Measuring Attitude Towards Chemistry, Biology, and Math at a Hispanic-Serving Institution

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Abstract

This work describes the evaluation of the Attitude toward the Subject of Chemistry Inventory (ASCI), as well as two modifications (one for attitude toward math and one for attitude toward biology), for college students at a Hispanic Serving Institution. Confirmatory factor analysis supported a two-factor structure, similar to an existing model of a revised version of the ASCI, for all three instruments. These instruments show little change in student attitude with respect to biology, chemistry, or math during a typical semester. However, major perturbations, such as switching to remote instruction mid-semester, can lead to small but significant increases and decreases in attitude.

Introduction

Fostering positive student attitudes toward science is an important component to education, and attitude has been shown to correlate strongly with student achievement, persistence, and retention.[1-16] However, while nearly all faculty likely feel competent to assess student skills and knowledge, assessing attitude is often viewed as much more difficult, in part due to their lack of knowledge about attitude. For this reason a few instruments for measuring attitude in science classrooms have been developed.[1, 17-26]

One of these measures is the Attitude toward the Subject of Chemistry Inventory (ASCI), developed by Bauer.[19] While the ASCI showed promise and was used to measure attitude towards chemistry for a number of studies there was some concern about interpretation of the instrument as well as how applicable it was to various populations. To address these concerns Xu and Lewis refined the ASCI to make it easier to interpret and to be more valid for a wider range of student populations, as well as a second refinement altering the item order to improve the instrument's factor structure.[1, 5]

As part of a 5-year goal for the chemistry department to implement and assess pedagogical changes in the lower-division chemistry courses, we were interested in measuring student attitude. However, while we planned on using one of the ASCI variants there were two issues that concerned us. First, while the ASCIv2 and ASCIv3 had been shown to be valid instruments for a variety of undergraduate populations,[5, 8-9] there are cultural differences to how the questions are interpreted.[27] In addition, it was unclear that either instrument had been validated at a Hispanic-Serving Institution. Second, we were interested in comparing student attitudes not just towards chemistry, but comparing student attitudes in chemistry, biology, and math. Therefore, the focus of this study was to investigate how to measure student attitudes reliably, understand how attitude might vary over the course of a semester, and gauge how student attitudes might differ based on subject. With this in mind, three questions guided our initial work:

1. Can students' attitudes at a Hispanic-Serving Institution be measured using the same instrument and similar methods as at a non-minority institution?

2. How do student's attitudes change over the course of a typical semester?
3. How similar are students' attitudes for chemistry, biology, and math?

In addition, the switch to emergency remote instruction (ERI) due to the COVID-19 pandemic occurred during a semester we were collecting this data, which led to a fourth question:

4. How did the switch to ERI impact student attitudes?

Methods

All work involving human subjects were approved by UC Merced's Institutional Review Board (study #UCM2018-102). The only exclusion criteria was age (students not 18 or older).

The Attitude toward the Subject of Chemistry Inventory (ASCI V1), as well as two modified versions of the ASCI V1, were administered twice (pre- and post-semester) to three samples of students. One of the modified surveys consisted of changing the survey prompt from "Chemistry is" to "Math is", while the other modified survey had the prompt changed to "Biology is", in an effort to measure student attitudes towards chemistry, math, and biology, based on prior work by Wachsmuth et al. modifying the ASCI V2 to measure attitudes towards math held by biology students.[23]

For each administration, the instruments were distributed via email as a single Qualtrics survey to students in the Preparatory Chemistry, First-semester General Chemistry, Second-semester General Chemistry, and First-semester Organic Chemistry courses at a western public research university that is also a Hispanic serving institution (HSI). The survey was distributed twice per semester, once during the first week of instruction ("presemester") and once during the final week of instruction ("postsemester"). For the students in the Preparatory Chemistry, and General Chemistry courses, time was allotted during the first discussion session for the students to take the presemester survey during the discussion. Due to time limitations for these courses there was no time set aside for the postsemester survey. Additionally, the Organic Chemistry course did not have discussion sections, and so students were asked to take the presemester and postsemester surveys on their own time. Survey responses from students who did not consent to participate were not included in the analysis. In addition, any responses with missing data were excluded from analysis. The missing data was checked to determine if it might bias the findings, but no evidence of bias was found.

Descriptive statistics were performed in Python using the pingouin package for all items after the negatively stated items were recoded. Skewness and kurtosis of the data was less than $|1|$ for most, and less than $|2|$ for all, of the data, revealing good normality of item scores. Internal consistencies were calculated by Cronbach's α for proposed subscales. Differences in factor scores were quantified by Cohen's d effect size, using common guidelines ($d > 0.2$, small effect; $d > 0.5$, medium effect; $d > 0.8$, large effect).[28]

Confirmatory factor analysis (CFA) was used to confirm three different models: 1) the four-factor model proposed by Bauer, 2) the two-factor model proposed by Xu and Lewis and 3) a modified two-factor model. CFA was performed in R using the lavaan package. To allow for comparison with other work, similar CFA methods, fit measures and evaluation criteria were used. Specifically, CFA was performed using the variance-covariance matrix with a maximum-likelihood method of estimation. All items were set to load on their assumed factors, and χ^2, comparative fit index (CFI) and standardized root-mean-squared residual (SRMR) values were calculated, and a model was rejected if the CFI was below 0.9 or the SRMR was above 0.08.

Results and discussion

Factor analysis

Consistent with prior work by Xu and Lewis, the results from the CFA indicated that, for our population, the data does not support the four-factor model proposed by Bauer.[1] Furthermore, the CFA results indicated that, for our population, the data only sometimes supports the two-factor model proposed by Xu and Lewis. Specifically, while the CFI and SRMR thresholds were usually met for both the chemistry and math attitude surveys, they were not met for the biology attitude survey. Analysis of the residual variances indicated that item 10 (challenging/not challenging) and item 17 (chaotic/organized) only weakly contribute to the intellectual accessibility and emotional satisfaction factors, respectively. Interestingly, item 10 has also been shown to have high variance and poor loading for a sample of Saudi Arabian students, suggesting that the challenging/not challenging item is problematic for students from a variety of cultures.[27] Therefore, we tested an alternative two-factor model with these items removed. CFA results for this alternative model indicated that, for our population, the data always supports this revised two-factor model, except for the Spring, 2019, biology postsemester survey. Table 1 compares the results of the CFA for both models. These results stand in contrast to prior work on developing the Attitude toward the Subject of Mathematics Inventory, where the exploratory factor analysis on the ASCI V2, modified to measure attitudes of math among biology students, didn't neatly resolve into two factors, in part because of issues with item 10.[23]

Table 1: Cronbach's alpha, chi-square, comparison fit index, and standardized root-mean-square residual values for the original two-factor model and revised two-factor model for pre and post semester surveys administered during the Spring, 2019, Fall, 2019, and Spring, 2020, surveys

Semester	Survey	N	Xu and Lewis model					Revised two-factor model				
			$\alpha 1$	$\alpha 2$	χ^2	CFI	SRMR	$\alpha 1$	$\alpha 2$	χ^2	CFI	SRMR
2019 Spring	Biology pre	690	0.78	0.75	170.3	0.886	0.093	0.77	0.79	71.9	0.939	0.066
	Chemistry pre	699	0.78	0.76	133.3	0.928	0.062	0.78	0.80	49.5	0.967	0.046
	Math pre	685	0.83	0.82	216.1	0.912	0.077	0.83	0.85	95.8	0.950	0.053
	Biology post	178	0.82	0.79	106.4	0.852	0.133	0.78	0.88	38.1	0.931	0.085
	Chemistry post	190	0.82	0.81	68.4	0.919	0.061	0.81	0.84	30.7	0.955	0.054
	Math post	174	0.87	0.83	54.8	0.944	0.055	0.87	0.87	17.9	0.979	0.038
2019 Fall	Biology pre	394	0.74	0.79	145.1	0.863	0.105	0.73	0.84	50.8	0.945	0.068
	Chemistry pre	401	0.81	0.80	109.9	0.927	0.066	0.81	0.84	56.7	0.951	0.055
	Math pre	389	0.80	0.79	110.7	0.917	0.069	0.81	0.84	55.4	0.945	0.059
	Biology post	204	0.84	0.82	41.6	0.957	0.069	0.85	0.84	13.8	0.984	0.044
	Chemistry post	210	0.77	0.79	67.2	0.911	0.082	0.76	0.81	38.4	0.931	0.071
	Math post	203	0.86	0.81	38.2	0.970	0.050	0.85	0.85	15.1	0.987	0.033
2020 Spring	Biology pre	308	0.78	0.76	84.0	0.882	0.104	0.74	0.82	41.8	0.930	0.079
	Chemistry pre	317	0.79	0.76	93.3	0.908	0.080	0.80	0.80	37.3	0.953	0.064
	Math pre	305	0.83	0.79	91.7	0.927	0.074	0.82	0.84	38.5	0.960	0.057

	Biology post	114	0.86	0.80	75.6	0.869	0.098	0.88	0.84	39.1	0.917	0.080
	Chemistry post	120	0.79	0.77	41.8	0.931	0.083	0.74	0.87	13.6	0.980	0.053
	Math post	111	0.84	0.83	80.3	0.868	0.090	0.84	0.86	16.7	0.972	0.049

Table 2: Presemester and postsemester mean scores, reported as percentages, and effect sizes for the intellectual accessibility and emotional satisfaction scales for each subject, from the Spring, 2019, and Fall, 2019, semesters.

Spring 2019	Presemester	Postsemester	p-value	Effect size
Intellectual accessibility				
CHEM	49.26	47.02	0.094	0.14
BIO	53.20	50.48	0.089	0.15
MATH	46.59	46.58	0.995	0.00
Emotional satisfaction				
CHEM	62.93	60.40	0.086	0.15
BIO	68.48	64.85	0.018	0.22
MATH	61.87	62.21	0.862	0.02
Fall 2019	Presemester	Postsemester	p-value	Effect size
Intellectual accessibility				
CHEM	44.83	46.10	0.380	0.08
BIO	52.25	54.30	0.231	0.11
MATH	47.02	46.40	0.741	0.03
Emotional satisfaction				
CHEM	60.08	60.79	0.656	0.04
BIO	69.10	66.57	0.091	0.15
MATH	62.90	60.05	0.132	0.13

Comparing the survey results from the Spring, 2019, and Fall, 2019, semesters we find students feel all three subjects are more emotionally satisfying than intellectually accessible (Table 2). In addition, these attitudes are fairly stable. Over the course of a semester we measure little to no change in intellectual accessibility or emotional satisfaction with respect to chemistry, biology, and math. The one exception is a small, but statistically significant, decrease in emotional satisfaction with respect to biology during the Spring, 2019, semester, although we note that the SRMR value for the postsemester survey suggests that this result may be an artifact. Furthermore, we find that, early in both semesters, students find biology more intellectually accessible and emotionally satisfying then either math or chemistry (Table 3). While these differences in attitudes are small they can persist over the course of a semester, for example they mostly disappear during the Spring, 2019, semester but remain (or increase) during the Fall, 2019, semester.

Table 3: Difference in means, p-values, and effect sizes for presemester and postsemester surveys comparing the three subjects (Chem-Bio, Bio-Math, and Math-Chem) during the Spring, 2019 and Fall, 2020 semesters.

	Presemester			Postsemester		
Spring 2019	**Difference in means**	**p-value**	**Effect size**	**Difference in means**	**p-value**	**Effect size**
Intellectual accessibility						
CHEM-BIO	-3.94	< .001	0.24	-3.46	0.066	0.19
BIO-MATH	6.61	< .001	0.34	3.90	0.089	0.18
MATH-CHEM	-2.67	0.007	0.15	-0.44	0.838	0.02
Emotional satisfaction						
CHEM-BIO	-5.56	< .001	0.35	-4.45	0.022	0.24
BIO-MATH	6.61	< .001	0.36	2.64	0.242	0.13
MATH-CHEM	-1.06	0.296	0.06	1.80	0.414	0.09
	Presemester			**Postsemester**		
Fall 2019	**Difference in means**	**p-value**	**Effect size**	**Difference in means**	**p-value**	**Effect size**
Intellectual accessibility						
CHEM-BIO	-7.42	< .001	0.43	-8.20	< .001	0.43
BIO-MATH	5.23	< .001	0.27	7.90	< .001	0.37
MATH-CHEM	2.19	0.101	0.12	0.30	0.878	0.02
Emotional satisfaction						
CHEM-BIO	-9.02	< .001	0.52	-5.78	0.002	0.31
BIO-MATH	6.20	< .001	0.33	6.52	0.001	0.32
MATH-CHEM	2.82	0.042	0.15	-0.74	0.718	0.04

While student attitudes are relatively stable over the course of a typical semester, what about during an atypical semester? In March 2020, the campus switched to emergency remote instruction because of the COVID-19 pandemic. By the end of this semester there was a statistically significant change in student attitudes half of the categories (Table 4). Over the course of this semester there was a small increase in intellectual accessibility with respect to chemistry, as well as a small decrease in intellectual accessibility with respect to biology and a medium-sized decrease in emotional satisfaction with respect to biology. Furthermore, as Table 5 shows, students viewed biology as both much more accessible and satisfying than chemistry or math at the start of the semester, consistent with prior semesters, but by the end of the semester there was no significant difference in student attitudes. While more work is needed to understand why these shifts occurred, it seems clear that the emergency remote instruction situation during the Spring 2020 semester impacted students' attitudes, with smaller shifts in subjects that are more quantitative.

Table 4: Presemester and postsemester mean scores, reported as percentages, and effect sizes for the intellectual accessibility and emotional satisfaction scales for each subject, from the Spring, 2020 semester.

Spring 2020	Presemester	Postsemester	p-value	Effect size
Intellectual accessibility				
CHEM	44.30	47.78	0.041	0.22

BIO	53.31	48.87	0.036	0.24
MATH	45.03	44.62	0.853	0.02
Emotional satisfaction				
CHEM	62.76	63.89	0.553	0.07
BIO	70.83	63.32	< .001	0.44
MATH	62.42	63.75	0.560	0.06

Table 5: Difference in means, p-values, and effect sizes for presemester and postsemester surveys comparing the three subjects (Chem-Bio, Bio-Math, and Math-Chem) during the Spring, 2020 semester.

	Presemester			**Postsemester**		
Spring 2020	**Difference in means**	**p-value**	**Effect size**	**Difference in means**	**p-value**	**Effect size**
Intellectual accessibility						
CHEM-BIO	-9.01	< .001	0.54	-1.09	0.642	0.06
BIO-MATH	8.28	< .001	0.44	4.26	0.108	0.22
MATH-CHEM	0.73	0.620	0.04	-3.16	0.184	0.18
Emotional satisfaction						
CHEM-BIO	-8.06	< .001	0.48	0.56	0.811	0.03
BIO-MATH	8.41	< .001	0.45	-0.42	0.869	0.02
MATH-CHEM	-0.34	0.821	0.02	-0.14	0.956	0.01

Conclusions

We have modified the ASCI to create surveys that measure attitudes with respect to chemistry, biology, and math that are valid for a population of students a Hispanic Serving Institution. These surveys show that students generally find biology more intellectually accessible and emotionally satisfying than either chemistry or math, although these differences narrow over the course of a typical semester. Finally, the switch to remote instruction during March, 2020, in response to the COVID-19 pandemic, lead to measurable changes in student attitudes, with an increase in intellectual accessibility with respect to chemistry, and a decrease in both intellectual accessibility and emotional satisfaction with respect to biology.

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