The Design and Validation of the Colorado Learning Attitudes about Science Survey

W. K. Adams, K. K. Perkins, M. Dubson, N. D. Finkelstein and C. E. Wieman

Department of Physics, University of Colorado, Boulder

Abstract. The Colorado Learning Attitudes about Science Survey (CLASS) is a new instrument designed to measure various facets of student attitudes and beliefs about learning physics. This instrument extends previous work by probing additional facets of student attitudes and beliefs. It has been written to be suitably worded for students in a variety of different courses. This paper introduces the CLASS and its design and validation studies which include analyzing results from over 2400 students, interviews and factor analyses. Methodology used to determine categories and how to analyze the robustness of categories for probing various facets of student learning are also described. This paper serves as the foundation for the results and conclusions from the analysis of our survey data.[4,5]

Over the last decade, researchers in science education have identified a variety of student attitudes and beliefs (ABs) that shape and are shaped by student classroom experience.[1] Over the last year at Colorado, we have developed and validated an instrument, the Colorado Learning Attitudes about Science Survey, CLASS[2], which builds on existing surveys (MPEX, VASS, EBAPS)[3]. This survey probes student's ABs and distinguishes the ABs of experts from novices. The CLASS was written to make the questions as clear and concise as possible and is readily adapted to use in a wide variety of science courses. Students are asked to respond on a Likert-like (5-point agree to disagree) scale to questions such as: "I study physics to learn knowledge that will be useful in life.", or "After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.", or "To learn physics, I *only* need to memorize important equations and definitions." In this paper we will discuss the methods used to validate the survey. We will also discuss the subtleties of choosing categories of questions and list the seven categories we have chosen. The survey has generated some very interesting results which are discussed briefly here and in depth in the companion papers by Perkins et al.[4] and Pollock et al.[5].

The CLASS was designed for use with a broad population, takes only ten minutes to complete and covers many areas of student's ABs about physics. To make it suitable for a variety of courses serving non-science majors, physics majors or graduate students words such as "domain" or "concepts", which are not prevalent in a typical introductory student's vocabulary, were avoided. Every effort was made to avoid questions that include two different statements. Finally, one of the most difficult tasks was creating questions that were interpreted in only one way in interviews with both faculty and students.

Students (though perhaps not physicists) apply the word physics in at least three ways: a particular course, the scientific discipline, or the physics that describes nature. We designed the survey to embrace a single meaning of the word physics to avoid confusion. We focused the questions on physics that describes nature; noting this sense sometimes overlaps with physics as a discipline. By taking this approach, it made the questions meaningful even if a student had never taken a physics course.

This survey has been administered before (pre) and after (post) instruction to 2400 students in 10 courses over the past year either online or paper and pencil. Scoring is done by determining the percentage of a group of students who agree with the experts' view. The survey is scored overall and then in the seven categories listed in Table 2. Each category consists of three to eight questions that correlate with one another and target a specific attitude or belief about science.

VALIDITY AND RELIABILITY

Validation was done in three steps: First experts were interviewed and then took the survey; second students were interviewed to confirm the clarity and meaning of questions; and finally a detailed factor analysis was performed to create and verify existing categories of questions.

Three experts underwent a series of interviews once the initial design was complete. These experts were physicists who have extensive experience with teaching introductory courses and worked with thousands of students. Some of these experts are involved with physics education research others are simply practicing physicists interested in teaching. Their comments were used to hone the questions and remove any that could be interpreted more than one way. When this process was complete, seven experts took the survey. Their answers matched on all except three questions, two of which have been reworded. Their answers were used to determine the expert point of view for scoring.

Student interviews were carried out by obtaining 34 volunteers from six different courses at a mid-size multipurpose state university (MMSU) and a large state research university (LSRU). Care was taken to acquire a diverse group of interviewees. Interviews consisted of first having the student take the survey with pencil and paper. Then, during the first ten minutes, students were asked about their major, course load, best/worst classes, how they study, class attendance and future aspirations to characterize the student and their interests. After this, the interviewer read the questions to the students while the student looked at a written version. The students were asked to answer each question using the 5-point scale and then talk about whatever thoughts each question elicited. If the student did not say anything, he/she was prompted to explain his/her choice. After the first five or six questions, the students no longer required prompting. If the students asked questions of the interviewer, they were not answered until the very end of the interview.

Interview results showed students and experts had consistent interpretations on nearly all of the questions. A few questions were unclear or misinterpreted by some of the students. Some of these were reworded or removed in the Spring version 2 of the survey and a few remain to be changed. Finally there were questions that elicited unexpected student ideas, which will be used for further refinement of the survey.

Statistical analyses were used to test the validity of the sub-groupings of questions into categories. We performed a factor analysis, a data reduction technique that groups similar questions using correlations between question responses. We used the principle components extraction method along with a direct oblimin rotation and performed both an exploratory and a confirmatory factor analysis. For more detail on factor analysis see reference 6.

First we did an exploratory factor analysis, which analyzes the results from all questions and then groups questions that were answered similarly by students into independent factors. The exploratory factor analysis was performed with Spring version 2 of the survey on three sets of data from a calculus-based physics I course (N=416): pre-test results, post-test results and the shift from pre to post. The results from this exploratory factor analysis were used to indicate potentially bad questions (gave inconsistent results or seemed to be independent of the rest of the questions) and provided a set of independent categories. These categories emerge from the student responses and thus are factors that span the space of student ideas and characterize our students.

TABLE 1. Confirmatory Factor Analysis of Categories

Original Categories	Robustness	Solution	Exploratory Categories	Robustness	Solution
Independence	MF	How to Learn	Category 1	BQ	How to Learn
Coherence	PC	Coherence	Category 2	SS*	Reality World and Personal
Concepts	MF	How to Learn	Category 3	BQ	Metacognition
Reality World View	S	Reality World	Category 4	WF	Dropped
Reality Personal View	S	Reality Personal	Category 5	NS	Dropped
Math	S	Math	Category 6	SF	Sense Making
Effort	PC	Dropped	Category 7	WF	Dropped
Skepticism	PC	Dropped			

SS = Strong Single Factor; BQ = Better with 1 or 2 different questions; WF = Weak Factor; NS = Questions didn't make sense together; MF = Multiple factors;PC = Poorly Correlated

* This category is a single factor; however, even stronger when split into two

TABLE 2. Version 2 CLASS Categories

Category	Description
Reality Personal View	Physics is part of the student's life – student cares about physics.
Reality World View	Physics describes phenomena in the World around us.
Math	Mathematical formulae describe physical phenomena.
Sense Making	It is important to me to make sense out of things when learning physics.
Metacognition	Awareness of what is necessary to learn and understand physics – self reflection.
How to Learn	Best learned by memorization of facts and methods without understanding.
Coherence	Physics consists of connected ideas.

Another useful perspective is to look at specific groups of questions that probe facets of learning that the physics professor can directly address. Following this idea we chose our original categories based on the categories used by the MPEX and the VASS and expanded upon them slightly during the first two phases of validation of the CLASS. These types of categories emphasize both what a physicist believes is a useful breakdown of what is important for a student to learn physics and pedagogical organization (expert perspective) rather than emphasizing the way students think (student perspective). This means that some of these categories may not be independent of one another; however, if questions are properly designed, these categories are still self-consistent and provide useful information.

We performed a confirmatory factor analysis next using our originally chosen categories and the exploratory factor analysis categories. With a confirmatory factor analysis, the categories are predetermined by the researcher and the analysis determines how well each question within a factor correlates with that particular factor. Results of this analysis were used in conjunction with correlations between individual questions to create seven very robust (defined below), albeit not completely independent, categories. Table 1 above lists both our original categories and the exploratory categories and their robustness. Robustness is determined by the confirmatory factor analysis and our assessment of the usefulness of that grouping of questions as a research tool. If a category was not robust, we either made it stronger by adding/subtracting questions or simply dropped the category. The third column lists the fate of each category after completing the analysis. Table 2 lists the categories that resulted from this process.

Reliability studies were conducted in Calculus-based physics I at LSRU which is offered every semester with an enrollment over 500 students. During the 2003-2004 school year the course was taught by the same professor, who allowed us to administer the survey to his course pre and post, both Fall and Spring semester. The pre and post results for the two semesters were not statistically different for questions that were the same on both surveys. See Table 3 for overall scores, Reality World View and Math for both Fall and Spring semesters.

TABLE 3. Reliability Data

Category	Pre	Post	Uncertainty
Fall			
Overall	63%	65%	1%
Reality World	73%	76%	2%
Math	71%	69%	2%
Spring			
Overall	64%	66%	1%
Reality World	73%	76%	1%
Math	69%	68%	1%

APPLICATIONS

There are several useful ways to use the scores from the CLASS. One can look at the pre-test results and their influence on student learning or retention. One can also look at the change in attitudes over a semester, the shifts, to determine what effect instruction had on students' ABs. In Table 4 we show results for six courses covering a range of introductory physics classes. We see that students' *incoming* 'Reality Personal View' increases with level of physics course. Thus, students who make larger commitments to studying physics tend to be those who identify physics as being relevant to their own lives. As seen with other surveys, the CLASS shows student ABs deteriorate after instruction; unless, ABs are explicitly addressed by the instructor. We see in Table 4 that in the courses at LSRU, which explicitly attended to ABs, the overall scores did not deteriorate; however, in the courses at MMSU there was a substantial decline in ABs. A companion paper by Perkins et al.[4] goes into more detail on these courses and also carefully looks at correlations of students' ABs with their learning gains. They show that students with large learning gains have a greater

TABLE 4. Correlations between favorable 'Reality Personal' and physics course selection

Course Type	School Type/Term	Dominant student population	# of students w/ CLASS	Overall %favorable$		Reality Personal %favorable on Pre-test (uncertainty)
				Pre	Post	
Non-Sci-I	LSRU/Fa03	non-sci	77	56%	57%	44% (4%)
Non-Sci-II	LSRU/Sp04	non-sci	34	71%	73%	61% (5%)
Alg-I	MMSU/Fa03	pre-meds	36	**60%**	**51%**	61% (5%)
Calc-I	LSRU/Fa03	engineers	174	63%	65%	63% (2%)
Calc-I	LSRU/Sp04	engineers	416	64%	66%	64% (1%)
Calc-I	MMSU/Fa03	physics maj	41	**64%**	**54%**	71% (5%)

I=1st semester, II=2nd semester; $ typical standard deviation for 'Overall' is ~16%.

positive shift in ABs while students with lower learning gains show a deterioration in ABs.

CONCLUSIONS AND FURTHER WORK

This paper describes the philosophy and methods behind the development of the CLASS. In addition we detail the validity and reliability studies for this survey. We also define a process of selecting categories of questions and determining their robustness. This paper serves as the foundation for the results and conclusions from the analysis of our survey data and future applications of the survey.

Analysis and refinement of the CLASS is still in process. Over the next year we plan to perform a factor analysis of the results for other courses, a final revision of the current questions and creation of questions to target other categories that were not adequately addressed by the current version of the survey. The survey will also be altered slightly to be appropriate for use in Biology, Math, Astronomy and Chemistry and administered to these courses this Fall. Finally we would like to step beyond simply characterizing groups of students to identifying individual student characteristics.

ACKNOWLEDGMENTS

Thank you to Steven Pollock and Courtney Willis for many helpful discussions and the members of the PER@C group. This work is supported in part by NSF.

REFERENCES

1. Bransford, J.D., Brown, A.L., and Cocking, R.R. (2002). *How People Learn* Washington D.C.: National AcademyPress.
   Hammer, D. (2000) Student resources for learning introductory physics, *American Journal of Physics, 68,* S52-S59.
   Redish, E.F.,(2003). *Teaching Physics with Physics Suite*, John Wiley & Sons. Seymour, E. and Hewitt, N.,(1997). *Talking about Leaving*, Westview Press.

2. A copy of the CLASS can be found at http://cosmos.colorado.edu/phet/survey/CLASS/

3. Redish, E., Saul, J.M. and Steinberg, R.N. (1998). Student Expectations in Introductory Physics *American Journal of Physics, 66,* 212-224. www.physics.umd.edu/perg/expects/index.html
   Halloun, I. A. "Views About Science and Physics Achievement: The VASS Story." In The Changing Role of Physics Departments in Modern Universities: Proceedings of the ICUPE, E.F.http://modeling.asu.edu/R&E/Research.html
   Elby, A., Epistemological Beliefs Assessment for Physical Science. http://www2.physics.umd.edu/~elby/EBAPS/home.htm

4. Perkins, K., Adams, W., Finkelstein, N. and Wieman, C. (2004). Correlating student attitudes with student learning using the Colorado Learning Attitudes about Science Survey, *submitted to PERC Proceedings 2004.*

5. Pollock, S.(2004). No Single Cause: Learning Gains, Student Attitudes, and the Impacts of Multiple Effective Reforms, *submitted to PERC Proceedings 2004*.

6. Crocker, L. and Algina, J., (1986). *Introduction to Classical and Modern Test Theory*, Fort Worth: Hold, Rinehart and Winston, Inc.
   Kachigan, S. K., (1986). *Statistical Analysis*, New York: Radius Press.
   Kim, J. and Mueller, C. W., (1978). *Factor Analysis – Statistical Methods and Practical Issues*, Beverly Hills: Sage Publications