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REGULAR ARTICLE

Development of Physics Attitude Scale (PAS): An Instrument to Measure Students' Attitudes Toward Physics

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Abstract The present study is focused on the detailed description of Physics Attitude Scale (PAS) to measure students' attitudes toward physics. The development of this new instrument involved extensive interviews with both the experts as well as the students. This was followed by expert reviews and pilot testing of the instrument. The duly revised draft was used to collect responses from 624 students, aged 15–18 from Government Model Senior Secondary Schools, India. The factor analysis carried out on the resulting data revealed that the final form of the Physics Attitude Scale consists of five dimensions: Enthusiasm toward Physics, Physics Learning, Physics as a Process, Physics Teacher, and Physics as a Future Vocation. The content validity of the scale has been confirmed by the close agreement of experts on the statements. The reliability analysis showed that the scale consists of internally consistent items for each dimension. These findings demonstrate that the Physics Attitude Scale (PAS) possesses robust psychometric properties. It has been further found that a positive correlations exist between (a) enthusiasm toward physics and physics learning; (b) enthusiasm toward physics and physics as a process; (c) enthusiasm toward physics and physics as a future vocation; and (d) physics teacher and physics learning. Thus, the newly developed PAS can be used as an effective instrument by researchers and teachers to assess students' attitudes toward physics.

Keywords Attitude · Physics · Attitude toward physics · Instrument development · Validation

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Introduction

Affective domain in science education has always been an important concern for science educators. Over a span of several decades, there has been a significant research pertaining to the area of students' attitude toward science. As a result, an extensive literature is available concerning the investigation of attitudes toward science in relation to multiple factors such as achievement, anxiety, gender, age, ethnicity, family background, teacher, learning environment, and parental attitudes (Gardner 1975; Fraser 1981; Fraser and Fisher 1982; Hadden and Johnstone 1983; Haladyna et al. 1983; Schibeci and Riley 1986; Germann 1988; Schibeci 1989; Simpson and Oliver 1990; Myers and Fouts 1992; Greenfield 1996; Neathery 1997; Zacharia 2003; Aalderen-Smeets and Walma van der Molen 2015). The periodic reviews in the area of attitudinal research have further enriched the developing body of knowledge (Boeck and Washton 1961; Aiken and Aiken 1969; Pearl 1973; Ormerod and Duckworth 1975; Gardner 1975; Gauld and Hukins 1980; Haladyna and Shaughnessy 1982; Schibeci 1984; Laforgia 1988; Osborne et al. 2003).

There are several contributing factors from various studies which have re-emphasized on the significance of the topic. Some of the prominent factors highlighted in the literature include a constant decline in the post-compulsory high school science enrollment (Smithers and Robinson 1988; Dekkers and DeLaeter 2001; Garg and Gupta 2003; Blalock et al. 2008); reluctance among the students to choose science courses, especially physical science courses in their final years of secondary education (Simpson and Oliver 1990; Garg and Gupta 2003; Trumper 2006); and a change in our value system as a result of which science-related careers are not perceived attractive in terms of employment opportunities (Garg and Gupta 2003). To add to this, the constricted approach of understanding science by the general public has pared down the number of young people choosing to pursue the study of science and science as career choices (Durant et al. 1989; Durant and Bauer 1997; Miller et al. 1997; Bensaude-Vincent 2002; Stocklmayer and Bryant 2012). These aforementioned factors have caused a major stir regarding the development of scientific vigor and progress of scientific literacy among the youth.

In this regard, there have been numerous studies on attitudes and its correlates (Häussler and Hoffmann 2000; Osborne and Collins 2001; Osborne et al. 2003; Christidou 2006, 2011). The review study by Gardner (1975) highlighted the relationship of attitudes toward science with internal variables (cognitive variables, personality, sex) and external variables (home background, school environment, curriculum, and instructional variables). In continuation with this scheme of categorization, Haladyna and Shaughnessy (1982) have postulated that the students' attitude toward school subject can be attributed to the interactions between three variables: teacher, student, and learning environment. Each of these three variables has been further subdivided into exogenous and endogenous variables. The exogenous variables include those that are outside the direct control of educational process, for example, age of the student, sex of the student, family background, and cultural factors. On the other hand, the endogenous variables have been considered to be under the direct control of educational process. Such variables involve teacher, student, and the learning environment. The relationship among these variables is not simply linear, but exhibits nonlinear characteristics resulting from mutual interactions. These studies have shown that the students' attitudes toward science are more influenced by endogenous variables as compared the exogenous variables. The study by Haladyna et al. (1983) has shown that the student' perceptions of the importance of science, teacher quality, and learning environment are highly correlated to science attitudes. It has been shown that positive attitudes toward science enhance the cognitive outcomes as well as results in an increased tendency to choose career in science or science-related field (Mager 1968; Christidou 2011; Tytler and Osborne 2012). Thus, more emphasis should be laid on linking students' perception, treatments, and learning as it influences the students' attitude toward subject (Walberg 1976). These results are further supported by the findings of Myers and Fouts (1992), Woolnough (1994), and Christidou (2011). As per these studies, school environment comprising science teachers, science teaching, and extracurricular activities are the factors that may encourage or discourage students toward higher education and in choosing careers in physics. It has also been shown that a highly teacher-dominated classroom leads to students' passivity, reduced interest in physics, and consequently, a feeling of general negative attitude toward physics (Ahlgren and Walberg 1973; McDermott 2001). Alternatively, learner-centered classroom provides a more conducive environment for the students to actively participate in the classroom and thus invigorate the enthusiasm toward physics learning. This evokes the student's interest as well as builds a positive attitude toward physics. It has been well documented that an incompetent physics teacher (Hendley et al. 1995; Sundberg et al. 1994; Woolnough 1994; Archibald 2006; Oon and Subramaniam 2010; Buabeng et al. 2015), poor teaching methodology (Briggs 1976; McDermott 2001; Smart and Marshall 2012; Tytler 2014; Juuti and Lavonen 2016), and curriculum loaded with undemanding activities such as recall, copying, and lack of intellectual challenge (Osborne et al. 2003; Häussler and Hoffmann 2000; Semela 2010; Anderhag et al. 2013) are responsible for eroding students' interest in physics and positive attitudes toward physics, particularly at junior high school level (Kahle and Lakes 1983; Baird and Penna 1992; Christidou 2006; Koballa and Glynn 2007; Christidou 2011). Thus, a multipronged approach is required in the field of physics education to bring out a qualitative change.

Various interventions or modifications in the teaching–learning process have been developed to bring desirable changes in students' attitudes toward science (Akinbobola 2010; Chen and Howard 2010; Azar and Sengulec 2011; Chen et al. 2013; Luchembe et al. 2014; Rutten et al. 2015). The effectiveness of these interventions can be determined by the shift in students' attitudes toward science. Thus, an appropriate instrument with robust psychometric properties is required to measure the quantitative change in students' attitudes. Gardner (1975), Munby (1983), Schibeci (1984), Lederman et al. (2002), Blalock et al. (2008), and Potvin and Hasni (2014) conducted a comprehensive analysis of the existing instruments and concluded that the measurement of attitudes toward science is a challenging task. The aforementioned studies have delineated several shortcomings in the earlier studies. Some of the major concerns raised by Munby (1983), Schibeci (1984), Lederman et al. (2002), Blalock et al. (2008), and Potvin and Hasni (2014) have been discussed later in this article.

The first major issue that has been outlined is the lack of common agreement regarding the operational definition of science attitude. In the review of the literature concerning attitudes toward science and its implications, Osborne (2003) highlighted that the concept of attitude is poorly articulated and misinterpreted due to the complex nature of the construct itself. There has been a semantic dubiety regarding 'scientific attitude,' 'attitude toward science,' and 'attitude toward science and scientists' (Koballa 1983).

The studies have also shown that the structural build-up of attitudes toward science consists of multiple components rather than being one-dimensional in nature (Klopfer 1971; Gardner 1975; Haladyna and Shaughnessy 1982; Koballa 1988; Woolnough 1994). The multidimensional nature of attitude pointed in the study of Gardner (1975) has been endorsed by the studies of Munby (1983), Koballa (1983), Blalock et al. (2008), Tytler and Osborne (2012), Potvin and Hasni (2014), and Kennedy et al. (2016). The review of available instruments revealed that each one of them (a) uses different definitions of attitudes toward science (b) has specific epistemology, and (c) measures the specific dimensions of attitude toward science which were distinct from each other. Therefore, an emphasis on the elucidation of the complex construct 'attitudes toward science' and its dimensions is required to produce valid and reliable results. The second concern, which has been raised, is associated with the type of the instrument and the scoring technique used for the measurement of attitudes toward science. Gardner (1975) discussed different techniques adopted by the researchers in order to obtain data on respondents' attitudes. These include differential (Thurstone) scales, rating scales, summated rating scales, semantic differential scales, interest inventories, preference ranking, projective techniques, and qualitative data. The Views about Science Survey (VASS) by Halloun and Hestenes (1996), The Colorado Learning Attitudes about Science Survey by Adams et al. (2006), and Epistemological Beliefs Assessment about Physical Science (EBAPS) developed by Elby et al. (2006) favored the forced choice closed-item questionnaire. It has been pointed by Munby (1983) that the items reflecting multiple attitudinal dimensions cannot be represented by a single score. Further, Lederman et al. (2002) raised the issues related to lengthy statements leading to ambiguity of items, which in turn led to the development of open-ended questionnaires followed by interviews such as views of nature of science (VNOS) questionnaire. The VNOS questionnaire consists of a series of three forms that can be used at different grade levels. However, the time-intensive nature and the specific focus limit the usage of VNOS questionnaire (Hillman et al. 2016). The third concern that has been outlined is regarding the reliability and the validity of the available instruments. Munby (1983), Schibeci (1984), Lederman et al. (2002), Blalock et al. (2008), and Potvin and Hasni (2014) concurred that most of the attitude measures have poor psychometric quality, indicating toward the lack of reliability as well the validity of items. These concerns have also been duly considered in the recent studies on development of instruments to measure attitudes toward science at different levels: elementary, secondary, and higher secondary (Wang and Berlin 2010; Abd-El-Khalick et al. 2015; Hillman et al. 2016; Kennedy et al. 2016; Navarro et al. 2016). Moreover, it has been also been shown that the differences in the educational system and cultural background also affect the development of an instrument (van Rensburg et al. 1999; Pell and Manganye 2007).

Thus, it is evident that there are various theoretical and methodological concerns on issues such as poorly defined attitude and its related concepts, design, lack of psychometric standards of adequate sample size, pilot testing, reliability, and validity in the available attitude-measuring instruments. The limitations in the presently available instruments coupled with some other factors, which are discussed later served as the motivation to develop a new attitude measure, called PAS: an instrument to measure students' attitude toward physics. The new instrument aims to measure students' attitudes toward physics rather than general science. In the present study, attitudes toward physics can be described as the feelings, beliefs, and values held toward physics which includes physics curriculum, physics learning, physics teacher, and physics as a career, expressed in the form of like or dislike; positive or negative reaction toward physics. This instrument intends to examine the various dimensions that conflate to represent the attitudes toward physics. For this purpose, students' attitudes toward physics has been studied with special emphasis on the trilogy of teacher, student, and the classroom practices that lead them to understand physics effectively and make better career choices. The differences arising in the attitude measurement due to demographic and cultural parameters, socioeconomic status, language, and educational settings (curriculum, teacher, teaching methodology, classroom environment, and availability of resources, examination system, and educational policies) also contribute toward the development of a new instrument.

In the present study, PAS has been developed and validated to measure students' attitude toward physics. The above mentioned factors have been considered as frame of reference for the development Physics Attitude Scale. The scale has been validated using the responses collected from 624, XI grade students studying in state-run schools called '*Government Model Senior Secondary School*.' The higher secondary stage (XI grade) has been specifically taken because it is the transition phase in which the students have to make a choice of the subjects. At this crucial point in their careers, students have to go through rigorous entrance examinations and tough competition to get admission in higher studies. A wrong choice in the beginning due to poor attitudes, peer pressure, parental pressure, influenced decisions, tough completion, teacher, teaching methodology, and learning environment may prove disastrous for the student's career (Verma et al. 2002; National Curriculum Framework 2005; Roysircar et al. 2010; Sharma 2014; Deb et al. 2015). Hence, it is necessary to measure students' attitudes at the high school stage so that the students are successful in their future instead of getting burnout under the academic stress.

The detailed description of the development of the scale has been discussed in the subsequent sections.

Methodology

Design

The instrument has been designed in accordance with the various guidelines which includes multidimensional nature of attitude, easy scoring of the responses and robust psychometric properties. The various aspects related to students views about physics, their fervor toward learning and understanding the subject, physics teacher, teaching methodology, and physics as a career have been included.

In India, formal education system in schools has been categorized as primary, upper primary, secondary, and higher secondary stages. According to the National Curriculum Framework (2005), Science at the higher secondary stage should be introduced as one of the separate disciplines, with emphasis on experiments/technology and problem solving. Students follow a common interdisciplinary curriculum till secondary school stage with physics, chemistry, and biology as the main science subjects. At the higher secondary stage, students have to choose a major field of study from science, commerce, and humanities. The students are evaluated by a subjective examination process at the end of grade 12 (senior secondary school), which is then followed by taking an entrance examinations to get admission into respective colleges/universities. Physics is considered as one of the important subjects in the curriculum. It not only provides explanation to the various phenomena taking place around but also develops creativity and problem-solving abilities among the students. In actual practice, the core topics of physics, taking into account the recent advances in the subject, involve a large number of topics to be covered within these two years of schooling. It has been reported in the literature (Yashpal Committee Report MHRD 1992; National Curriculum Framework 2005; Continuous Comprehensive Evaluation in Science 2011) that the steep gradients between the secondary and higher secondary science syllabi, overpowering examination system, rote learning, and students' perceptions make understanding of physics as one of the most difficult challenges. These concerns in physics classrooms in Indian settings are in consensus with various research findings at the global level (Maloney et al. 2001; McDermott 2001; Meltzer 2005). As a result, fewer students are attracted toward physics (Rivard and Straw 2000; Mattern and Schau 2002; Erdemir 2009).

Development of Physics Attitude Scale

The PAS has been developed and validated in a stage-wise manner. The first stage comprised the literature review for the planning and development of item pool. The planning involved thorough examination of statements of already available physics attitude scales such as M*aryland Physics Expectations* (MPEX) *survey* by Redish et al. (1998); The Colorado Learning Attitudes about Science Survey (CLASS) by Adams et al. (2006), and Epistemological Beliefs Assessment about Physical Science (EBAPS) developed by Elby et al. (2006). In addition to this, various other science-related attitude-measuring instruments were also reviewed [Test of Science Related Attitudes (TOSRA)] by Fraser 1981; Views About Science Survey (VASS) by Halloun and Hestenes (1996). Interviews with experts were conducted to understand their views and ideas regarding students' attitudes toward physics. In this regard, a total of 12 faculty members involved in physics teaching and research at premiere engineering institutes, Government Universities, Degree colleges, and Government Model Senior Secondary Schools were consulted for their views. These experts have extensive teaching experience in the domain of physics acquired through teaching physics courses spanning from small study groups to large lectures comprising hundreds of students at school, college, and university levels. In addition to this, four faculty members from the departments of education of different universities with expertise in teaching of science and educational psychology were also consulted in order to comprehend the concept of 'attitude toward science/physics' and discuss design of the instrument in detail. Such a diversity of experts owing to their different educational backgrounds and experiences in terms of teaching physics at different levels aided to bring together a variety of perspectives while discussing the topic regarding attitudes toward physics. The experts' views evoked a wide spectrum of concerns regarding teaching–learning of physics at school and post-school levels. These different viewpoints aided to gather information on the epistemology of physics, students' keenness toward physics learning, views about physics as a discipline, problems faced in physics learning, students' aspirations and careers in the field of pure sciences, interest regarding applied sciences, or science-related careers at school and post-school levels. These factors play a crucial role not only at school-level physics learning but also affects students future choices in taking physics in higher education and pursuing careers in this field. In addition to this, 108 grade XI science students from Government Model Senior secondary schools were interviewed in informal setting to represent their views on major subjects, personal interest, work load, career orientation, classroom activities, etc. The students' views were listened to and written down to formulate the statements.

Thus, on the basis of the literature review and data gathered from experts' and students' interviews, 101 items formed the first draft of the scale. The statements have been framed in such a manner that it does not simply deal with physics as a subject. In fact, the main emphasis was to represent physics as a useful process or phenomena that describe its coherent nature rather than simply represented as a coursework merely restricted to textbook discussions. The statements included various factors related to student interest, enjoyment, physics teacher, future aspirations, students views regarding physicist and physics as a career, classroom activities, curriculum, etc. which were missing in the previous surveys. Another important point that emerged from discussion with experts was the need to involve both positively and negatively worded items in the scale. This is so because asking only type of statements may influence the respondent to elicit a patterned response. For example, if a person has agreed several times in a row, he/she may continue to agree. Thus, a deliberate pattern breaking is required to overcome the monotony and get unbiased response from the respondent. Such patterned response can be broken up by asking *reversal questions*, where the sense of the question is reversed. However, sometimes this reversal may lead to bias. Hence, the statements were carefully structured to ensure that the essence remains preserved. In order to keep the respondent engrossed throughout the response process, the positive and negative items were randomly arranged. In this way, the respondent will read each statement carefully before answering instead of answering in a pattern form, which is a normal human tendency.

The second stage involved validation of the statements forming the first draft. This draft was evaluated by 12 experts in terms of content validity, relevance, and distractors. The experts were requested to rate each item on three categories by answering the undermentioned question: "Is the attitude/view measured by the item? -essential, -useful but not essential, or -not necessary?" After collecting their opinions on every statement, content validity ratios (C.V.R.s) were calculated based on Lawshe formula (1975):

$$C.V.R. = \frac{n_e - N/2}{N/2}$$

where $N =$ Number of physics experts forming the panel, and $n_e =$ Number of panelists indicating an item essential. In the present study, $N = 12$.

According to Lawshe's criterion, the statements with C.V.Rs of 0.56 or more were retained. This is because C.V.R. = 0.56 or more is significant at 0.05 level of significance for $N = 12$ (Lawshe 1975). In this way, the content validity of statements was ascertained quantitatively. In this evaluation process, 14 items were rejected, and three items were rephrased to improve readability.

The revised statements on attitudes toward physics scale were arranged on Likert (1932) type of instrument. It included five categories: S.A.—Strongly Agree; A—Agree; N—Neutral; D—Disagree; and S.D.—Strongly Disagree. The response on this type of scale shows the direction (for or against) as well as intensity (strength) of the attitudes toward physics. There have been arguments regarding the inclusion or exclusion of a neutral point in the Likert scale. According to Dumas (1999), elimination of neutral point provides a better measure of the intensity of participants' attitudes or opinions.' It has been argued by DuBois and Burns (1975), Stone (2004, p. 201) that the respondents misuse the middle response or neutral category as 'dumping grounds.' Because of ambivalence or indifference, the respondent may merely use neutral or middle category, thus adversely affecting the reliability and validity of the study (Eyesenck 1998). On other hand, Kulas et al. (2008) advocated that the omission of neutral or uncertain category from the scale represents an item as a forced choice option and limits the respondent to express his/her opinion. Hence, it could reduce the reliability of the scale as the results will not necessarily be true. Therefore, a neutral response option should be available in case the respondent wishes to express neutral feelings toward a situation or object in a given statement. Kulas et al. (2008) further pointed that the inclusion of middle point does not adversely affect reliability and validity of the study.

This instrument was administered to 152 students of grade XI for pilot testing. The students were instructed to assign anyone of the five categories and to mark the item/words which were difficult to understand after carefully reading each statement. In this process, following two statements were pointed out by the students: '*learning physics is beyond my competency*.' and '*My physics teacher occasionally discuss physics problems.*' These statements were rephrased to '*learning physics is beyond my capabilities*.' and '*My physics teacher rarely discuss the numerical problems related to a physics topic taught in the class.*' respectively.

The revised physics attitude scale was administered in regular classrooms to 642, grade XI students from different '*Government Model Senior Secondary Schools*' Chandigarh, India. The *Government Model Senior Secondary Schools'* are state-run schools which were chosen because of the following reasons: (a) They represent the maximum percentage of schools in the union territory, Chandigarh in comparison with private schools (b) They maintain uniformity in terms of syllabus and examination pattern. (c) They eliminate the bias in the study due to socioeconomic status and institutional infrastructure. The medium of instruction followed in these schools is English. The Physics attitude scale was administered to the students in a booklet form with 15 questions on each page, and their responses were collected in paper–pencil form. The students were ensured that the data filled by them would be kept confidential in order to avoid any kind of bias in the responses. Although the students were given no time limit, but a majority of them completed within 25–30 min. The students who took unnecessarily long time to complete were not considered in the scoring process. From the entire group, 13 students gave incomplete sheets and five students did not participate at all.

Scoring

The scoring was done according to the scoring procedure suggested by Likert (1932). The positive statements were scored as Strongly Agree response-5, Agree response-4, Neutral response-3, Disagree response-2, and Strongly Disagree response-1. The scoring system was reversed for negative statements. The final form of the scale consisted of 60 items. The maximum and minimum scores of the scale were 300 and 60, respectively.

Data Analysis

The data were compiled by scoring response sheets and analyzed to determine the discriminating ability of the individual items, reliability, validity, and internal consistency. The internal consistency of the physics attitude scale as a whole and its each dimension were computed using Cronbach's alpha coefficient (α). The validation of the scale involved interviews with experts and students. It was followed by an extensive statistical process comprising factor analysis to determine the underlying dimensions of the scale.

Results and Discussion

The results of the data analysis are discussed below:

Item Analysis

From the total sample, 27% of the subjects with the highest total scores and 27% of the subjects with the lowest total scores were selected from the data. These were termed as high and low groups, respectively. The *t*-values were computed to evaluate the responses of the high and low groups on each statement. The *t*-values for 87 statements are given in the Table 1.

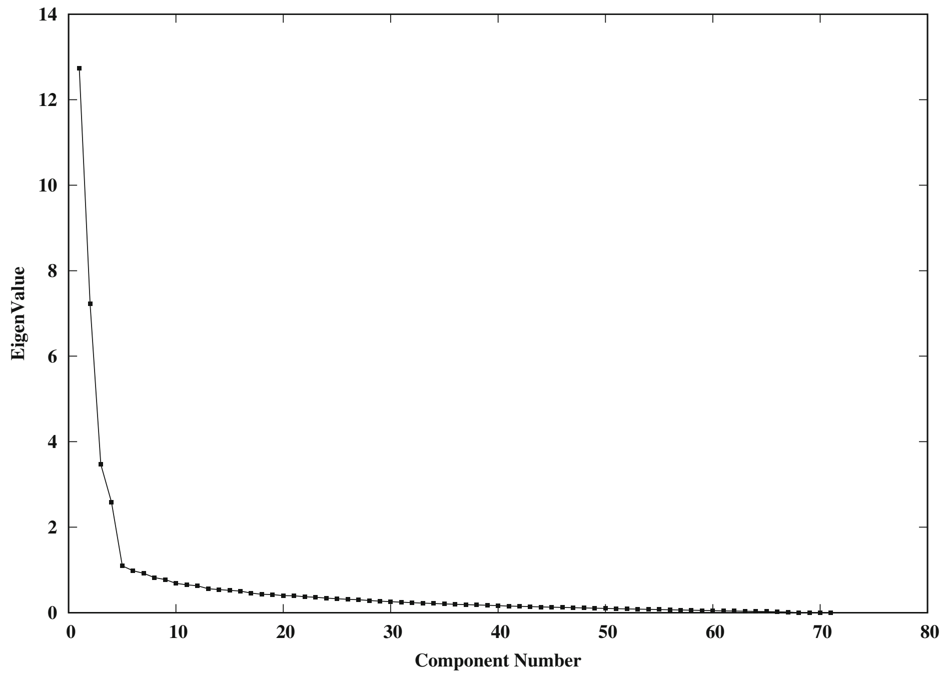
From Table 1, it follows that the *t* test results were found to be not significant for 16 items. Thus, these items were dropped from the scale.

Table 1 *t*-Test means and *p*-values of upper and lower points

Item no.	*t*	*p*	Item no.	*t*	*p*
1.	11.29	0.000	45.	**8.00**	**0.238**
2.	8.84	0.000	46.	8.63	0.000
3.	10.58	0.000	47.	10.61	0.000
4.	11.61	0.000	48.	10.04	0.000
5.	**2.72**	**0.102**	50.	5.86	0.000
6.	8.26	0.000	51.	10.16	0.000
7.	13.51	0.000	52.	7.15	0.000
8.	10.68	0.000	53.	8.38	0.000
9.	7.29	0.000	54.	9.34	0.000
10.	11.35	0.000	55.	**10.39**	**0.112**
11.	9.17	0.000	56.	13.48	0.000
12.	10.82	0.000	57.	**7.27**	**0.901**
13.	**9.72**	**0.573**	58.	16.42	0.000
14.	14.59	0.000	59.	7.31	0.000
15.	7.56	0.000	60.	7.55	0.000
16.	18.86	0.000	61.	13.8	0.000
17.	15.29	0.000	62.	8.60	0.000
18.	5.05	0.000	63.	11.65	0.000
19.	**10.43**	**0.097**	64.	5.53	0.000
20.	9.97	0.000	65.	**10.44**	**0.742**
21.	5.22	0.000	66.	12.41	0.000
22.	**11.18**	**0.356**	67.	12.28	0.000
23.	9.20	0.000	68.	**7.38**	**0.538**
24.	8.65	0.000	69.	10.13	0.000
25.	10.89	0.000	70.	8.07	0.000
26.	11.74	0.000	71.	9.54	0.000
27.	7.27	0.000	72.	12.32	0.000
28.	8.56	0.000	73.	14.63	0.000
29.	9.99	0.000	74.	13.54	0.000
30.	8.42	0.000	75.	12.65	0.000
31.	**6.20**	**0.074**	76.	**4.80**	**0.067**
32.	8.02	0.000	77.	9.39	0.000
33.	9.28	0.000	78.	**6.95**	**0.083**
34.	10.35	0.000	79.	12.16	0.000
35.	6.77	0.000	80.	13.95	0.000
36.	6.70	0.000	81.	9.17	0.000
37.	5.34	0.000	82.	13.40	0.000
38.	**5.50**	**0.635**	83.	**11.17**	**0.287**
39.	5.90	0.000	84.	12.30	0.000
40.	6.55	0.000	85.	**5.17**	**0.436**
41.	**3.98**	**0.218**	86.	16.85	0.000
42.	9.67	0.000	87.	12.55	0.000
43.	9.43	0.000	–	–	–

* Values marked in bold are nonsignificant

Fig. 1 Scree plot



Factor Analysis

Prior to the factor analysis, the Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity were checked to ascertain whether the data were suitable for factor analysis. The calculations revealed a KMO value of 0.889. The Bartlett's test of sphericity was found to be significant ($\chi^2 = 41{,}506.47$; $p < 0.000$). A significant value of χ^2 obtained from Bartlett's test of sphericity indicates the multivariate normal distribution of the data. These results implied the suitability of the data for factor analysis (Tabachnick and Fidell 2007, p. 651; Field 2009, p. 179). The principal component analysis with direct oblimin rotation has been used in the present study. Considering the complexity of the variable 'attitude' (Fishbein and Ajzen 1975; Eagly and Chaiken 1993) some correlation among factors can generally be expected. As a result, attitude cannot be compartmentalized into units that function independent of each other. Therefore, in order to avoid any loss of valuable information arising due to correlation of factor (if any), direct oblimin rotation has been considered (Costello and Jason 2005). The results of factor analysis have been analyzed in order to include those items which contribute to a meaningful measure of an underlying factor and reject the items that weaken the measurement of the underlying factor. In this regard, three cross loading items that load at 0.32 and higher on two factors were dropped from the scale as there were several adequate to strongloaders (0.50 or better) on each factor (Costello and Jason 2005; Field 2009). Eight items with factor loadings less than 0.32 were also omitted (Kline 1994, p. 6; Tabachnick and Fidell 2007, p. 654; Field 2009). Further, communalities explained by the extracted factors were found to be greater than 0.40 for each item and varied from 0.44 to 0.81.These results were found to be consistent with the thumb rules as suggested by Velicer and Fava (1998); Field (2009). Moreover, the inspection of correlation matrix for the variables has not shown high correlations (above 0.90) and the determinant score for correlation matrix is above the thumb rule of 0.00001 (Field 2009). This indicates the absence of multicollinearity. The factor analysis has thus revealed five factors and led to the deletion of 11 items. In order to keep a check on overestimating the number of factors retained, alternative methods were employed. These methods included Eigenvalue Statistics, Scree test, total variance percentage method.

The scree plot is a graphic method proposed by Cattell (1966). Figure 1 shows five factors in sharp descent, which levels off after the fifth factor. Similarly, the Eigenvalues analysis (Table 2) shows the retention of first five factors with eigenvalue more than one (Kaiser 1960). In addition to this, a parallel analysis (Horn 1965) for principal component analysis was carried out to prevent the over extraction of the factors. The randomly generated eigenvalues by parallel analysis engine were compared with the calculated eigenvalues. This confirmed the extraction of the first five factors. The initial eigenvalues of the five factors ranged between 12.739 and 1.096. As seen from Table 2, the percentage of variances for the different factors ranged from 26.393% for factor I to 5.487% for factor

Table 2 Eigen values, variances, and total variances of the five factors

Factors	Eigen values	Percentages of variances	Percentages of total variances
Factor 1: enthusiasm toward physics	12.739	26.393	26.393
Factor 2: physics learning	7.223	12.991	39.384
Factor 3: physics as a process	3.470	11.508	50.891
Factor 4: physics teacher	2.586	7.868	58.759
Factor 5: physics as a future vocation	1.096	5.487	64.246

V. The total variance for all the five factors has been found to be 64.246%. The factor loadings for the final draft of 60-item PAS varied between 0.876 and 0.404. The items of the physics attitude scale, factor structures, and factor loadings are presented in Table 3.

Dimensions of the Physics Attitude Scale

From Table 3, it can be interpreted that factor 1 includes ten statements related to student's feelings about physics. It takes into account the positive extreme of the continuum in which the student considers physics as an important activity leading to enjoyment in the process. On the other hand, the negative extreme represents the aversion of the student toward physics. Therefore, the first factor was named '*Enthusiasm toward Physics*'.

The second factor included 14 statements related to the components of physics learning. It features discovery, participation, comprehension, and problem solving as the positive views. Formal, limited, and mechanical natures were considered as the negative views. This factor was called '*Physics Learning*.'

The third factor consisted of 11 statements which deal with the student's views on physics. The positive views consider physics as tentative, dynamic, and coherent, whereas, the negative view is taken as physics being nearly complete, certain, and rigid. Thus, the third factor was named as '*Physics as a Process*'.

The fourth factor considered 14 statements that include student's views on the physics teacher. The positive views consider physics teacher as dynamic, interactive, and creative in nature. The negative views represent the physics teacher as dominant, dull, and outdated. This factor was called '*Physics Teacher*'.

The fifth factor included 11 statements on student's view on physicist and physics as a career. The positive views consider physicist as normal and active individuals who are specially trained in the respective fields. The positive views regarding physicists may contribute in student's choice of a physics-related career. The negative extreme considers physicist as eccentric, abnormal, and antisocial individual. As a result of the negative perception regarding physics and physicist, the student may not likely pursue the subject in higher courses and as a career choice. This factor was therefore called '*Physics as a future vocation*.'

The analysis of factor correlation matrix (Table 4) points toward a positive correlation between enthusiasm toward physics and physics learning ($r = 0.63$). This explains that the enthusiastic students have positive views about physics learning. A positive correlation between enthusiasm toward physics and physics as a process ($r = 0.45$) shows that the students enthusiastic toward physics are more eager toward learning of physics. This eagerness to learn the subject in turn also leads to positive perception of the students' toward physics as a process. A positive correlation between enthusiasm toward physics and physics as a future vocation ($r = 0.58$) implies that such students exhibit a stronger tendency toward pursuing physics in higher education and careers in the field of physics. In the present study, the following dimensions: physics as a process, students' enthusiasm toward physics, and physics learning were found to be similar to those considered in CLASS by Adams et al. (2006); MPEX survey by Redish et al. (1998). These dimensions were labeled in the form of conceptual connections, personal interest, applied conceptual understanding, problem solving, reality link, math link and effort. Some statements of PAS (pertaining to physics as a process, enthusiasm toward physics, and physics learning) were akin to the statements of CLASS and MPEX survey. However, these statements have been found to be placed under the following dimensions: conceptual connections, personal interest, applied conceptual understanding, problem solving. While, CLASS involved only one statement pertaining to physics teacher, two statements on physicists/physics as a career and very few statements on teaching practices in physics. MPEX did not consider any statements regarding physics teacher, teaching practices, and career in physics. Majority of the statements were focused on student beliefs about the nature of learning physics. The dimensions pertaining to students' enjoyment of science lessons and Leisure interest in science, and Career interest in science have also been undertaken in TOSRA developed by Fraser (1981). A strong correlation has been reported between the aforementioned subscales which strongly suggest that students' interest and enjoyment of science lessons would likely lead

Table 3 Factor structures and factor loadings of the 60 items in the physics attitude scale

Items	F1	F2	F3	F4	F5
Factor I: enthusiasm toward physics					
Learning physical phenomena and their description is most enjoyable to me	0.638	–	–	–	–
Studying topics on Physics in greater detail is not worth it	0.567	–	–	–	–
My confidence level increases by doing physics experiment in laboratory	0.566	–	–	–	–
The basic knowledge of physics is useful for everyone	0.668	–	–	–	–
Physics is a boring subject for me	0.526	–	–	–	–
The successful completion of a physics experiment excites me to do other experiments	0.498	–	–	–	–
I will be happy if the practical work in physics is reduced so that I may devote more time in studying theory	0.416	–	–	–	–
I am punctual with physics homework	0.404	–	–	–	–
I wait eagerly for physics period	0.508	–	–	–	–
I discuss physics with my friends	0.490	–	–	–	–
Factor II: physics learning					
I feel very pleased and satisfied on answering the questions in physics class	–	0.876	–	–	–
Laboratory work in physics improves individual productiveness	–	0.869	–	–	–
I keep on practicing the problems done in the class till I attain proficiency	–	0.809	–	–	–
I feel stressed in my physics class	–	0.803	–	–	–
Active participation of students in practical and theory classes result in effective understanding of physics	–	0.793	–	–	–
Absence of tutorials in physics is responsible for not getting good marks	–	0.749	–	–	–
I try to correlate the physics problem with daily life situation	–	0.744	–	–	–
I try to focus more on memorizing laws and derivations given in textbook rather than solving physics problems	–	0.734	–	–	–
There are many situations in physics which are difficult to visualize	–	0.727	–	–	–
It is very difficult to succeed in physics exam without cheating	–	0.724	–	–	–
Difficult topics in physics do not interest me	–	0.723	–	–	–
Parents and teacher compel me to study physics	–	0.722	–	–	–
I study physics only when my exams are around	–	0.707	–	–	–
Learning physics is beyond my capability	–	0.668	–	–	–
Factor III: physics as a process					
The subject of physics is ever evolving	–	–	0.644	–	–
Physics is not just knowledge but is a process of gaining knowledge	–	–	0.642	–	–
There is no need to further verify the laws already discovered	–	–	0.638	–	–
Scientific knowledge is developing so rapidly that the facts of physics may be found untrue tomorrow	–	–	0.629	–	–
After sometime all the laws of physics will be discovered	–	–	0.617	–	–
The results of physics experiments are very slow	–	–	0.603	–	–
Physics play an important role in the advancement of civilization and society	–	–	0.560	–	–
There is nothing creative about physics; it's about memorizing laws and formulas	–	–	0.543	–	–
Physics has contributed greatly to science and other fields	–	–	0.535	–	–
Physics helps develop person's mind and teaches him to think	–	–	0.530	–	–
Huge infrastructure is needed to build a physics laboratory in order to understand the subject	–	–	0.513	–	–
Factor IV: physics teacher					
I am scared of my physics teacher	–	–	–	0.637	–
My physics teacher always overburdens the students with assignments	–	–	–	0.583	–
My physics teacher encourages problem solving	–	–	–	0.581	–
My physics teacher rarely discuss the numerical problems related to a physics topic taught in the class	–	–	–	0.572	–
My physics teacher always comes to the class regularly	–	–	–	0.570	–
My physics teacher does not encourage raising doubts in the class	–	–	–	0.538	–
My physics teacher does not make coherent statements on the topic taught in the class	–	–	–	0.504	–
My physics teacher uses a combination of teaching aids while teaching in the class	–	–	–	0.503	–
My physics teacher often uses a lecture format to teach	–	–	–	0.501	–

Table 3 continued

Items	F1	F2	F3	F4	F5
My physics teacher spends the necessary amount of time helping me understand physics concepts	–	–	–	0.452	–
My physics teacher does not believe that I am capable of learning physics	–	–	–	0.451	–
My physics teacher often becomes frustrated with me	–	–	–	0.450	–
My physics teacher emphasizes on understanding and not just memorization	–	–	–	0.447	–
I aspire to be a physics teacher	–	–	–	0.437	–
Factor V: physics as a future vocation					
The scope of professional growth as a physicist is very slow	–	–	–	–	0.729
Immense patience and tolerance is required to pursue physics	–	–	–	–	0.721
The progress of a physicist is rather slow	–	–	–	–	0.716
There is lack of job opportunities in physics	–	–	–	–	0.715
Physics is beneficial for those who want to pursue engineering courses	–	–	–	–	0.706
Physicist is a highly dedicated individual working toward the improvement of society	–	–	–	–	0.675
Physics as a vocation lacks creativity	–	–	–	–	0.670
Physicist spends his life by doing physics experiments	–	–	–	–	0.606
Studying physics at a higher level leads to glorious future	–	–	–	–	0.591
Physicists waste public money as all the research work does not have practical applications	–	–	–	–	0.584
Physicist generally remains isolated from society	–	–	–	–	0.580

Table 4 Factor correlation matrix obtained by factor analysis using direct oblimin rotation on 60 items ($n = 624$)

Factor	1	2	3	4	5
1	1.00	–	–	–	–
2	**0.63**	1.00	–	–	–
3	**0.45**	0.28	1.00	–	–
4	0.20	**0.37**	0.19	1.00	–
5	**0.58**	0.24	0.13	0.17	1.00

* Correlations > 0.30 are considered significant and indicated in bold

Table 5 Internal consistency values for the factors of the physics attitude scale

Factors	Cronbach alpha
Factor 1: enthusiasm toward physics	0.86
Factor 2: physics learning	0.78
Factor 3: physics as a process	0.80
Factor 4: physics teacher	0.75
Factor 5: physics as a future vocation	0.82
Total	0.89

them to plan to pursue a scientific career or have a science-related job (Fraser 1981; Fraser et al. 2010; Navarro et al. 2016). A positive correlation between physics teacher and physics learning ($r = 0.37$) demonstrates a relation between physics teacher and physics learning. This implies that the physics learning is influenced by physics teacher and the teaching methodology. The influence of pedagogical practices on attitudinal factors have been further supported in the studies by Redish et al. (1998), Adams et al. (2006), Juuti and Lavonen (2016). Most teaching practices cause significant decrease in students' physics scores and a decline in their interest to pursue the subject at higher levels.

The reliability of the physics attitude scale has been measured by computing Cronbach's alpha (α) reliability coefficient (Cronbach 1951). It is a measure of the internal consistency of a test or scale which lies between 0 and 1. Internal consistency reliability refers to the extent to which different items in a test measure the same construct. It depends upon the number of test items, inter-item correlation, and dimensionality. The acceptable values of alpha ranges from .70 to .95 (Bland and Altman 1997; DeVellis 2003, p. 27; Field 2009, p. 675; Tavako Dennick 2011). While Nunally (1978 p. 518) has pointed the threshold value of .7 for Cronbach's alpha coefficient, George and Mallery (2003) discussed the following thumb rule for the same: $\alpha \geq .9$ – Excellent, $\alpha \geq .8$ – Good, $\alpha \geq .7$ – Acceptable, $\alpha \geq .6$ – Questionable, $\alpha \geq .5$ – Poor, and $\alpha < .5$ – Unacceptable. A maximum alpha value of 0.90 has been recommended (Field 2009, p. 675; Streiner 2003). A high value of alpha (>0.90) may suggest that either some of the test items are redundant or the test is too lengthy (Cortina 1993; Nunnally and Bernstein 1994, p. 262; Streiner 2003; Tavakol and Dennick 2011). The internal consistency analysis of the instrument as a whole and each of the dimensions revealed a significant value of Cronbach Alpha coefficient. From Table 5, it follows that the values of Cronbach Alpha coefficient ranged between 0.75 and 0.89. The content validity of the Physics Attitude Scale was established by the close agreement of experts on the statements.

Summary and Conclusions

The present study encompasses the development and validation of PAS to measure students' attitudes toward physics. The development of the instrument has been carried out in a step-wise manner. The initial pool of statements was assimilated on the basis of literature review as well as by interviewing the experts and students. The initial draft was thoroughly reviewed by a panel of experts, and their recommendations were used to finalize the draft for pilot testing. This draft was administered to 152 students for pilot testing, and the feedback was used to further revise the draft. The revised draft was used to collect the responses from 624 students, aged 15–18 from different Government Model Senior Secondary Schools, India. The data were compiled by scoring the response sheets. The suitability of data for factor analysis was confirmed using the Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity. The factor analysis revealed that the final form of the scale comprises 60 items arranged under five dimensions namely: Enthusiasm toward Physics, Physics Learning, Physics as a Process, Physics Teacher and Physics as a Future Vocation. The factor correlation matrix further revealed that there is a positive correlation between (a) enthusiasm toward physics and physics learning ($r = 0.63$) (b) enthusiasm toward physics and physics as a process ($r = 0.45$) (c) enthusiasm toward physics and physics as future vocation ($r = 0.58$) (d) physics teacher and physics learning ($r = 0.37$). These results indicate the students enthusiastic toward physics are more eager toward learning of physics. This eagerness to learn the subject in turn yields a positive perception toward physics as a process. Such students exhibit a stronger tendency toward pursuing physics in higher education and opting physics as a career choice. A positive correlation between physics teacher and physics learning highlights that physics learning is influenced by physics teacher as well as teaching methodology.

From the results of the study, it follows that the PAS serves as an effective instrument with strong psychometric properties to measure the attitudes of the students toward physics and assess the changes taking place in their attitudes with regard to the physics teacher, teaching methodology, and curriculum. The improved attitudes of the students will stimulate student's interest in the subject and enhance the learning outcomes in physics. The positive attitudes toward physics will help the students in making better career choices in physics and other science related fields. The teachers can use the instrument to assess the attitude of students toward physics during the coursework. Accordingly, appropriate teaching strategies and classroom practices can be planned in the curriculum to make significant changes in the students' attitudes toward physics. Thus, the physics attitude scale developed in the present study will serve as an important instrument for the researchers and instructors to measure the students' attitudes toward physics.

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References

Aalderen-Smeets, S. I., & van der Molen, J. H. M. (2015). Improving primary teachers' attitudes toward science by attitude-focused professional development. *Journal of research in science teaching, 52*(5), 710–734. doi:10.1002/tea.21218.

Abd-El-Khalick, F., Summers, R., Said, Z., Wang, S., & Culbertson, M. (2015). Development and large-scale validation of an instrument to assess Arabic speaking students' attitudes toward science. *International Journal of Science Education, 37*(16), 2637–2663. doi:10.1080/09500693.2015.1098789.

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). New instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey. *Physical Review Special Topics-Physics Education Research, 2,* 010101. doi:10.1103/PhysRevSTPER.2.010101.

Ahlgren, A., & Walberg, H. J. (1973). Changing attitudes towards science among adolescents. *Nature, 24,* 187–190. doi: 10.1038/245187a0.

Aiken, L. R., & Aiken, D. R. (1969). Recent Research on Attitudes toward Science. *Science Education, 53,* 295–305. doi: 10.1002/sce.3730530405.

Akinbobola, A.O. (2010). Enhancing students' attitude towards Nigerian senior secondary school physics through the use of cooperative, competitive and individualistic learning strategies. *Australian Journal of Teacher Education*, 34, 1. Retrieved March 23, 2017 from http://ro.ecu.edu.au/ajte/vol34/iss1/1.

Anderhag, P., Emanuelsson, P., Wickman, P. O., & Hamza, K. M. (2013). Students' choice of post compulsory science. In search of schools that compensate for the socioeconomic background of their students. *International Journal of Science Education, 35*(18), 3141–3160.

Archibald, S. (2006). Narrowing in on educational resources that do affect student achievement. *Peabody Journal of Education, 81*(4), 23–42.

Azar, A. & Sengulec, O. A. (2011). Computer assisted and laboratory assisted teaching method in physics; the effect on students' physics achievement and attitude towards physics. *Eurasian Journal of Physics and Chemistry Education*, 43–50. Retrieved June 11, 2017 from http://www.eurasianjournals.com.

Baird, J. R., & Penna, C. (1992). Survey research. In R. Baird (Ed.), *Shared adventure: A view of quality teaching and learning (Second Report of the Teaching and Learning Science in Schools Project)* (pp. 185–274). Victoria: Monash University.

Bensaude-Vincent, B. (2002). A genealogy of the increasing gap between science and the public. *Public Understanding of Science, 10,* 99–113.

Blalock, C., Lichtenstein, M., Owen, S., Pruski, L., Marshall, C., & Toepperwein, M. (2008). In pursuit of validity: A comprehensive review of science attitude instruments 1935–2005. *International*

Journal of Science Education, 30(7), 961–977. doi:10.1080/09500690701344578.
Bland, J., & Altman, D. (1997). Statistics notes: Cronbach's alpha. *BMJ, 314,* 275. doi:10.1136/bmj.314.7080.572.
Boeck, C. H., & Washton, N. S. (1961). Science in the secondary school. *Review of Educational Research, 31,* 260–271.
Briggs, B. H. (1976). Student attitudes to physics. *Physics Education, 11*(7), 483–487. doi:10.1088/0031-9120/11/7/003.
Buabeng, I., Conner, L., & Winter, D. (2015). The lack of physics teachers: "Like a bath with the plug out and the tap half on". *American Journal of Educational Research, 3*(6), 721–730. doi:10.12691/education-3-6-9.
Cattell, R. B. (1966). The scree test for the number of factors. *Multivariate Behavioral Research, 1,* 245–276. doi:10.1207/s15327906mbr0102_10.
Chen, C. H., & Howard, B. (2010). Effect of live simulation on middle school students' attitudes and learning toward science. *Educational Technology & Society, 13*(1), 133–139.
Chen, C. H., Wu, I. C., & Jen, F. L. (2013). Designing online scaffolds for interactive computer simulation. *Interactive Learning Environments, 21*(3), 229–243. doi:10.1080/10494820.2010.549831.
Christidou, V. (2006). Greek students science-related interests and experiences: Gender differences and correlations. *International Journal of Science Education, 28,* 1181–1199.
Christidou, V. (2011). Interest, attitudes and images related to science: Combining students' voices with the voices of school Science, teachers, and popular science. *International Journal of Environmental and Science Education, 6*(2), 141–159.
Continuous Comprehensive Evaluation in Science (2011). State Council of Educational Research and Training (SCERT). New Delhi.
Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology, 78,* 98–104. doi:10.1037/0021-9010.78.1.98.
Costello, A. B., & Jason, W. O. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research & Evaluation, 10*(7), 1–9.
Cronbach, L. (1951). Coefficient alpha and the internal structure of tests. *Psychomerika, 16,* 297–334. doi:10.1007/BF02310555.
Deb, S., Strodl, E., & Sun, J. (2015). Academic stress, parental pressure, anxiety and mental health among Indian high school students. *International Journal of Psychology and Behavioral Sciences, 5*(1), 26–34. doi:10.5923/j.ijpbs.20150501.04.
Dekkers, J., & DeLaeter, J. (2001). Enrolments trends in school science education in Australia. *International Journal of Science Education, 2,* 487–500.
DeVellis, R. (2003). *Scale development: Theory and Applications*. Thousand Oaks: Sage.
DuBois, B., & Burns, J. A. (1975). An analysis of the meaning of the question mark response category in attitude scales. *Educational and Psychological Measurement, 35,* 869–884.
Dumas, J. (1999). Usability testing methods: Subjective measures, part II—Measuring Attitudes and Opinions. American Institute for Research. Retrieved March 4, 2015 from http://documents.mx/education/summary-of-usability-testing-methods-subjective-measures-part-i-and-ii-by-joe-dumas.html.
Durant, J. & Bauer, M. (1997). *Public understanding of science: the 1996 survey*. Paper presented at a seminar at the Royal Society. Retrieved December 8, 1997.
Durant, J. R., Evans, G. A., & Thomas, G. P. (1989). The public understanding of Science. *Nature, 340,* 11–14.
Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Fort Worth: Harcourt.
Erdemir, N. (2009). Determining students' attitude towards physics through problem-solving strategy, Asia-Pacific. *Forum on Science Learning and Teaching*, 10(2). Retrieved February 8, 2015 from http://www.ied.edu.hk/apfslt/v10_issue2/erdemir/erdemir8.htm.
Elby, A. Frederiksen, J. Schwarz, C. & White, B. (2006). Epistemological Beliefs Assessment about Physical Science (EBAPS). Retrieved January 17, 2015 from http://www2.physics.umd.edu/~elby/EBAPS/home.htm.
Eyesenck, M. (1998). *Psychology: An integrated approach*. Essex: Addison Wesley Longman.
Field, A. (2009). *Discovering statistics using SPSS*. London: Sage.
Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research*. Reading: Addison-Wesley.
Fraser, B. (1981). *Test of science related attitudes (TOSRA)*. Melbourne: Australian Council for Educational Research.
Fraser, B., Aldridge, J., & Adolphe, F. (2010). A cross-national study of secondary science classroom environments in Australia and Indonesia. *Research in Science Education, 40*(4), 551–571. doi:10.1007/s11165-009-9133-1.
Fraser, B., & Fisher, D. L. (1982). Effects of anxiety on science-related attitudes. *European Journal of Science Education, 4,* 441–450.
Gardner, P. (1975). Attitudes to science: A review. *Studies in Science Education, 2,* 1–41. doi:10.1080/03057267508559818.
Garg, K., & Gupta, B. (2003). Decline in science education in India: A case study at +2 and undergraduate level. *Current Science, 84,* 1198–1201.
Gauld, C. F., & Hukins, A. A. (1980). Scientific attitudes: A review. *Studies in Science Education, 7*(1), 129–161.
George, D., & Mallery, P. (2003). *SPSS for windows step by step: A simple guide and reference*. Boston: Allyn & Bacon.
Germann, P. J. (1988). Development of the attitude toward science in school assessment and its use to investigate the relationship between science achievement and attitude toward science in school. *Journal of Research in Science Teaching, 25*(8), 689–703.
Greenfield, T. A. (1996). Gender, ethnicity, science achievement and attitudes. *Journal of Research in Science Teaching, 33,* 901–993.
Hadden, R. A., & Johnstone, A. H. (1983). Secondary school pupils' attitudes to science: the year of erosion. *European Journal of Science Education, 5,* 309–318.
Haladyna, T., Olsen, R., & Shaugnessy, J. (1983). Correlates of class attitude toward science. *Journal of Research in Science Teaching, 20*(4), 311–324.
Haladyna, T., & Shaughnessy, J. (1982). Attitudes towards science: A qualitative synthesis. *Journal of Research in Science Teaching, 66*(4), 547–563.
Halloun, I. & Hestenes, D. (1996). Views about sciences survey VASS. In proceedings of the International Conference on Undergraduate Physics Education, College Park, Maryland. Retrieved January 28, 2015 from http://files.eric.ed.gov/fulltext/ED399182.pdf.
Häussler, P., & Hoffmann, L. (2000). A curricular frame for Physics education: Development, comparison with students interests, and impact on students achievement and self-concept. *Science Education, 84,* 689–705.
Hendley, D., Parkinson, J., Stables, A., & Tanner, H. (1995). Gender differences in pupil attitudes to the national curriculum foundation subjects of English, mathematics, science and technology in Key Stage 3 in South Wales. *Educational Studies, 21,* 85–97.
Hillman, S. J., Zeeman, S. I., Tilburg, C. E., & List, H. E. (2016). My attitudes toward science (MATS): the development of a multidimensional instrument measuring students' science attitudes. *Learning Environment Research, 19,* 203–219. doi:10.1007/s10984-016-9205-x.

Horn, J. L. (1965). A rationale and test for the number of factors in factor analysis. *Psychometrika, 30,* 179–185. doi:10.1007/BF02289447.

Juuti, K., & Lavonen, J. (2016). How teaching practices are connected to student intention to enrol in upper secondary school physics courses. *Research in Science & Technological Education*. doi:10.1080/02635143.2015.1124848.

Kahle, J., & Lakes, M. (1983). The myth of equality in science classrooms. *Journal of Research in Science Teaching, 20,* 131–140.

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement, 20,* 141–151. doi:10.1177/001316446002000116.

Kennedy, J., Quinn, F., & Taylor, N. (2016). The school science attitude survey: a new instrument for measuring attitudes towards school science. *International Journal of Research & Method in Education, 39*(4), 422–445. doi:10.1080/1743727X.2016.1160046.

Kline, P. (1994). *An easy guide to factor analysis*. London: Routledge.

Klopfer, L. (1971). Evaluation of learning in science. In B. S. Bloom, J. T. Hastings, & G. F. Madaus (Eds.), *Handbook on summative and formative evaluation of student learning* (pp. 559–642). New York: McGraw-Hill.

Koballa, T. R. (1983). Comments on 'The development of the image of science and scientists scale'. *Journal of Research in Science Teaching, 20*(6), 595–597. doi:10.1002/tea.3660200613.

Koballa, T. R., Jr. (1988). Attitude and related concepts in science education. *Science Education, 72,* 115–126. doi:10.1002/sce.3730720202.

Koballa, T. R., Jr., & Glynn, S. M. (2007). Attitudinal and motivational constructs in science learning. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 75–102). Mahwah: Lawrence Erlbaum.

Kulas, J. T., Stachowski, A. A., & Haynes, B. A. (2008). Middle response functioning in Likert-responses to personality items. *Journal of Business and Psychology, 22,* 251–259. doi:10.1007/s10869-008-9064-2.

Laforgia, J. (1988). The affective domain related to science education and its evaluation. *Science Education, 72,* 407–421.

Lawshe, C. H. (1975). A quantitative approach to content validity. *Personnel Psychology, 28,* 563–575. doi:10.1111/j.1744-6570.1975.tb01393.x.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39,* 497–521. doi:10.1002/tea.10034.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology, 140,* 1–55.

Luchembe, D., Chinyama, K., & Jumbe, J. (2014). The effect of using concept mapping on student's attitude and achievement when learning the physics topic of circular and rotational motion. *European Journal of Physics Education, 5*(4), 10–29.

Mager, R. (1968). *Developing attitude toward learning*. Palo Alto: Fearon.

Maloney, D. P., O'Kuma, T. L., Hieggelke, C. J., & Heuvelen, A. V. (2001). Surveying students' conceptual knowledge of electricity and magnetism. *American Journal of Physics, 69*(S1), 12–23. doi:10.1119/1.1371296.

Mattern, N., & Schau, C. (2002). Gender difference in attitude-achievement relationships over time among white middle-school students. *Journal of Research in Science Teaching, 39*(4), 324–340. doi:10.1002/tea.10024.

McDermott, L. C. (2001). Oersted medal lecture 2001: Physics education research-the key to student learning. *American Journal of Physics, 69*(11), 1127–1137. doi:10.1119/1.1389280.

Meltzer, D. (2005). Relation between students' problem-solving performance and representational format. *American Journal of Physics, 73*(5), 463–478. doi:10.1119/1.1862636.

Miller, J. D., Pardo, R., & Niwa, F. (1997). *Public perceptions of science and technology: A comparative study of the European Union, the United States, Japan, and Canada*. Madrid: BBV Foundation.

Munby, H. (1983). Thirty studies involving the "Scientific Attitude Inventory': What confidence can we have in this instrument? *Journal of Reassert in Science teaching, 20*(2), 141–162.

Myers, R. E., & Fouts, J. T. (1992). A cluster analysis of classroom environments and attitude toward science. *Journal of Research in Science Teaching, 29,* 929–937. doi:10.1002/tea.3660290904.

National Curriculum Framework (2005). National Council of Educational Research and Training (NCERT). New Delhi.

Navarro, M., Förster, C., González, C., & GonzálezPose, P. (2016). Attitudes toward science: measurement and psychometric properties of the Test of science-related attitudes for its use in Spanish-speaking classrooms. *International Journal of Science Education, 38*(9), 1459–1482. doi:10.1080/09500693.2016.1195521.

Neathery, F.M. (1997). Elementary and secondary students' perceptions toward science and the correlation with gender, ethnicity, ability, grade, and science achievement. *Electronic Journal of Science Education*, 2(1). Retrieved January 4, 2015 from http://unr.edu/homepage/jcannon/ejse/ejsev2n1.html.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory*. New York: McGrawHill.

Nunnaly, J. (1978). *Psychometric theory*. New York: McGraw-Hill.

Oon, P.-T., & Subramaniam, R. (2010). Views of physics teachers on how to address the declining enrolment in physics at the University level. *Research in Science & Technological Education, 28*(3), 277–289. doi:10.1080/02635143.2010.501749.

Ormerod, M., & Duckworth, D. (1975). *Pupils' attitudes to science*. Slough: National Foundation for Educational Research.

Osborne, J., & Collins, S. (2001). Students' views of the role and value of the science curriculum: a focus-group study. *International Journal of Science Education, 23,* 441–467.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes toward science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079. doi:10.1080/0950069032000032199.

Pearl, R. E. (1973). The present status of science attitude measurement: history, theory and availability of measurement instruments. *School Science and Mathematics, 73,* 375–381.

Pell, A. W., & Manganye, H. T. (2007). South African primary children's attitudes to science. *Evaluation and Research in Education, 20*(3), 121–143.

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: a systematic review of 12 years of educational research. *Studies in Science Education, 50*(1), 85–129. doi:10.1080/03057267.2014.881626.

Redish, E. F., Saul, J. M., & Steinberg, R. N. (1998). Student expectations in introductory physics. *American Association of Physics Teachers, 66,* 212–224. doi:10.1119/1.18847.

Rivard, L. P., & Straw, S. P. (2000). The effect of talk and writing on learning science: An exploratory study. *Science Education, 84,* 566–593. doi:10.1002/1098-237X(200009)84:5<566.

Roysircar, G., Carey, J., & Koroma, S. (2010). Asian Indian college students' science and math preferences: Influences of cultural contexts. *Journal of Career Development, 36,* 324–347. doi: 10.1177/0894845309345671.

Rutten, N., van der Veen, J. T., & van Joolingen, W. R. (2015). Inquiry-based whole-class teaching with computer simulations in physics. *International Journal of Science Education*. doi: 10.1080/09500693.2015.1029033.

Schibeci, R. (1984). Attitudes to science: An update. *Studies in Science Education, 11,* 26–59.

Schibeci, R. A. (1989). Home, school, and peer group influences on student attitudes and achievement in science. *Science Education, 73,* 13–24.

Schibeci, R. A., & Riley, J. P. (1986). Influence of students' background and perceptions on science attitudes and achievement. *Journal of Research in Science Teaching, 23,* 177–187.

Semela, T. (2010). Who is joining physics and why? Factors influencing the choice of physics among Ethiopian university students. *International Journal of Environmental and Science Education, 5,* 319–340.

Sharma, S. K. (2014). Reforms in Examination and Education System: "India has examination system, not education system". *International Journal of Research, 1*(5), 100–111.

Simpson, R. D., & Oliver, J. S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education, 74,* 1–18.

Smart, J. B., & Marshall, J. C. (2012). Interactions between classroom discourse, teacher questioning, and student cognitive engagement in middle school science. *Journal of Science Teacher Education, 24,* 249–267.

Smithers, A., & Robinson, P. (1988). *The growth of mixed A-levels*. Manchester: University of Manchester, Department of Education.

Stocklmayer, S. M., & Bryant, C. (2012). Science and the public-What should people know? *International Journal of Science Education, 2*(1), 81–101. doi:10.1080/09500693.2010.543186.

Stone, M. H. (2004). Substantive scale construction. In E. V. Smith Jr. & R. M. Smith (Eds.), *Introduction to Rasch measurement* (pp. 201–225). Maple Grove: JAM Press.

Streiner, D. (2003). Starting at the beginning: an introduction to coefficient alpha and internal consistency. *Journal of Personality Assessment, 80,* 99–103. doi:10.1207/S15327752JPA8001_18.

Sundberg, M., Dini, M., & Li, E. (1994). Decreasing course content improves student comprehension of science and attitudes toward science among adolescent students. *Journal of Research in Science Teaching, 31,* 679–693.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics*. Boston: Pearson.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education, 2,* 53–55. doi:10.5116/ijme.4dfb.8dfd.

Trumper, R. (2006). Factors affecting junior high school students' interest in physics. *Journal of Science Education and Technology, 15*(1), 47–58. doi:10.1007/s10956-006-0355-6.

Tytler, R. (2014). Attitudes, identity, and aspirations toward science. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (Vol. II, pp. 82–103). New York: Routledge.

Tytler, R., & Osborne, J. (2012). Student attitudes and aspirations towards science. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (Vol. 1, pp. 597–625). Dordrecht: Springer, Netherlands.

Van Rensburg, S., Ankiewicz, P., & Myburgh, C. (1999). Assessing South African learners' attitudes towards technology by using the PATT (pupils' attitudes towards technology) questionnaire. *International Journal of Technology and Design Education, 9*(2), 137151.

Velicer, W. F., & Fava, J. L. (1998). Effects of variable and subject sampling on factor pattern recovery. *Psychological Methods, 3*(2), 231–251.

Verma, S., Sharma, D., & Larson, R. W. (2002). School stress in India: Effects on time and daily emotions. *International Journal of Behavioral Development, 26*(6), 500–508. doi:10.1080/01650250143000454.

Walberg, H. J. (1976). The psychology of learning environments: behavioral, structural, or perceptual? *Review of Research in Education, 4,* 142–178.

Wang, T. L., & Berlin, D. (2010). Construction and validation of an instrument to measure Taiwanese elementary students' attitudes toward their science class. *International Journal of Science Education, 32*(18), 2413–2428. doi:10.1080/09500690903431561.

Woolnough, B. E. (1994). Why students choose physics, or reject it. *Physics Education, 29,* 368–374. doi:10.1088/0031-9120/29/6/006.

Yashpal Committee report MHRD. (1992). "Learning without Burden"- a Report of the National Advisory Committee appointed by the Ministry of Human Resource Development, Department of Education, Govt. of India].

Zacharia, Z. (2003). Beliefs, attitudes, and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics. *Journal of Research in Science Teaching, 40,* 792–823. doi:10.1002/tea.10112.