Developing a physics laboratory anxiety scale

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Contents

Abstract

Although the level of cognitive behaviours is continually controlled in school environments, affective behaviours cannot be both acquired and measured in a planned manner way. In fact, the functionality of educational activities, which are orientated towards cognitive targets, can be enhanced by placing more emphasis on the affective dimension. Physics especially is a subject which often attracts negative attitudes. Students possess negative attitudes towards the physics laboratory as much as towards physics lesson and physics exams. It is evident that this negative attitude is largely expressed as anxiety. Thus, this research has aimed at developing a scale that can be applied to determine anxieties related to the physics laboratory lessons of students from secondary schools and higher education institutions. Primarily, an item pool associated with laboratory anxiety was formed in the scale development process. This item pool was tested on 245 undergraduates in a physics laboratory lesson at Necmettin Erbakan University and exploratory factor analyses, confirmatory factor analyses and reliability analyses were performed. A scale with four sub-dimensions and 16 items subsequently emerged. Six items of the scale measure anxiety about finishing experiments; four items measure anxiety about doing the experiment correctly; three items measure constant anxiety about the physics laboratory; and three items measure anxiety related to the use of materials in the laboratory.

Keywords: physics laboratory, anxiety, physics anxiety, science anxiety, affective learning

Introduction

Since the mid-nineteenth century, the importance accorded to laboratory methods in the physical sciences has been increasing, and it is now accepted that the laboratory has become an inseparable part of science education (Çepni, Akdeniz & Ayas, 1995; Kılıç, Emsen & Soran, 2011; Wheatley, 1975). Thus, many studies emphasising the contribution of laboratory applications to science education have been conducted (Bryant & Marek, 1987; Freedman, 1997; Hofstein & Lunetta, 1982; Hofstein & Mamlok-Naaman, 2007; Kang & Wallace, 2005; Osborne & Wittrock, 1983; Serin, 2001; Shymansky & Kyle, 1988; Tamir, 1977; Tsai, 1999; White, 1996). Many studies question the necessity of laboratory use in teaching physics, which is one of the physical sciences (Arons, 1993; Hake, 1992; Krieger & Stith, 1990; Roth, 1994; Thornton & Sokoloff 1998). The likelihood of encountering the principles of physics in everyday life has made it necessary to provide the expected behavioural changes of students in physics teaching through the applications in the laboratory environment (Akdeniz & Karamustafaoğlu, 2003). Student laboratories have been an essential element of the physics curriculum for more than a century. Unfortunately, there is still no consensus on educational goals or the best method to assess those goals in physics laboratories (Trumper, 2003).

The laboratory method, which is recognised as necessary, is not applied appropriately in Turkey at present and there are various obstacles to achieving expected targets in this context. It has been determined that these difficulties are generally caused by factors relating to teaching such as the curriculum, environment, teachers and students (Yolaş Kolçak, 2010). Negative situations which decrease the performance of physics laboratories have been identified as inadequate lesson length, inefficient equipment, inadequate in-service training of teachers, the anxiety of students about preparation for university entrance exams, crowded classroom environments and an intensive curriculum (Bozdoğan and Yalçın 2004, 2004; Çepni, Akdeniz & Ayas, 1995; Çepni, Kaya & Küçük, 2005; Şahin, 2001). The variables associated with students have effects on the performance of laboratory applications as well as the laboratory environment (Uluçınar, Cansaran and Karaca 2004). Affective dimensions of learning such as anxiety, attitudes and self-efficacy are perceived as important predictors of student performance in laboratory situations (Bowen, 1999).

Whereas the level of cognitive behaviours is continually controlled in school environments, affective behaviours cannot be both acquired and measured in a planned manner. In fact, affective input features have the capacity to explain the changes in learning products at the level of 25%. Therefore, achievement can be raised by making the affective input features positive (Senemoğlu 2005). Being equipped only with cognitive features will cause individuals to labour under the burden of knowledge. Thus, they need to be equipped with both cognitive and affective aspects and there must be more effort made concerning the affective dimension of education, which determines pupils' futures. It is fair to say that the functionality of education activities, which are cognitive and target-orientated, can be enhanced by placing more emphasis on the affective dimension (Gömleksiz & Kan, 2012).

Science anxiety attracts attention as one of the factors influencing success because high anxiety results in poor performance (Czemiak & Chiarelott, 1984). Science anxiety, according to Mallow (2006), can be described as feeling anxiety and stress in terms of understanding and solving science problems in daily and academic life.

The reasons for science anxiety vary; family, school and/or environment are possible causes. It is expected that students whose parents are good at science will be more successful than other students. Female students are expected to be less successful than male students and this situation causes anxiety which puts pressure on the student (Mallow & Greenburg, 1983). Interviews conducted with students with negative attitudes towards science show that they have received negative messages related to science from their educational background. Many science teachers believe that science skills are possessed by only a small number of select people. Another reason for science anxiety is the absence of role models. According to the data provided by the American Institute of Physics, the number of female undergraduates in physics departments was 6% in 1994 and only 10% in 2002. The percentage of female physics teachers in 2000-01 was only 29% (Mallow, 2006).

When science anxiety is mentioned, science exams spring to mind (Mallow, 2010). Actually, anxiety related to science does not only consist of test anxiety: students have also shown anxiety about laboratory lessons, which are a prerequisite for science education. Some studies have measured anxiety, especially in chemistry laboratories (Anılan, Görgülü and Balbağ 2009; Azizioğlu and Uzuntiryaki 2006; Bowen 1999; Clement and Khan, 1999; Jegede 2007; Kurbanoğlu and Akın 2010; McCarthy and Widanski 2009) but few have examined anxiety related to the physics laboratory, although many have evaluated attitudes towards physics lessons (Adams et al., 2006; Gardner, 1976; Kurnaz and Yiğit 2010; O'Brien & Porter, 1994; Skryabina, 2000; Tekbıyık & Akdeniz, 2010). It has been confirmed repeatedly that students find physics lessons difficult, boring and full of unnecessary information. What is the situation with regard to the laboratory environment? In which situations do students feel anxious when they are in the physics laboratory? This study aims at developing a scale which can be used for measuring the anxiety of students towards the physics laboratory in order to find answers to these questions and meet the deficiency in this context.

Method

The purpose of the research

This research was conducted to develop a scale which can be applied to determine the anxieties related to physics laboratory lessons of students from secondary schools and higher education institutions.

Study group

The study group consisted of 245 undergraduates taking physics laboratory lessons during the 2011-12 academic year at Necmettin Erbakan University, Ahmet Keleşoğlu Faculty of Education, in Turkey.

They were undergraduates in physics, chemistry and science and their ages ranged from 17 to 20. 67 (27.3%) undergraduates in the sample were male and 178 (72.7%) were female.

Development Process

1. Forming the design of the scale: in order to determine the items required for a physics laboratory anxiety scale, 20 undergraduates taking physics laboratory lessons were asked to write down any anxieties they had about the physics lesson. These were then discussed. The item pool, which was based on these answers, was examined by seven physics lecturers and the 42-item scale design was formed.

2. Content validity: content validity is the indicator which shows whether items are qualitatively and quantitatively adequate for measuring the behaviour that is to be measured (Büyüköztürk, 2007). Expert opinions were employed in order to determine the content validity. Besides the seven physics academics whose opinions were used during the scale design, an assessment and evaluation expert and a Turkish teaching academic were consulted. After implementation of the recommended changes, a 42-item scale design was completed.

3. Application: the 42-item scale, which is of five-point Likert type, was tested on 245 undergraduates in the sample group in the spring semester of the 2011-12 academic year.

4. Construct validity analysis: construct validity shows the degree to which a test correctly measures an abstract concept in terms of the behaviour that is to be measured (Büyüköztürk, 2007). Exploratory and confirmatory factor analyses were performed in order to examine the construct validity of the scale.

5. Reliability analysis: to test the reliability of the scale, the Cronbach's alpha reliability coefficient was calculated. The Cronbach's alpha reliability coefficient is an indicator of internal consistency between the test points of the scale. If Cronbach

α reliability is 0.70 or higher, the reliability of the instrument is adequate (Büyüköztürk, 2007).

Findings

1. Findings related to the construct validity of the scale

1.1. Exploratory factor analysis (EFA)

For EFA, the KMO (Kaiser-Meyer-Olkin parameter) value must be at least 0.60 and the Bartlett Sphericity Test should be significant (Büyüköztürk, 2007). Therefore, before factor analysis, the appropriateness of the data was tested with the KMO and the Bartlett Sphericity Test. The results showed that the data were suitable for factor analysis.

Table 1. Appropriateness of the data for factor analysis

Kaiser-Meyer-Olkin (KMO) parameter		0.892
Bartlett	Chi Square	1643.066
	Sd	171
	Significance	0.000

EFA is a statistical technique which aims at explaining the measurement with few factors by gathering the variables that measure the same structure or quality (Büyüköztürk, 2007). With regard to EFA, four factors with Eigenvalues greater than one were found which explained 57.7% of the total variance. These four factors include 19 items.

Table 2. Eigenvalues of the scale's sub-dimensions and percentage of variance

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.731	35.428	35.428	3.767	19.828	19.828
2	1.774	9.337	44.765	3.013	15.860	35.687
3	1.276	6.715	51.480	2.197	11.561	47.248
4	1.185	6.239	57.719	1.989	10.471	57.719

The given values related to the factor structure were found for rotations that were undertaken with the varimax method. The factor loading values of the scale range from 0.421 to 0.832.

Table 3. Rotated factor loading value

	Component			
	1	2	3	4
item30	**.763**			
item31	**.736**			
item35	**.704**			
item24	**.639**			
item32	**.623**			
item21	**.494**			
item29	**.491**			
item11		**.753**		
item18		**.732**		
item13		**.625**		
item20		**.509**		
item16		**.499**		
item3			**.832**	
item2			**.791**	
item15			**.578**	
item27			**.421**	
item19				**.770**
item7				**.689**
item33				**.647**

1.2. Confirmatory factor analysis (CFA)

In CFA, testing a previously established hypothesis or theory concerning the relationship between the variables is the objective (Büyüköztürk 2007). After EFA testing, four sub-dimensions of the scale were tested through CFA.

Finally, CFA was conducted in order to test whether the model was four-dimensional. For this purpose, the data were prepared in Microsoft Excel, WordPad and Statistica programmes and transferred to LISREL software. Path analysis (Figure 1) and consistency indices were calculated with the LISREL programme. The consistency of the model, which includes the structures of four relevant sub-scales, was examined by computing the consistency indices and comparative consistency indices.

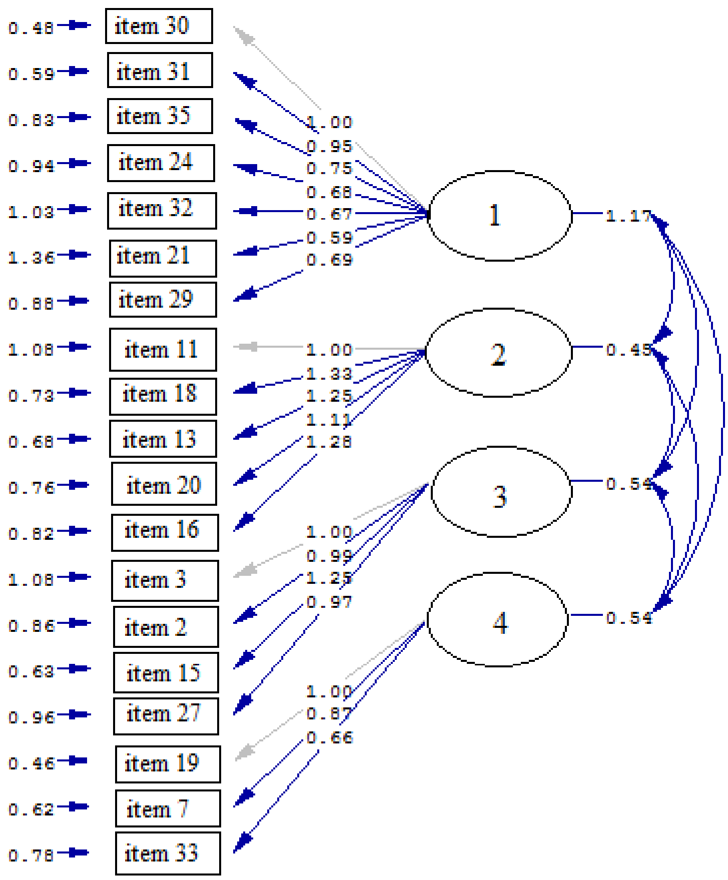

Figure 1. Four-factor model showing the relationship between the dimensions of the scale

Consistency index values according to the results of the CFA given in Figure 1 are as follows: **Chi-Square** (χ2) is % = 375.75; **Degrees of Freedom** (df) are 146 (P = 0.00) and accordingly %/ df is 2.57. If this latter value is less than one, it means that there is weak consistency; if the value is greater than five, it means that development within the model is required. The scale is consistent if this value is three (Schumacker & Lomax, 2004). Kelloway (1998) believes that a %/sd ratio of less than five is the indicator of good consistency. **Goodness of Fit Index** (GFI) is 0.862. The GFI value is between zero and one, which suggests better consistency as it is closer to one (Schumacker & Lomax, 2004). **Normed Fit Index (**NFI) is 0.80 and **Root Mean Square Error of Approximation** (RMSEA) is 0.080. Hooper et al. (2008) **state** that an RMSEA value between zero and 0.080 is the indicator of a good consistency and an RMSEA value between 0.05 and 0.10 is adequate for the consistency of the scale. Also, if the NFI value is 0.85 or above, this means that the scale is consistent (Cheng, 2001; Kelloway, 1998; Pang 1996).

In general, the consistency index values are appropriate for the evaluation criteria. Thus, it is fair to say that the results of EFA and CFA are consistent with each other.

1.3. Naming the factors

When the four-factor scale with 19-item, which emerged as a consequence of EFA and CFA, was examined, it was seen that six of the seven items in factor 1 represented 'anxiety about finishing the experiment'. It was also determined that four of the five items in factor 2 represented 'anxiety about doing the experiment as intended'. Three of the four items in factor 3 indicated 'constant anxiety towards the physics laboratory'.

Anxiety emerges when an individual feels that their self-esteem is under threat or feels that the current situation is stressful. This is called 'Constant Anxiety' (Öner & Le Compte, 1985). Constant anxiety is stable and is recognised as a personal characteristic. It was observed that three items in factor 4 were related to 'anxiety related to the use of materials in the laboratory'. By the end of this examination, three of the 19 items presented by the analyses were eliminated. The remaining 16-item scale was re-examined through CFA. The replicated CFA results of the 16-item, four-factor scale are displayed in the Figure 2 below.

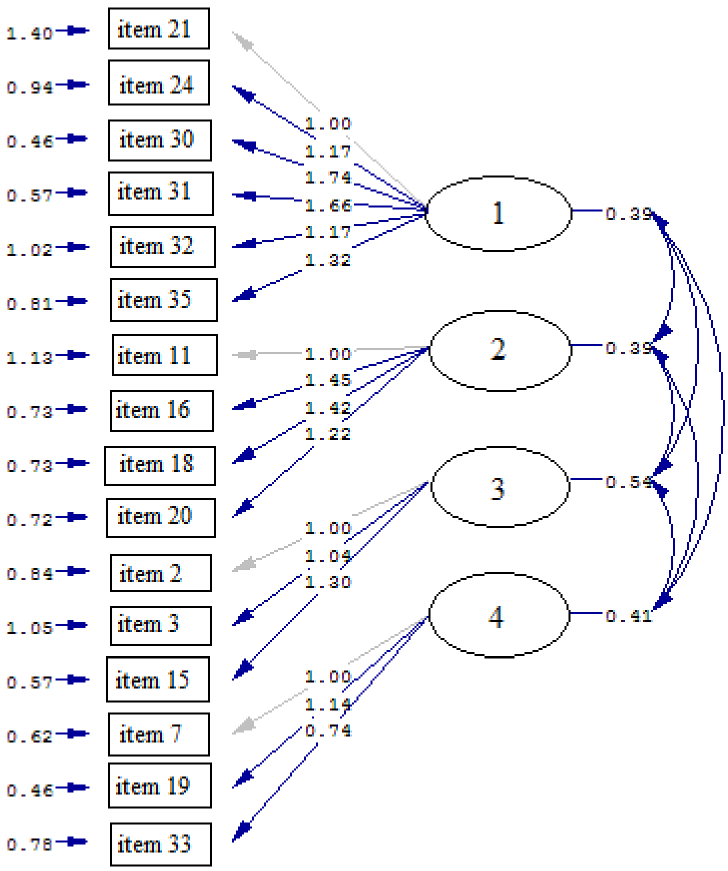

Figure 2. Second CFA results

According to the results of the first-level factor analysis given in Figure 2, the consistency index values are as follows: Chi-Square is {% = 267.27) and Degrees of Freedom (df) is 98 (P=0.00). Accordingly, %/ df is 2.72. Goodness of Fit Index (GFI) is 0.88, Normed Fit Index (NFI) is 0.82, and Root Mean Square Error of Approximation (RMSEA) is 0.084. When all of the index values were evaluated altogether, it was concluded that the scale is valid.

2. Findings related to the validity of the scale

Cronbach α reliability

If there are three or more answers for the test items, the Cronbach α reliability coefficient is applied. Where the Cronbach α reliability coefficient is 0.70 or above, the reliability of the test points is accepted as adequate (Büyüköztürk, 2007). In consequence of analyses, a scale including 16 items was finally obtained. The Cronbach α reliability values of the scale are given in Table 3.

Table 3. Reliability values related to the final form of the scale

Sub-dimensions	Cronbach α
Factor 1: Anxiety about finishing the experiment	.81
Factor 2: Anxiety about doing the experiment as intended	.73
Factor 3: Constant anxiety towards the physics laboratory	.72
Factor 4: Anxiety related to the use of materials in the laboratory	.61
Scale	.87

The Cronbach α value was computed as 0.87. This value means that the scale has a high internal consistency.

Difference reliability between the bottom 27% and the top 27% groups

The total average scores of participants in the bottom 27% and the participants in the top 27% group were compared for each item through t-tests. The t-test results are given in Table 4.

Table 4. T-test results for the bottom 27% and the top 27% groups

Sub-dimensions	**t**	**p**
Factor 1 : Anxiety about finishing the experiment	-29.77	.000
Factor 2: Anxiety about doing the experiment as intended	-28.34	.000
Factor 3: Constant anxiety towards the physics laboratory	-29.32	.000
Factor 4: Anxiety related to the use of materials in the laboratory	-26.76	.000
Scale	-25.61	.000

Table 4 shows that all of the items are significant at the level of $p < 0.001$. This means that the scale can discriminate participants with low scores from participants with high scores.

Split halves test reliability

By splitting the items of the test into two equal halves as odd-even, the first half-remaining half or neutral, the correlation coefficient is computed for the whole test through the Spearman Brown formula. The correlation coefficient is explained with split halves test reliability, which is based on the relationship between two halves of the test. Split halves test reliability shows the consistency between the collected test scores (Büyüköztürk, 2007).

The split-halves test reliability provided by the Spearman Brown formula is 0.78 and the split-halves test reliability calculated via the Guttman Split-Half technique is 0.77. These values indicate that internal consistency and split halves test reliability of the scale are high.

3. Item Analyses

Table 5. Mean, standard deviation and item-total correlation values of scale items

Item no	Mean	Std. Deviation (S)	Corrected Item-Total Correlation (r)
Item 21	2.69	1.345	.41
Item 24	2.79	1.225	.54
Item 30	3.00	1.288	.67
Item 31	3.00	1.273	.62
Item 32	3.45	1.240	.54
Item 35	2.62	1.232	.56
Item 11	2.84	1.251	.40
Item 16	2.97	1.238	.64
Item 18	2.84	1.221	.55
Item 20	3.00	1.141	.56
Item 2	3.40	1.164	.46
Item 3	3.60	1.282	.31
Item 15	3.48	1.201	.60
Item 7	4.07	1.021	.39
Item 19	3.78	1.012	.39
Item 33	3.80	1.012	.30

As seen in Table 5, corrected item-total correlations range between 0.30 and 0.67. As stated by Büyüköztürk (2007), these results indicate that the items are distinctive because they score 0.30 and above.

Results

EFA, CFA and reliability analyses were performed on the collected data. The physics laboratory-orientated item pool became a scale with 16 items and four sub-dimensions comprising 'Anxiety about finishing the experiment', 'Anxiety about doing the experiment as intended', 'Constant anxiety towards the physics laboratory' and 'Anxiety related to the use of materials in the laboratory'. Three of the items contained positive judgements and 13 of the items involved negative judgements. The items and dimensions formed by the items belonging to the developed 'Physics Laboratory Anxiety Scale' are shown in Table 6.

Table 6. Items and dimensions formed by the items belonging to the developed 'Physics Laboratory Anxiety Scale'

Anxiety about finishing the experiment
I am afraid of not being able to draw a conclusion from the data that I collect.
I am afraid that the data that I collect disagree with the physical hypothesis.
Not being able to reach the correct conclusion causes me stress.
I shrink from answering the questions related to the conclusion of the experiment.
I feel anxious about preparing a graphic with the data that I collect.
Being late with the experiment because of spoilt materials in the laboratory stresses me.
Anxiety about doing the experiment as intended
I am worried about determining the material required for the experiment.
I feel anxious about not being able to do the experiment appropriately.
I feel nervous about not being able to understand the purpose of the experiment clearly.
I feel worried as I am not sure whether I can do the experiment correctly or not.
Constant anxiety towards the physics laboratory
I would not take physics laboratory lessons if I were not forced to.
I shrink from the questions asked by the teacher.
I feel anxious while doing the experiments.
Anxiety related to the use of materials in the laboratory
I can easily install the experimental set-up.
I am relaxed when I use the laboratory equipment.
I can easily comment on graphics.

Discussion and Suggestions

As stated above, Physics is defined as a theoretical, boring and difficult lesson causing anxiety by the students. Attitudes that are more positive are expected from physics laboratory applications in comparison to Physics lesson because they are not theoretical. However, students may have anxieties about the physics laboratory because it requires skills such as applying theoretical knowledge in situations based on practice, manipulating laboratory materials and making comments on results. The developed physics laboratory scale reveals that the anxiety about the physics laboratory has different dimensions. The anxiety levels of students who experience failure in physics laboratory applications about the physics laboratory and in which situations they feel anxious can be determined through the physics laboratory anxiety scale. Thus, preliminary scientific information needed to perform physics laboratory applications is obtained. If the situations in which students feel anxious are determined, applications are planned in a more accurate manner by investigating the reasons behind situations causing anxiety and their solutions. This would change both achievement and attitudes of students related to the physics laboratory in a positive way. For example, if it is determined that the anxiety about finishing the experiment affects success, preliminary information about the experimental process and its phases can be provided for students. If students' anxiety about doing the experiment as intended is determined, a theoretical assignment including theoretical information related to the experiment can be requested before the experiment. If there is a majority of students having anxiety about using materials in the physics laboratory, materials can be introduced and their usage can be explained before the experiment. For children having constant anxiety towards the physics laboratory, motivating environments, which would make the lesson more enjoyable, can be created and applications can be performed. It is possible to make the attitudes and reactions of teachers more tolerant and constructive. More enjoyable and more interesting experiments can initially be preferred in laboratory applications. In short, we can enhance the number of these examples.

Laboratory lessons are effective for students' development of their researching and problem-solving skills. They are also required in order to develop manual skills and observation ability. Determining the situations in which anxiety towards physics laboratory lessons is present, which is extremely important for physics as well as other sciences, and the level of this anxiety, is necessary. That would indicate measures that can be taken to decrease anxiety and increase attachment to the lesson.

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