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Reliability and Validity of Colorado Learning Attitudes about Science Survey (CLASS)

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Abstract

This study aimed to propose revisions in the psychometric properties of Colorado Learning Attitudes for Science Survey (CLASS) based on the evidence found from this study. CLASS is a 42-item instrument that measures students' attitudes towards physics and learning physics. In determining the validity of CLASS, 227 senior high school students from different schools in Metro Manila and in Cavite, Philippines participated in the study. Statements in CLASS underwent exploratory factor analysis through principal factor analysis to determine its factor structure. Results showed that from the original 42 items in CLASS, 13 items did not reach acceptable correlation coefficient and factor loadings, thus they were deleted. From the remaining 29 items, four categories emerged: Personal Interest and Real-World Connection, Sense Making/Effort and Problem Solving, Conceptual Connections, and Applied Conceptual Understanding, compared to the eight categories from the original version CLASS. Specifically, the four factors were composed of the following number of items: 8 for Personal Interest and Real-World Connection, 7 for Sense Making/Effort and Problem Solving, 8 for Conceptual Connections, and 6 for Applied Conceptual Understanding. Reliability also reached acceptable overall Cronbach's alpha value, α=0.745. This study proposes this revised 29-item instrument of CLASS as a valid instrument which measures students' attitude in the areas of personal interest, real world connection, personal effort and approaches in a physics course, and to problem solving.

Keywords: *Colorado Learning Attitudes about Science Survey; Physics; Senior High School Students; Validation*

INTRODUCTION

Measurement is an indispensable process towards the improvement of education. A change of quality goes with a change of quality of output mirrored through the measurement. Measurements in education is related to several things especially during evaluation and assessment (Hamdi and Kartowagiran, 2018). The quality of a study is highly dependent on the quality and validity of data which relies heavily on the quality or validity of the instrument used (Syahfitri et al., 2019).

According to AERA, APA, and NCME (1999): "validity refers to the degree to which evidence and theory support the interpretations of test scores entailed by proposed uses of tests. Validity is, therefore, the most fundamental consideration in developing evaluating tests. The process of validation involves accumulating evidence to provide sound scientific basis for the proposed score interpretations. It is the interpretations of test scores required by proposed uses that are evaluated, not the test itself. When test scores are used or interpreted in more than one way, each intended interpretation must be validated (p. 9)."

There are different evidence of validity based on test content, response process, internal structure, and other variables like criterion-related and construct validity. Despite these aspects, validity is a unitary concept

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(Goodwin and Leech, 2003). Re-evaluation of existing instruments is common among varying disciplines like counseling, marketing, gerontology, and organizational research because instrument development is repetitive. Establishing the psychometric soundness of an instrument requires persistent effort because it tries to cater to different settings and populations. Some instruments are strong in some aspects of validity and not in others (Hong et al., 2011).Congruent to this is the statement of Douglas et al. (2014) that the trustworthiness of a study and its instrument requires replicability. Thus, it is the responsibility of users and creators of research tools to notify the community of any issue that compromises the instrument's validity.

Colorado Learning Attitudes about Science Survey (CLASS)

In a nutshell, the Colorado Learning Attitudes about Science Survey (CLASS) is an instrument that aims to examine students' perceptions about physics, learning physics and to separate novices' views from those of experts.Since its conception, CLASS has been a staple in academic papers especially in physics education research. As of May 5, 2020, the two seminal papers Adams et al., 2005 and Adams et al., 2006 of CLASS had 88 and 766 citations, respectively, in Google Scholar. The instrument can be modified to be used in Biology, Chemistry, and Physics and has been officially translated in to Arabic, Chinese, Finnish, German, Japanese, Portuguese, and Turkish regulated by PhysPort (see https://www.physport.org/), a subsidiary of the American Association of Physics Teachers (AAPT). The CLASS was developed in the University of Colorado which was built on existing surveys such as the 'Maryland Physics Expectations Survey' (MPEX), 'Epistemological Beliefs Assessment for Physical Science' (EBAPS), and 'Views About Science Survey' (VASS) (Adams et al., 2005). According to Adams et al. (2006), CLASS stands out for the following reasons:

1. it caters a wider variety of important issues considered in learning physics;
2. the wording of statements is clear and concise;
3. the statements are meaningful even for students new to physics;
4. the scoring of responses is simple and obvious;
5. The survey takes less than 10 minutes;
6. the administration is easy and an online automated scoring can be easily utilised; and
7. The survey's categories of student beliefs were subjected to rigorous statistical analysis.

In the course of the development and validation of CLASS since 2003, it has been administered to over 7000 students in 60 physics courses in at least 45 universities. It has undergone the process of face validity, construct validity, and concurrent validity. In its latest version, CLASS is composed of 42 statements that either affirm or contradict expert views in Physics. It is answered on a 5-point Likert scale ranging from ranging from 1-5 with a verbal interpretation of strongly disagree to strongly agree. Out of these 42 statements, 26 have shown overlapping factors: Real World Connections, Personal Interest, Sense Making and Effort, Conceptual Connections, Applied Conceptual Understanding, Problem Solving General, Problem Solving Confidence, and Problem Solving Sophistication.

Research Aim

This study aimed to examine the psychometric properties of a widely used assessment instrument in the research of students' attitudes, 'Colorado Learning Attitudes About Science Survey' (CLASS), and propose revisions based on evidence found.

RESEARCH METHOD

Research Design

Researchers need to be careful when using or adapting a previously designed instrument for their own research, because when samples are different, it is possible that the factor structure of the same instrument needs to be adjusted. To cross-validate or 're-visit' an established instrument with moderate psychometric evidence, we suggest researchers start with a Confirmatory Factor Analysis (CFA) to test the fit of the factor structure with the current sample. If the factor structure fits the current sample, then there is no need to proceed any further because the factor structure has been proven valid using a different sample. However, if the factor structure does not fit the sample then it is necessary to go back and use Exploratory Factor Analysis (EFA) to explore whether the original factor structure truly represents or explains the intercorrelations among the factors. If the objective is to validate a newly-designed instrument, we suggest using Messick's (1995) guidelines on instrument design and validation (Hong et al., 2011).

Respondents

A total of 227 Senior High School (SHS) students from the 2020-2021 Academic Year (A.Y.) provided their voluntary consent to participate in this study. Respondents came from the four strands in SHS such as Science, Technology, Engineering and Mathematics (STEM), Accounting, Business and Management (ABM), Technological Vocational Livelihood (TVL) and Humanities and Social Science (HUMMS) to include both public and private schools in Metro Manila and in Cavite. Purposive sampling method was used to determine the respondents of the study. Additional demographic information of the respondents is given in Table 1.

Table 1: Demographic Information of Participants (N=227)

Demographic Information		***Frequencies (f)***	***Percentages (%)***
Gender	Male	104	45.8
	Female	123	54.2
School Type	Public	99	43.6
	Private	128	56.4
Grade Level	Grade 11 (16-17 years old)	20	8.8
	Grade 12 (17-18 years old)	207	91.2
Strand	STEM	216	95.2
	ABM	7	3.1
	TVL	3	1.3
	HUMMS	1	0.4

Instrument

In this study, the physics version of Colorado Learning Attitudes for Science Survey (CLASS) was adapted to measure students' attitudes about learning physics. Statements in CLASS can either be favorable or unfavorable. Favorable statements show that the more the respondent agrees with the statement, the more positive their attitude about learning physics is, however, unfavorable statements show that the more the respondent agrees with the statement, the more negative their attitude about learning physics is.

Research Procedure

Participants completed the adapted 42-item physics version of CLASS via Google Forms. CLASS was administered by the researchers along with the demographic information survey questionnaire. Data collection lasted for five days before being consolidated and analyzed.

The researchers adapted the suggestion of Hong et al. (2011) that in cross-validating instruments:

start with a CFA to test the fit of the factor structure with the current sample. If the factor structure fits the current sample, then there is no need to proceed any further because the factor structure is proved valid using a different sample. However, if the factor structure does not fit the sample then it is necessary to go back and use EFA to explore whether the original factor structure truly represents or explains the inter-correlations among the factors. (p. 815).

Data Analysis

Responses of the participants on the 42-item statements in CLASS were first counter checked to ensure that responses of the students who responded incorrectly to the monitoring item, that is item #31 and who had the same answers in all the items were omitted. Prior to factor analysis, descriptive analysis such as mean and standard deviation and inter-item correlations were conducted. Inter-item correlations were done to verify that there is homogeneity on the constructs. This means that items that correlate significantly with other items measure a single construct whereas items that do not correlate significantly with other items measure the same construct, thus, must be deleted (Douglas et al., 2014).

After data cleaning and inter-item correlations, EFA can now be performed to analyze the data. EFA is used to determine the number of factors influencing the variables and to identify which of these variables belong to the same factor (Yong and Pearce, 2013). In this study, EFA was used to investigate the number of underlying factors in the statements in CLASS and to identify which of these statements go in the same factor. In a study conducted by Adams et al. (2006), eight categories (factors) of CLASS emerged. In this study, the researcher would like to know if the same results will be yielded or not.

Lastly, reliability analysis using Cronbach's alpha was used to determine the internal consistency of the items in each factor extracted from EFA.

FINDINGS AND DISCUSSION

Descriptive Analysis

Before conducting descriptive analysis, the gathered data were screened by not including students who responded incorrectly in item number 31 and had the same answers in all the items. As descriptive analysis was performed on the responses of 227 respondents, results showed that 32 out of 41 items had means greater than 3.0 and 17 out of 41 items had standard deviations greater than 1.0. These results showed that the sample data had not been drawn from a normally distributed population as the data were categorical. Table 2 shows the descriptive statistics the inter-item correlations.

Table 2. Descriptive Statistics and Inter-item Correlations of CLASS

Item #	Mean	Std. Deviation	$r_{correlation}$	Item #	Mean	Std. Deviation	$r_{correlation}$
1	3.44	0.96	.264	22	3.76	1.01	.300
2	4.15	0.78	.261	23	2.66	1.18	.378
3	3.46	1.02	.476	24	4.19	0.84	.449
4	3.98	1.00	.327	25	3.34	1.07	.441
5	3.34	1.18	.321	26	4.11	0.87	.474
6	2.68	0.98	.306	27	3.91	1.06	.327
7	2.75	1.04	.215	28	4.24	0.85	.419
8	4.11	0.83	.393	29	2.84	1.27	.378
9	4.11	1.00	.312	30	4.19	0.86	.436

Item #	Mean	Std. Deviation	$r_{correlation}$	Item #	Mean	Std. Deviation	$r_{correlation}$
10	2.67	1.18	.366	32	2.04	1.05	.351
11	4.31	0.84	.318	33	3.59	1.06	.300
12	4.31	1.03	.316	34	3.35	0.92	.485
13	2.50	1.16	.351	35	3.22	1.29	.305
14	3.80	1.01	.476	36	3.76	0.99	.485
15	4.00	0.95	.410	37	3.62	1.12	.436
16	4.16	0.93	.407	38	3.28	1.17	.176
17	3.57	1.03	.327	39	3.96	0.84	.474
18	3.33	1.10	.375	40	2.82	1.16	.489
19	4.10	0.95	.245	41	3.78	0.94	.184
20	2.55	1.13	.314	42	4.13	0.84	.462
21	3.14	1.17	.489				

Table 2 shows that there were six items (#1, 2, 7, 19, 38, and 41) which had a correlation with other items less than 0.30. The rcorrelation must be equal to or greater than 0.30 as anything lower would suggest weak relationship between the variables (Tabachnick and Fidell, 2007). Items with rcorrelation lower than 0.30 were deleted since they did not correlate significantly with other items thus, they did not measure a single construct.

Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) using Principal Component Analysis (PCA) was used to analyze the responses of the students on the remaining items. PCA seeks to determine the linear combination of variables to extract the maximum variance from the items. When PCA is performed, communalities of the items should be checked first. Items with low communality should be deleted as they can result to the distortion of results. According to Comrey (1978), items with communalities less than 0.30 should be deleted, communalities between 0.40 and 0.70 are interpreted as 'good communality' and communalities between 0.80 and 0.90 are interpreted as 'high communality'. After performing PCA, results showed that six items (#4, 9, 11, 17, 20, and 33) had communalities lower than 0.30, hence, were deleted. After the removal of these items, PCA was performed again. Results showed that communalities of the remaining items were greater than 0.30.

The final model was comprised of 29 items. After looking at the communalities of these items, the Kaiser-Meyer Olkin (KMO) Sampling Adequacy and Bartlett's Test of Sphericity should next to be interpreted. KMO Sampling of Adequacy determines if the example is suitable for EFA. According to Kaiser (1974), KMO values greater than 0.5 are 'acceptable', values between 0.5 to 0.7 are 'mediocre', values between 0.7 to 0.8 are 'good' and values between 0.8 and 0.9 are 'great' value. Bartlett's Test of Sphericity confirms that the example has patterned relationships where the significant level of $\rho < .05$ should be observed. In this study, KMO measure of sampling adequacy was 0.833 interpreted as 'great'. The Bartlett's Test of Sphericity was also found to be significant ($x2 = 2011.69$, $\rho < 0.05$). These results showed that EFA can be performed given the sample size of 227 respondents.

EFA using PCA with varimax rotation was used to extract the underlying factors on the remaining 29-items of CLASS. Results revealed that four factors had an eigenvalue greater than 1. These factors explained 54.90% of the total variance results. Alternatively, scree plot can also be used to determine the appropriate number of factors produced in the factor analysis. The scree plot produced in this study is shown in Figure 1.

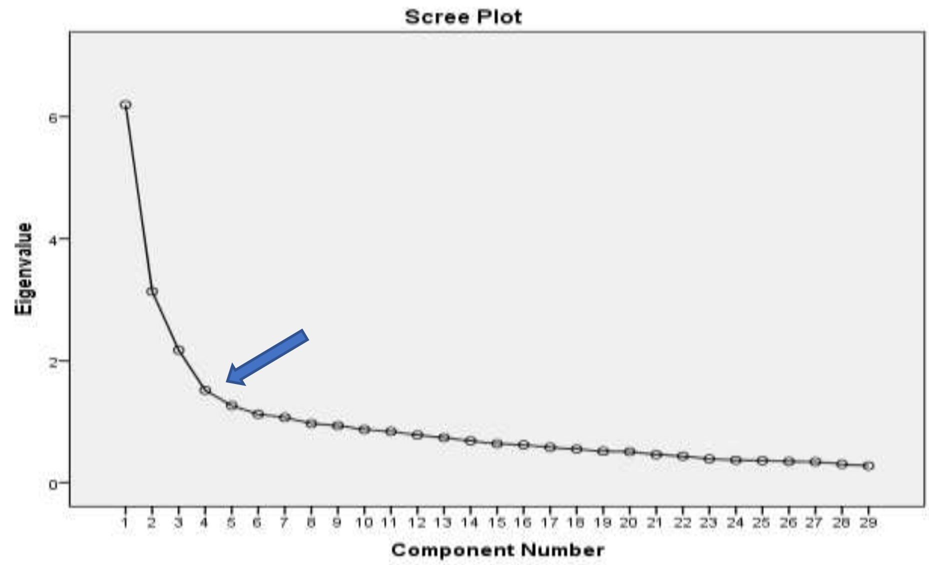

Figure 1. Scree plot scale

The scree plot scale is shown above, where an arrow indicates the point of inflexion on the curve. As seen in the scree plot, four components or factors had an eigenvalue greater than one.

As mentioned earlier, four factors explain 54.90% of the total variance results. The first factor contains eight items pertaining to how students internalize physics concepts and how they relate them to the real world. This factor is called Personal Interest and Real World Connection. The second factor contains seven items pertaining to students' attitude towards problem solving and their level of effort in understanding physics concepts. This factor is called Sense Making/Effort and Problem Solving. The third factor contains eight items pertaining to how students use conceptual connections when solving problems in physics. This factor is called Conceptual Connections. The final factor contains six items pertaining to students applied conceptual understanding. This factor is called Applied Conceptual Understanding. The factor loading matrix for these 29 items is presented in Table 3.

Table 3. Factor Matrix of the 29-item CLASS

Item	Statement	Factor				Communality
		1	2	3	4	
3	I think about the physics I experience in everyday life.	.643				.496
28	Learning physics changes my ideas about how the world works.	.636				.512
30	Reasoning skills used to understand physics can be helpful to me in my everyday life.	.630				.419
14	I study physics to learn knowledge that will be useful in my life outside of school.	.613				.400
37	To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.	.596				.374

Item	Statement	Factor 1	2	3	4	Communality
25	I enjoy solving physics problems.	.544				.517
26	In physics, mathematical formulas express meaningful relationships among measurable quantities.	.529				.557
16	Nearly everyone is capable of understanding physics if they work at it.	.499				.326
24	In physics, it is important for me to make sense out of formulas before I can use them correctly.		.637			.575
8	When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.		.632			.435
42	When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.		.626			.448
15	If I get stuck on a physics problem my first try, I usually try to figure out a different way that works.		.615			.470
36	There are times I solve a physics problem more than one way to help my understanding.		.587			.541
34	I can usually figure out a way to solve physics problems.		.536			.612
39	When I solve a physics problem, I explicitly think about which physics ideas apply to the problem.		.534			.499
29	To learn physics, I only need to memorize solutions to sample problems.			.677		.492
23	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.			.604		.372
10	There is usually only one correct approach to solving a physics problem. I am not satisfied until I understand why something works the way it does.			.590		.365
35	The subject of physics has little relation to what I experience in the real world.			.545		.355
13	I do not expect physics			.529		.404

Item	Statement	Factor				Communality
		1	2	3	4	
	equations to help my understanding of the ideas; they are just for doing calculations.					
6	Knowledge in physics consists of many disconnected topics.			.507		.456
18	There could be two different correct values to a physics problem if I use two different approaches.			.475		.341
32	Spending a lot of time understanding where formulas come from is a waste of time.			.455		.412
21	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.				.639	.568
12	I cannot learn physics if the teacher does not explain things well in class.				.586	.413
5	After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.				.563	.430
22	If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.				.505	.308
40	If I get stuck on a physics problem, there is no chance I'll figure it out on my own.				.503	.530
27	It is important for the government to approve new scientific ideas before they can be widely accepted.				.438	.395

Reliability Analysis

In measuring the reliability and internal consistency of the final 29 items of CLASS, Cronbach's alpha (α) reliability was used. Mills et al. (2010) noted that accepted reliability must have a reliability coefficient greater than 0.7. The summary of the reliability analysis of 29 items of CLASS per factor is presented in Table 4.

Table 4. Reliability Analysis per Factor

Factor	Number of Items	Item Number	Cronbach's Alpha (α)
1	8	3, 8, 14, 16, 25, 26, 30, 37	0.757
2	7	8, 15, 24, 34, 36, 39, 42	0.772
3	8	6, 10, 13, 18, 23, 29, 32, 35	0.720
4	6	5, 12, 21, 22, 27, 40	0.712

Cronbach's alpha was calculated as a measure of internal reliability for each factor and for the overall assessment of students' attitudes about physics and learning physics. Reported Cronbach's alpha showed that the items per factor reached acceptable reliability: Personal Interest and Real World Connection (Factor 1) α = 0.757; Sense Making/Effort and Problem Solving α = 0.772; Conceptual Connections α = 0.720; Applied Conceptual Understanding α = 0.712; Overall scale α = 0.745.

CONCLUSION

Table 5 compares the original version of the CLASS to the version resulting from this study. This study examined the psychometric properties of the Colorado Learning Attitudes for Science Survey (CLASS) and proposed revisions based on the evidence found. In addition, this also tested the reliability of CLASS, that is, if the same results from that of Adams et al. (2006) will be yielded when CLASS undergoes validation in the Philippines. While several items have been removed from the original survey and there is loss of item-level data, the result is an interpretable instrument that researchers can use to understand student attitudes.

Table 5. The Original Version of CLASS and the New Version of CLASS resulted in this study

Original Version of CLASS		New Version of CLASS	
Categories	**Items**	**Categories**	**Items**
Real World Connection	28; 30; 35; 37	Personal Interest and Real World Connection	3; 14; 16; 25; 26; 28; 30; 37
Personal Interest	3; 11; 14; 25; 28; 30	Sense Making/Effort and Problem Solving	8; 15; 24; 34; 36; 39; 42
Sense Making/Effort	11; 23; 24; 32; 36; 39; 42	Conceptual Connections	6; 10; 13; 18; 23; 29; 32; 35
Conceptual Connections	1; 5; 6; 13; 21; 32	Applied Conceptual Understanding	5; 12; 21; 22; 27;40
Applied Conceptual Understanding	1; 5; 6; 8; 21; 22; 40		
Problem Solving General	13; 15; 16; 25; 26; 34; 40; 42		
Problem Solving Confidence	15; 16; 34; 40		
Problem Solving Sophistication	5; 21; 22; 25; 34; 40		
Not Scored	4; 7; 9; 31; 33; 41		

Note.—Items in bold are scored more than once.

When the results of exploratory factor analysis were compared with the original factor structure from the study of Adams et al. (2006), similarities were found on the resulting factors. The first factor was a combination of the items in the Personal Interest and Real World Connection factors without item 11 and 35 which had a low communality in the exploratory factor analysis. The second factor was a combination of the items in Sense Making/Effort and Problem Solving General factors. The third and fourth factor, Conceptual Connections and Applied Conceptual Understanding, respectively, have almost exact items from the original Conceptual Connection and Applied Conceptual Understanding factors. Some results of this study were similar to the factor structure from the study conducted by Douglas et al. (2014) which was an evaluation of CLASS gathered from undergraduate introductory physics course. In addition, the resulting factors obtained from this study have also similar factor structure in the study of Heredia and Lewis (2012) where the chemistry version of CLASS was implemented.

The finding that the four factors, Personal Interest and Real World Connection; Sense Making/Effort and Problem Solving; Conceptual Connections; and Applied Conceptual Understanding, have significant correlations with each other and have accepted overall internal reliability showed that there was an apparent attitude in physics from the respondents who participated in this study. In addition, this study proposed the 29-item instrument of CLASS as a valid instrument which measures students' attitude in the areas of personal interest, real world connection, personal effort and approaches in a physics course and to problem solving.

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