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The Development and Validation of Learning Attitudes about Physics (LAAP) Inventory

Pembangunan dan Pengesahan Inventori Sikap Pembelajaran terhadap Fizik

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Abstract

Learning Attitudes about Physics (LAAP) inventory is an instrument designed to measure students' beliefs about physics and learning physics. This instrument was psychometrically adapted from the Colorado Learning Attitudes about Science Survey or CLASS (Adams et al., 2006), resulting in three clusters or factors of empirically determined groupings of statements that are grounded on 132 Malaysian university physics students' responses. The first factor, consisting of 10 items, reflects students' attitude towards an interest in metacognition as evidenced in their affinity in thinking, problem solving, relating, and establishing relationships amongst variables. The second 3-item factor reflects students' attitude towards learning physics, a composite view of what constitute the knowledge in physics, what step to take when the outcome in solving a problem is not as expected, and understanding physics formulas. Finally, a group of 3 items that forms the third factor reflects students' attitude towards applying physics. The overall percentage mean for interest in metacogntion, learning physics, and applying physics are 73.19, 72.58, and 60.40 respectively. Using the two-third rule, the findings suggest that students have a rather positive attitude towards an interest in metacognition and learning physics while the attitude towards applying physics was less favourable. However, there were no significant differences between the males and females across the three factors.

Keywords Physics learning attitude, metacognition, beliefs

Abstrak

Inventori Sikap Pembelajaran terhadap Fizik merupakan instrumen yang direka bentuk untuk mengukur kepercayaan pelajar tentang fizik dan pembelajaran fizik. Instrumen ini diadaptasi secara psikometrik daripada *Colorado Learning Attitudes about Science Survey* atau CLASS (Adams et al., 2006), yang menghasilkan tiga kluster atau faktor secara empirik melalui pengelompokan penyataan yang didasarkan ke atas 132 respon pelajar fizik universiti di Malaysia. Faktor pertama yang mengandungi 10 item, mewakili sikap pelajar terhadap minat dalam metakognisi yang dapat dilihat melalui kecenderungan berfikir, menyelesaikan masalah, mengaitkan, dan mewujudkan perkaitan antara pembolehubah. Faktor kedua yang mengandungi 3 item mewakili sikap pelajar terhadap pembelajaran fizik, iaitu gabungan pandangan tentang apakah itu pengetahuan fizik, apakah langkah-langkah yang harus diambil apabila hasil sesuatu penyelesaian masalah tidak seperti yang diharapkan, dan kefahaman tentang fomula fizik.

Akhirnya, sekumpulan 3 item membentuk faktor ketiga yang mewakili sikap pelajar terhadap aplikasi fizik. Min keseluruhan bagi minat terhadap metakognisi, pembelajaran fizik, dan mengaplikasi fizik adalah masing-masing 73.19, 72.58, dan 60.40. Menggunakan peraturan dua pertiga, dapatan menunjukkan bahawa pelajar mempunyai sikap yang agak positif dari segi minat terhadap metakognisi dan pembelajaran fizik manakala sikap terhadap aplikasi fizik adalah lebih rendah. Walau bagaimanapun, tidak terdapat perbezaan yang signifikan antara lelaki dan perempuan bagi ketiga-tiga faktor tersebut.

Kata Kunci Sikap terhadap pembelajaran fizik, metakognisi, kepercayaan

Introduction

The development of positive attitudes toward science has been one of the legitimate goals of science education globally. As such, it is unsurprising to note a considerable agreement among science educators on the importance of students' attitudes toward science lessons in school (Osborne, Simon, & Collins, 2003). Research on academic achievement points to a strong association between science achievement and science attitudes (Cannon & Simpson, 1985; Freedman, 1997; Schibeci & Riley, 1986). For example, Oliver and Simpson (1998) reported that achievement is positively and significantly correlated with students' self-concept of their ability in science.

The strong link between achievement and attitudes has prompted Gray (1996) to advise researchers on the importance of attitudinal measures when making an academic comparison between schools or gender. This piece of advice seems to be followed in international comparisons such as the **Trends in International Mathematics and Science Study** (TIMSS) undertaken in 1995, 1999, 2003, and 2007 that compared mathematics and science achievement of U.S. 4th- and 8th-grade students to that of students in other countries. For example, in TIMSS 1999 International Science Report (Martin et al., 2000), students' attitudes towards science was one of the ways to elicit information that could provide an educational context for interpreting the science achievement results.

Research in science education at institutions of higher learning indicates that students' attitudes, beliefs and expectations shape and are shaped by their classroom experience (Branford, Brown, & Cocking, 2002; Redish, 2003, Seymour & Hewitt, 1997). For example, work by Sadler and Tai (2001) indicate that students' expectations are better predictors of college science performance than the amount of high-school science or mathematics they completed. House (1995) reported that students' achievement expectations and academic self-concept were more significant predictors of chemistry achievement than were students' prior achievement and their prior instructional experience.

A review of the literature in attitudinal measures shows that attitude is a multidimensional construct and that ensuring items are indicative of attitude is crucial (Bennett et al., 2001). If an attitude scale contains an ill-defined hodge-podge of different items, and student responses are summarised as an average of these items, then what is being measured is questionable, misleading, meaningless and unreliable. In fact, Henderleiter and Pringle (1999) have cautioned that the validity of many attitude instruments is so notorious that science researchers do not trust the quantitative data generated by these instruments.

In addressing this problematic situation, Tapia and Marsh (2004, p.17) emphasised that 'attitude scales must withstand factor analysis, tap important dimensions of attitudes, and require a minimum amount of time for administration'. Factor analysis provides psychometric evidence for construct validity. Accordingly, Messick (1989) reckons that a systematic examination of the construct validity of attitudinal data is most critical because construct validity subsumes content relevance, content representativeness, and criterion-relatedness, and is the evidential basis of interpretation of data as well as the use of data.

Besides, researchers (i.e., Krosnick et al., 2005; Mayer & Richmond, 1982; Munby, 1997; Ramsden, 1998) have also criticised on the occurrence of an extensive duplication of effort in the development of attitude instruments. As a possible alternative, Mayer and Richmond (1982) recommended that efforts should be directed towards the revision or refinement of existing instruments.

In respond to the suggestions by Mayer and Richmond (1982) and Tapia and March (2004), this paper reports how we modified Colorado Learning Attitudes and Science Survey (CLASS) -- an instrument developed and validated by Adams et al. (2000) that measures students' beliefs about physics and learning physics. This instrument was chosen because it was developed by way of capitalising on a number of existing surveys that have been created to measure various aspects of students' beliefs and expectations, particularly the Maryland Physics Expectations Survey (MPEX) (Redish, Saul, & Steinberg, 1998) and Views About Science Survey (VAAS) (Holloun, 1997).

Framework of CLASS

There are 42 statements in CLASS that students respond on a 5-point Likert scale (agree to disagree) and the responses are scored overall and in eight categories. The eight categories, as claimed by Adams et al. (2000), were empirically determined groupings of statements based on student responses as opposed to *a priori* groupings of statements according to survey creators' beliefs and assumptions without psychometric evidence. Table 1 summarises the eight categories in CLASS while Appendix 1 itemises the statements for each of the eight categories.

Table 1 Eight categories in CLASS.

No	Categories	Statements
1	Real World Connection	25, 27, 30, 32
2	Personal Interest	3, 8, 11, 22, 25, 27
3	Sense Making/Effort	8, 20, 21, 28, 31, 34, 36
4	Conceptual Connections	1, 4, 5, 10, 18, 28
5	Applied Conceptual Understanding	1, 4, 5, 6, 18, 19, 35
6	Problem Solving General	10, 12, 13, 22, 23, 29, 35, 36
7	Problem Solving Confidence	12, 13, 29, 35
8	Problem Solving Sophistication	4, 18, 19, 22, 29, 35

While the development of CLASS has indeed gone through three of robust cycles (or iterations) culminating in CLASS version 3, we nevertheless were apprehensive of the overlapping of statements between and among categories. For example, statements 1, 4 and 5 were shared by categories of conceptual connections and applied conceptual understanding, while statement 35 was shared among three categories, namely applied conceptual understanding, problem solving confidence, and problem solving sophistication. Besides, while CLASS purports to provide a clear understanding of student ideas that were being identified through statistical analyses of American students' responses, it does not, however, represent the views and ideas of Malaysian students at higher institutions. As such, the responses gathered using CLASS should be statistically analysed so that the categories that emerged are grounded on Malaysian students' responses.

Development and Validation of Learning Attitudes About Physics (LAAP)

LAAP was psychometrically adapted from CLASS (Adams et al., 2006) using the responses of 132 physics students at Universiti Pendidikan Sultan Idris. Although the CLASS Version 3 has 42 items, 6 were eventually discarded in the improved version as they were deemed "not useful in their current form" (ibid., p.13). Exploratory factor analysis was used to examine whether, on the basis of students' responses to the 36 items in CLASS, a smaller number of factors could be identified. This 'inductive approach to scaling' (De Vaus, 2001, p.257) clusters items that 'go together', reflecting the sets of items students responded to in a consistent way. As such, these empirically determined clusters of statements are robust, valid and Malaysian-based given that they are grounded on Malaysian physics students' responses.

Factor Analysis

There are 36 five-point Likert scale statements in CLASS, each has a value from 1 to 5 with 1 for strong disagree, 2 for disagree, 3 for neutral, 4 for agree, and 5 for strongly agree. In educational research, it is acceptable to assume the characteristics of Likert scale as either an interval scale or an ordinal scale. The former entails the assumption that the spacing between each of these values (1 to 5) bearing equal weight, hence amenable to parametric statistics. The latter, by contrast, assumes that the spacing between each possible response is not of equal difference, and as such is suitably analysed with non-parametric statistics. The overall internal reliability, established using Cronbach's coefficient alpha, was measured at 0.80, indicating that the 36 items in CLASS have high internal consistency.

When subjected to principal components factor analysis with varimax rotation, 12-factor solution emerges on the basis of retaining factors with eigenvalues greater than 1 (Kaiser, 1960). Varimax rotation was chosen because it produces "factors that are unrelated to or independent of one another" (Bryman & Cramer, 1998, p. 284) and hence, "are easy to interpret" (Brace, Kemp, & Snelgar, 2003, p.304). Meanwhile, an eigenvalue is a "measure that attaches to factors and indicates the amount of variance in the pool of original variables that the factor explains… [and] to be retained, factors must have an eigenvalue greater than 1" (De Vaus, 2001, p.261). However, while the factors attracted substantial loadings from certain items, these items were not distinct as they failed to fall into coherent factors. Some have multiple loadings while others have much lower loadings as compared to the rest of the items that loaded onto the same factor.

This problematic scenario prompted a series of factor analyses for comparison, each time specifying a different number of factors as suggested by Tabachnick and Fidell (1996). When 12-, 8-, 4- and 3-factor models were explored, the adequacy and plausibility of extraction favoured the 3-factor model. In essence, the 3-factor model provides a more comprehensible factor structure and has the least number of residuals with absolute values exceeding 0.05 as compared to other models, suggesting a good analysis. Additionally, after the removal items with either low communalities or multiple loadings, the remaining items loaded persuasively into 3 coherent factors, which taken together, account for 42.62% of the total variance explained. Table 2 shows the results of 3-factor model loadings.

The first group of 10 items seems to be factorially distinct, all with loadings greater than 0.50 on Factor 1. Taken together, this group of items, which forms Factor 1, reflects an attitude towards an interest in metacognition as evidence in their affinity in thinking, problem solving, relating, and establishing relationships amongst variables. Therefore, it is best labelled as *Interest in Metacognition.*

The second factor, which seems to reflect students' attitude towards learning physics, a composite view of what constitute the knowledge in physics, what step to take when the outcome in solving a problem is not as expected, and understanding physics formulas, is composed of three items with factor loadings between 0.44 and 0.76. Therefore, the second factor is best labelled as *Learning Physics.*

The third factor is most strongly associated with three items with factor loadings between 0.57 and 0.70. Taken together, this group of items reflects students' attitude towards applying physics as evidenced in solving problems in similar conditions, applying formulae after having made sense of them, and solving problems with regard to a topic after having understood that particular topic. Therefore, it is best labelled as *Applying Physics.*

On internal consistency reliability, the subscale reliabilities for factors 1, 2, and 3 were found to be at 0.68, 0.50 and 0.40 respectively. While De Vaus (2001) recommended at least 0.7 for a scale (or subscale) to be rendered reliable, Gay and Airasian (2000) argued that it is extremely difficult to state appropriate reliability coefficients for different types of scales because reliability is "dependent on the group being tested" and that when scales are developed in new areas, "reliability often is low initially" (p.177). As such, the internal reliabilities for factors 1 through 3 respectively seem to be average, marginal and inadequate. Hence, the analysis arising from factors 2 and 3 thereof need to be treated with caution.

Table 2 Factor Loadings for the Varimax Rotated Factors.

Item		Factor Loadings		
		1	2	3
	Interest in Metacognition			
12	If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works.	.76		
34	When I solve a physics problem, I explicitly think about which physics ideas apply to the problem.	.64		
6	When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.	.64		
31	There are times I solve a physics problem more than one way to help my understanding.	.58		
22	I enjoy solving physics problems.	.58		
3	I think about the physics I experience in everyday life.	.57		
36	When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.	.55		
23	In physics, mathematical formulas express meaningful relationships among measurable quantities.	.54		

11	I study physics to learn knowledge that will be useful in my life outside of school.	.52		
32	To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.	.50		
	Learning Physics			
5	Knowledge in physics consists of many disconnected topics.		.76	
20	In doing a physics problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.		.70	
28	Spending a lot of time understanding where formulas come from is a waste of time.		.44	
	Applying Physics			
19	If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.			.70
21	In physics, it is important for me to make sense out of formulas before I can use them correctly.			.64
4	After I study a topic in physics and feel that I have understood it, I have difficulty solving problems on the same topic.			.57
	Eigenvalues	3.96	1.50	1.37
	% of variance	24.73	9.34	8.55
	Cronbach's Alpha	0.68	0.50	0.40

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Analysis by Categories

Table3 Descriptive Analysis of Data in LAAP

Categories	Number of items	Mean Score	Percentage Mean	SD
Interests in Metacognition	10	36.60	73.19	8.16
Learning Physics	3	10.89	72.58	15.42
Applying Physics	3	9.06	60.40	10.15

Table 3 shows the results of the descriptive analysis in terms of the new categories. The overall percentage mean for interest in metacognition, learning physics, and applying physics are 73.19, 72.58, and 60.40 respectively. Using the two-third rule, the findings suggest that students have a rather positive attitude towards an interest in metacognition and learning physics while the attitude towards applying physics was less favourable.

Table 4 Results Obtained for Categories in LAAP by Gender Using the t-test for Unpaired Samples

Categories	Males (n=20)		Females (n=112)			
	Mean	SD	Mean	SD	t	p
Interests in Metacognition	37.65	4.82	36.41	3.93	1.26	.21
Learning Physics	10.60	2.85	10.94	2.21	0.60	.55
Applying Physics	8.80	1.40	9.11	1.54	0.83	.41

Table 4 shows the results of comparison by gender across the categories in LAAP using a t-test for unpaired samples. As shown in Table 4, the t-test for unpaired samples yielded a t of 1.26, 0.60, and 0.83 respectively for interest in metacognition, learning physics, and applying physics which was not statistically significant ($p > .05$). This suggests that there were no significant differences between the males and females across the three categories.

Conclusion and discussion.

The 36-item CLASS was not wholly supported by statistical analysis, casting doubts on the eight category (subscale) concepts. This could be explained by the incongruence between Malaysian respondents' understanding and the wording of items used to portray the American college students' ideas inherent in CLASS. By revising the categories by means of iterative principal components factor analysis with varimax rotation, three coherent factors emerged. These factors explain, reflect and represent the way in which 132 Malaysian university physics students collectively perceive their attitudes towards physics. This line of argument is consistent with the findings of Aldridge and Fraser (1997) who acknowledge the occurrence of different interpretation to some of their questionnaire items from the way intended.

Nunnally (1967) recommends the threshold of 0.60 for the alpha reliability coefficient as being acceptable for research purposes. The post-hoc subscale reliabilities indicate that, while Factor 1 (Interest in Metacognition) meets the adequate level of reliability, Factors 2 (Learning Physics) and 3 (Applying Physics) fail to do so. Therefore, results for the Factors 2 and 3 of in LAAP need to be interpreted with caution.

In terms of two-third rule (i.e., above 67%), the Malaysian physics students indicated an adequate level of attitudes toward an interest in metacognition and in learning physics, but failed to meet the benchmark for attitudes toward applying physics. This may be explained by the ubiquitous perception of difficulty in learning physics among students (Ornek, Robinson, & Haugan, 2008) in general, and in applying physics among university physics students in particular. While this finding was derived from the self-reports of university physics students, similar pattern remains to be seen should the questionnaire be administered to university biology, chemistry, and mathematics student teachers, hence providing an avenue for future research.

In terms of gender difference across the three categories in LAAP, namely attitudes toward an interest in metacognition, learning physics, and applying physics, no markedly differences by gender were registered. This indicates that male and female undergraduate physics students perceived at an almost similar level for LAAP despite the previous findings that indicate females generally performed much better than males in terms if academic achievement. This gives rise to yet another avenue for further investigation in that whether or not such observed phenomenon is pervasive in the university regardless of students' specialisation, or does it only occur amongst physics students.

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Itemisation for each category in Colorado Learning Attitudes and Science Survey CLASS

F1	**Real World Connection**
25	Learning physics changes my ideas about how the world works.
27	Reasoning skills used to understand physics can be helpful to me in my everyday life.
30	The subject of physics has little relation to what I experience in the real world.
32	To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.
F2	**Personal Interest**
3	I think about the physics I experience in everyday life.
8	I am not satisfied until I understand why something works the way it does.
11	I study physics to learn knowledge that will be useful in my life outside of school.
22	I enjoy solving physics problems.
25	Learning physics changes my ideas about how the world works.
27	Reasoning skills used to understand physics can be helpful to me in my everyday life.
F3	**Sense Making/Effort**
8	I am not satisfied until I understand why something works the way it does.
20	In doing a physics problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.
21	In physics, it is important for me to make sense out of formulas before I can use them correctly.
28	Spending a lot of time understanding where formulas come from is a waste of time.
31	There are times I solve a physics problem more than one way to help my understanding.

34	When I solve a physics problem, I explicitly think about which physics ideas apply to the problem.
36	When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.
F4	**Conceptual Connections**
1	A significant problem in learning physics is being able to memorize all the information I need to know.
4	After I study a topic in physics and feel that I have understood it, I have difficulty solving problems on the same topic.
5	Knowledge in physics consists of many disconnected topics.
10	I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.
18	If I don’t remember a particular equation needed to solve a problem on an exam, there’s nothing much I can do (legally!) to come up with it.
28	Spending a lot of time understanding where formulas come from is a waste of time.
F5	**Applied Conceptual Understanding**
1	A significant problem in learning physics is being able to memorize all the information I need to know.
4	After I study a topic in physics and feel that I have understood it, I have difficulty solving problems on the same topic.
5	Knowledge in physics consists of many disconnected topics.
6	When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.
18	If I don’t remember a particular equation needed to solve a problem on an exam, there’s nothing much I can do (legally!) to come up with it.
19	If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.
35	If I get stuck on a physics problem, there is no chance I’ll figure it out on my own.
F6	**Problem Solving General**
10	I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.
12	If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works.
13	Nearly everyone is capable of understanding physics if they work at it.
22	I enjoy solving physics problems.
23	In physics, mathematical formulas express meaningful relationships among measurable quantities.
29	I can usually figure out a way to solve physics problems.
35	If I get stuck on a physics problem, there is no chance I’ll figure it out on my own.
36	When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.
F7	**Problem Solving Confidence**
12	If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works.
13	Nearly everyone is capable of understanding physics if they work at it.
29	I can usually figure out a way to solve physics problems.
35	If I get stuck on a physics problem, there is no chance I’ll figure it out on my own.
F8	**Problem Solving Sophistication**
4	After I study a topic in physics and feel that I have understood it, I have difficulty solving problems on the same topic.
18	If I don’t remember a particular equation needed to solve a problem on an exam, there’s nothing much I can do (legally!) to come up with it.

19	If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.
22	I enjoy solving physics problems.
29	I can usually figure out a way to solve physics problems.
35	If I get stuck on a physics problem, there is no chance I'll figure it out on my own.