial stereotyping, and the stereotyping of scientists in the popular media. Though some degree of anxiety may be helpful in the learning process, a high level of anxiety impedes optimum performance on science learning (Udo, Ramsey, & Mallow, 2004). Previous studies have demonstrated that anxiety causes students generally to withdraw from participation in teaching and learning process. It has been suggested that solution to an anxiety problem and its resulting lack of participation may be found in teaching methodologies that move away from more traditional, teacher-centered classrooms and concentrate more on student-centered, cooperative learning techniques (Gregersen, 1999).

Students may have different thoughts, attitudes, and anxiety levels towards physics laboratory. Ensuring that students develop positive attitudes towards physics laboratory classes and reducing their levels of anxiety will enhance students' abilities to learn physics concepts. Thus, when tools are developed for measuring the dimensions of the factors affecting the learning in physics laboratory, teaching can reach the intended destination. When we look at the literature (Berber, 2013; Bowen, 1999; Kurbanoğlu & Yücel, 2015; Kurbanoğlu, 2014; Mallow, 1994; Sahin, Caliskan, & Dilek, 2015), there are a few scales which measure students' levels of anxiety towards science classes. For this reason, this research was conducted to develop and assess the validity and reliability of a scale to be used for measuring university students' anxiety toward physics laboratory class.

Methodology of Research

General Background

This research is a scale development study. Survey design was used to collect data for this research. Participants were asked to complete the scale, consisting of a series of questions taken from the Physics Laboratory Anxiety Scale (P-LAS). All of the participants were informed about the purpose of the research before completing the scale. The scale was administered in a group format in each physics laboratory classes during the first semester of 2012-2013 academic years.

Sample

A convenience sample was recruited from science teacher candidates and a sufficient supply of surveys was distributed to three universities. Research sample consisted of 582 first grade students in science teacher training program. They took physics and/or physics laboratory classes at three different Faculties of Education (İbrahim Çeçen University, Sakarya University, and Cumhuriyet University) in Turkey at the first semester of 2012-13 academic years. Five hundred eighty-two valid surveys returned to researcher. The data were examined through control items and 25 samples were eliminated since these samples were thought to be involuntary responses. The remaining 557 (295 female and 262 male) samples were used as data for this study. Their ages ranged from 18 to 20 years, with a mean age of 19 years.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Preparation of Scale Items

Since the scale was intended to determine the anxiety of individuals about physics laboratory classes, researcher has reviewed the literature for similar scales and also brainstormed about situations which cause anxiety in students during physics laboratory classes. Items expressing these situations were noted down. A 23-item preliminary question pool was developed based on the content of physics laboratory classes. Items were designed to comprehensively cover the content of physics laboratory classes (Mechanics, Heat and Temperature, Electricity, Optics, and Electronics). Next, questions were reviewed by three content experts who work in the Faculty of Education at Sakarya University for readability, representation of content and how well they are likely to measure student anxiety for physics laboratory classes. Five items were excluded for their inability to scale or irrelevance, leaving an 18-item draft P-LAS. Respondents were asked to respond to each item using a 5-point Likert scale regarding how frequently each item makes me anxious: Never, sometimes, often, usually or always (Kurbanoğlu & Akın, 2012).

Procedure

Physics laboratory classes (ranging in size from 20 to 25 students) were selected randomly by the on-site data collector at the faculties of education of the three different universities. Before administration of the instrument, all participants were informed about the purposes of the study. Administration took almost 15 to 20 minutes. Analysis of the data was made in two ways: (a) calculating item total correlation estimates for item analysis to identify any faulty items, obtaining internal consistency reliability estimates of the scale scores and (b) testing the construct validity by exploratory factor analysis.

Validity and Reliability Assessment

Validity is one of the most important criteria for the development and assessment of an instrument. Validity refers to whether an item measures or defines a construct correctly. This study assessed structural validity of the P-LAS. Structural validity refers to whether the items are independent and evenly distributed, covering the intended range of the construct. This was assessed with an exploratory factor analysis, a statistical technique that measures the variance and accounts for it with the fewest number of structural factors (Büyüköztürk, 2004). Cronbach`s alpha coefficient of internal consistency was used to assess the significance of the difference in item means between the upper and lower 27th percentiles. Reliability of the instrument was also assessed with the item-total correlation by split-half reliability and t-tests. SPSS 13.0 software was used for statistical analyses.

Results of Research

Item Analysis and Reliability

The analyze result of the corrected item-total correlations of the 18 items ranged from 0.56 to 0.76. Estimated Cronbach's alpha reliability was 0.94. The split-half reliability coefficient was calculated as 0.76. Table 1 shows means, standard deviations, and the item total correlations of the 18 items.

Table 1. Means, standard deviations, and *item*-total correlations of the draft Physics Laboratory Anxiety Scale (P-LAS).

Items	$\overline{X}$	SD	*rjx*	t	Items	$\overline{X}$	SD	*rjx*	t
Q1	1,99	1,13	0.56	-10,81	Q10	1,80	0,99	0.75	-15,53
Q2	1,94	0,97	0.67	-12,16	Q11	1,92	1,01	0.75	-14,83
Q3	1,71	0,94	0.68	-10,68	Q12	1,91	1,00	0.76	-18,48
Q4	1,75	0,97	0.70	-11,41	Q13	1,91	1,00	0.74	-18,20
Q5	1,75	1,03	0.68	-13,85	Q14	1,86	0,95	0.70	-12,86

Items	$\overline{X}$	SD	*rjx*	t	Items	$\overline{X}$	SD	*rjx*	t
Q6	2,04	1,12	0.59	-15,24	Q15	1,94	0,99	0.67	-13,39
Q7	2,10	1,01	0.66	-13,55	Q16	2,07	1,01	0.66	-14,19
Q8	2,10	1,14	0.58	-14,50	Q17	2,11	1,07	0.66	-15,77
Q9	1,83	0,96	0.71	-15,04	Q18	2,05	1,04	0.68	-13,37

Construct Validity

For construct validity, exploratory factor analysis was conducted to validate the underlying structure of the model. Prior to the conduct of exploratory factor analysis, to assess the factorability of the scale, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were used (Tabachnick & Fidell, 2007). In this research, the KMO value (KMO=0.93) indicated that the degree of common variance among the variables was marvellous. The Bartlett's test of sphericity indicated a Chi square 711.541 with an observed significance level of $p<.001$. The KMO values are above the cut off of .60 and Bartlett's test of sphericity value is significant as suggested by Pallant (2001) and Tabachnick and Fidell (2007). Based on the results, it was inferred that the relationship between the variables was strong and appropriate for factor analysis. The loading values of all 18 items varied between 0.58 and 0.80 and one factor explained 52% of variance. All of the items had factor structure coefficients exceeding an absolute value of 0.30. Factor loadings and total percentages of explained variance are given in Table 2.

Table 2. Items and principal components un-rotated factor/structure component matrix solution of the Physics Laboratory Anxiety Scale (P-LAS).

Items		Factor loading
Q1	Entering the physics laboratory	0.588
Q2	Determining the elements in an electric circuit	0.708
Q3	Setting up an electric series connection	0.719
Q4	Setting up an electric parallel connection	0.740
Q5	Recording data obtained from the physics experiment	0.721
Q6	Drawing a table and graph from the obtained data	0.626
Q7	Explaining the laws of physics by conducting experiments	0.689
Q8	Preparing the physics laboratory	0.610
Q9	Determining the image obtained from the planar mirrors	0.760
Q10	Measuring the angle of incidence and angle of reflection obtained from the planar mirrors	0.797
Q11	Determining the focal point of a curve mirror	0.799
Q12	Determining the focal point of lens	0.809
Q13	Obtaining images from lens	0.790
Q14	Determining the difference between heat and temperature	0.747
Q15	Determining the measureable properties of matter	0.721
Q16	To make precise measurements for measurable properties of matter	0.696
Q17	Making interpretation of the data obtained from physical experiments	0.696
Q18	Setting up a test ring in physics laboratory	0.713

Explained Total Variance 52%

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Discussion

In researches dealing with the psychology of learning, one can identify various theoretical approaches pertaining to the role of anxiety in learning. One aspect that is emphasized is the strong relationship between anxiety, attitude and motivation. Another emotional dimension of the affective factors that has received increasing attention in recent decades is anxiety. The negative anxiety has considerable significance in learning and achievement situations. The psychological studies illustrate the significance of anxiety in both learning and performance situations (Berdonosov et al., 1999; Black & Deci, 2000; Eddy, 2000; Möller, 1996). Jerusalem and Pekrun (1999) showed that negative anxiety was frequently related to learning and performance situations. Czerniak and Chiarelott (1984) indicated science anxiety as a factor influencing science achievement in primary school students and suggested that high science anxiety may cause low science achievement. Furthermore, there is a general agreement in the empirical literature that test anxiety is associated with lower academic performance (Chapell et al., 2005; Kurbanoğlu & Nefes, 2015, 2016; Mallow et al., 2010; Zeidner, 1998).

It is believed that physics laboratory anxiety, which appears to be ignored by most of the researchers, is one of the significant factors like attitude and motivation which have been studied extensively in the physics education. Physics laboratory courses have been generally acknowledged as an important component of the undergraduate curriculum, particularly with respect to developing students' interest in, and understanding of experimental physics. Also, physics laboratory is one of the most important courses for undergraduate students majoring in applied chemistry, polymer chemistry, material chemistry, chemical engineering, life science, and environmental engineering and science. Designing research based instructional strategies according to the results of physics laboratory anxiety 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. Therefore, in present research a measurement tool was developed in order to measure the anxiety level of university students' towards physics laboratory classes.

There are a few anxiety scale development studies in international science literature and they generally have been focused on the determination of physics (Berber, 2013), science anxiety questionnaire (Mallow, 1994), and chemistry (Bowen, 1999; Kurbanoğlu & Yücel, 2015), and biology laboratory classes (Kurbanoğlu, 2014). Furthermore, Berber (2013) developed and validated physics laboratory anxiety scale and it was a scale with four sub-dimensions and 16 items. The internal consistency reliability coefficient of the scale, using Cronbach alpha, was 0.87.

In this research, the P-LAS was developed through the use of four-step model. Following an extensive review of literature, the authors constructed initial draft of the instrument and then, this initial draft was reviewed by the experts (on science education). Based on the principle of measuring physics laboratory anxiety by a global scale, we proposed an eighteen-item global measure of physics laboratory anxiety and the proposed P-LAS was administered to 557 university students in three different universities to provide validity and further reliability evidences.

Construct related content validity was confirmed by the mostly successful item and scale validity. Of the 23 items, item scale criteria were unsatisfactory in only 5 items. In order to determine the scale factorial structure, an investigation was carried out and it was observed that the scale items collectively comprised one factor. Principal components analysis was performed such that the eigenvalue of the 18 items would be 1 in the factor analysis and a varimax rotation with the factor analysis revealed a one-dimensional structure that explained 52% of total variance. This rate is above the minimum of 30% typically considered sufficient for scale development (Büyüköztürk, 2004). The results of the factor analyses show that the loading values of all 18 items ranged from 0.58 and 0.80. In addition, the results of item analysis indicated that the item-total correlations of the 18 items ranged from 0.56 to 0.76. Estimated Cronbach's alpha reliability was 0.94. The split-half reliability coefficient was calculated as 0.76. Results of our analysis on the psychometric properties of the P-LAS demonstrated an overall satisfactory evidence of acceptability, reliability, and validity of the included questions.

Conclusions

This research aimed to develop a measurement tool assessing the anxiety levels of university students in a physics laboratory class. The measurement tool study is being rigorously developed as the first validated tool for measuring university students' physics laboratory anxiety in physics educational programs. As a result, the findings obtained from the analyses show that P-LAS has high reliability criteria. Moreover, this measurement tool is a potentially valid and reliable tool for the use in future studies to assess students' anxiety level for physics laboratory class. Also, future studies are needed to assess the responsiveness and predictive validity of this instrument.

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Received: *April 24, 2017* Accepted: *June 29, 2017*

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