The Curricular Effectiveness of Evolution Education:
Examining Latent Mean Differences in the Evolutionary Attitudes and Literacy Survey (EALS)

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Presented at the13th annual meeting of the Society for Personality and Social Psychology, January 26th, 2012, San Diego, CA

INTRODUCTION

The Midwest and Kansas in particular have recently received considerable attention concerning the issue of evolution education. The 2005 Kansas Evolution Hearings initiated a dramatic change to the state's science education standards opening the door to Intelligent Design and creationism perspectives, which was repealed two years later. Meanwhile, several national teaching and educational organizations view evolutionary theory as a fundamental part of science education. Thus, one step for science educators aiming to instruct their students on this fundamental theory is to understand both students' attitudes toward and knowledge of evolution theory, and mechanisms for their change.

Hawley and colleagues interested in empirically examining evolutionary attitudes developed a variety of scale items to measure not only political and spiritual leanings, but also knowledge of evolution, distrust of the scientific enterprise, and attitudes towards and objections against evolutionary theory. The Evolutionary Attitudes and Literacy Survey (EALS; see Hawley et al., 2010) is a multidimensional scale that consists of 16 lower order and 6 higher order constructs developed to measure the wide array of factors that influence both an individual's endorsement of and objection to evolutionary theory.

Previous research has largely examined undergraduate biology students on just a few constructs relevant to evolution education (e.g., knowledge of evolution, evolution misconceptions). The present study sought to expand this research by examining both biology and non-biology students from a variety of courses a psychometrically validated measure. Therefore, we examined changes in university students' attitudes toward and knowledge of evolution measuring students with the previously validated Evolutionary Attitudes and Literacy Survey (EALS) before and after completing an undergraduate Political Science (the comparison group), Biology, or Evolutionary Psychology course.

METHODS

Participants

Three courses were examined. The first course consisted of 631 undergraduates representing 36 majors, including 246 men and 303 women from an introductory biology course covering the principles of cellular and molecular biology developed for biology majors or students planning to take additional biology courses (Age: $M = 19.18$, $SD = 2.74$).

The second sample consisted of 366 students from the introduction to U. S. Politics course with students representing 43 different majors. The sample consisted of 113 men and 139 women (Age: $M = 20.04$, $SD = 3.26$). This course was selected as a comparison group that contained no biology or evolution instruction.

The third sample consisted of 65 students from a course in Evolutionary Psychology representing 11 majors. The sample consisted of 37 men and 28 women (Age: $M = 21.30$, $SD = 1.26$).

Analysis

The collected data contained three groups measured across two time points (pre-course and post-course). A confirmatory factor analysis (CFA) measurement model demonstrating the relationships between the measured (e.g., manifest) indicators and the latent constructs was specified with 12 latent constructs, including the six higher-order EALS constructs (e.g., Political Activity, Religious Conservatism, Creationist Reasoning, Knowledge/Relevance of Evolution, Evolutionary Misconceptions, and Exposure to Evolution) for the pre-course (i.e., Time 1) and post-course (i.e., Time 2) assessment. All models were identified by the effects-coding to maintain the scaling metric of the indicators (see Little, Slegers, & Card, 2006). Missing data were only moderate (<25%) and were handled via full information maximum likelihood (FIML) estimation within Mplus version 6.0 (Muthén & Muthén, 2011).

For model comparisons, a repeated measures multiple groups CFA was conducted to examine the levels of measurement invariance across both time and groups simultaneously. Once strong invariance was established, other tests could be competed. First, phantom constructs were created to test the equality of latent correlations across time and groups. Next, latent mean invariance tests were performed to examine potential mean differences across groups and time. All constrained means models were compared to the strong invariance model via a chi-square difference test to determine if equality constraints were tenable.

RESULTS

Table 1 shows the results of the simultaneous group and time invariance test. Each nested model contains its constraints, plus the constraints of all previous, tenable models. Due to the sensitivity of the Chi square difference test, a "reasonableness" test was used where the constraint was considered tenable if the two model's RMSEAs were within one another's confidence intervals, and the Δ CFI was < .01.

Model	χ^2	df	p	$\Delta\chi^2$	Δ df	p	RMSEA	RMSEA 90% CI	NNFI	CFI	Constraint Tenable
Null Model	54323.1	2709	<.001	---	---	---	---	---	---	---	---
Configural Invariance[1]	3858.48	2178	<.001	---	---	---	0.047	0.044-0.049	0.925	0.937	---
Weak Invariance[1]	4082.19	2268	<.001	---	---	---	0.048	0.045-0.050	0.922	0.932	Yes
Strong Invariance[1]	4391.27	2243	<.001	---	---	---	0.050	0.047-0.052	0.915	0.923	Yes
Homogeneity of Variances/Covars[2]	4717.39	2505	<.001	326.118	162	<.001	---	---	---	---	No
Group	4696.85	2499	<.001	305.57	156	<.001					No
Time	4433.34	2363	<.001	42.066	19	<.01					No
Homogeneity of Variances[2]	4454.43	2373	<.001	63.154	30	<.001	---	---	---	---	No
Equality of Corrs. (Phantom Constructs)[2]	4489.71	2418	<.001	98.432	75	.0362	---	---	---	---	Yes
Latent Mean Invariance[2]	4596.73	2373	<.001	205.46	30	<.001	---	---	---	---	No

[1] Evaluated with RMSEA Model Test
[2] Evaluated with χ^2 Difference Test

Table 2 displays the intercorrelations among the pre-course (T1) and post-course (T2) assessments for each of the six higher-order EALS constructs. Correlations are taken from the Equality of Correlations (Phantom Constructs) model.

Construct	1	2	3	4	5	6	7	8	9	10	11	12
1. T1 Political Activity	1.00											
2.T1 Religious Conservatism	-0.04*	1.00										
3.T1 Knowledge/Relevance	0.16	-0.53	1.00									
4. T1 Creationist Reasoning	-0.09	0.70	-0.73	1.00								
5. T1 Evo Misconceptions	-0.01*	0.06*	-0.10	0.21	1.00							
6. T1Exposure to Evolution	0.31	-0.37	0.43	-0.38	-0.07	1.00						
7. T2 Political Activity	0.72	-0.05*	0.20	-0.16	-0.02*	0.17	1.00					
8.T2 Religious Conservatism	-0.10	0.93	-0.56	0.71	0.07*	-0.40	-0.04*	1.00				
9. T2 Knowledge/Relevance	0.07*	-0.53	0.90	-0.71	-0.13	0.40	0.16	-0.53	1.00			
10. T2 Creationist Reasoning	-0.03*	0.69	-0.69	0.87	0.12*	-0.37	-0.09	0.70	-0.73	1.00		
11. T2 Evo Misconceptions	-0.08*	0.03*	-0.10*	0.19	0.28	-0.05*	-0.01*	0.06*	-0.10	0.21	1.00	
12. T2 Exposure to Evolution	0.39	-0.35	0.44	-0.38	-0.23	0.72	0.31	-0.37	0.43	-0.38	-0.07	1.00

Note. * $p > .05$.

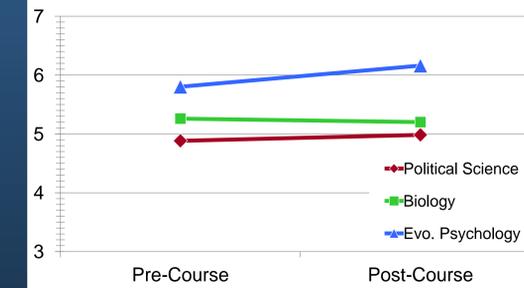**Table 3** displays the unconstrained latent means and standard deviations for each of the three courses at both assessments.

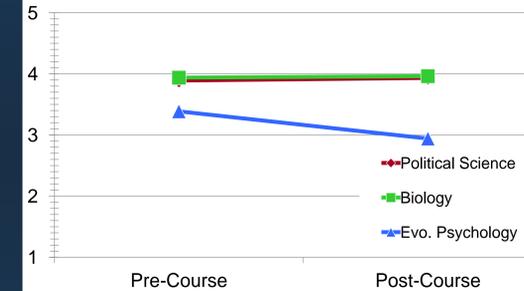|	Political Science Pre-Course	Political Science Post-Course	Biology Pre-Course	Biology Post-Course	Evolutionary Psychology Pre-Course	Evolutionary Psychology Post-Course
Political Activity	3.304 (1.587)	3.272 (1.587)	2.895 (1.306)	2.979 (1.356)	2.991 (1.201)	2.991 (1.129)
Religious Conservatism	2.284 (1.224)	2.274 (1.186)	2.267 (1.407)	2.267 (1.407)	1.657 (0.766)	1.598 (0.750)
Knowledge/Relevance	4.883 (1.014)	4.984 (1.052)	5.260 (1.105)	5.201 (1.181)	5.802 (0.798)	6.161 (0.774)
Creationist Reasoning	2.501 (1.244)	2.498 (1.301)	2.327 (1.457)	2.332 (1.507)	1.881 (0.790)	1.495 (0.661)
Evolutionary Misconceptions	3.891 (0.957)	3.933 (0.995)	3.938 (0.955)	3.962 (1.105)	3.387 (1.040)	2.942 (1.145)
Exposure to Evolution	2.243 (0.765)	2.252 (0.784)	2.373 (0.728)	2.394 (0.779)	2.560 (0.677)	2.702 (0.645)

Note. Latent Means (Standard Deviations)

Figures 1 – 3. display the latent means for pre and post course assessments for the three constructs that demonstrated significant mean differences: evolutionary knowledge/relevance, evolutionary misconceptions, and creationist reasoning.
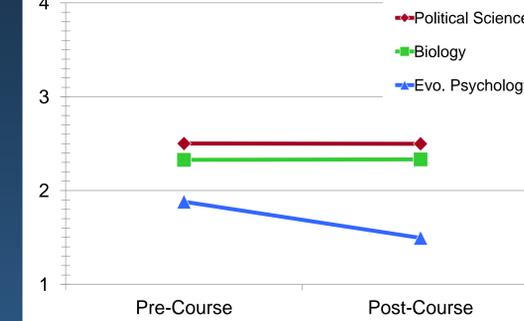

Evolutionary Knowledge/Relevance — Political Science, Biology, Evo. Psychology (Pre-Course, Post-Course)

Evolutionary Misconceptions — Political Science, Biology, Evo. Psychology (Pre-Course, Post-Course)

Creationist Reasoning — Political Science, Biology, Evo. Psychology (Pre-Course, Post-Course)

Table 4 includes the omnibus test of latent mean invariance, as well as additional follow-up tests exploring mean differences within group and time. The omnibus test of latent mean invariance was significant, $\Delta\chi^2$ (30) = 205.46, $p < .0001$, as well as the main effect for Course, $\Delta\chi^2$ (24) = 24, $p < .0001$, and the main effect of time, $\Delta\chi^2$ (18) = 53.69, $p < .0001$. Because both main effects were significant, simple main effects for each construct were examined within time

Model	χ^2	df	p	$\Delta\chi^2$	Δ df	p	Const. Tenable	Effect Size[1]
Intercept Invariance (Baseline model)	4391.27	2243	<.001	---	---	---	---	---
Latent Mean Invariance	4596.73	2373	<.001	205.46	30	<.001	No	---
Group	4586.812	2367		195.539	24		No	---
Time	4444.967	2361		53.694	18	<.001	No	---
Political Activity	4394.456	2346	<.0001	3.183	3	0.364	Yes	---
Religious Conservatism	4395.917	2346	<.0001	4.644	3	0.200	Yes	---
Knowledge/Relevance	4415.143	2346	<.0001	23.87	3	<.001	No	---
Political Science	4399.081	2344	<.0001	7.808	1	<.01	No	0.13
Biology	4394.628	2344	<.0001	3.355	1	0.067	Yes	---
Evolutionary Psychology	4403.98	2344	<.0001	12.707	1	<.001	No	0.52
Creationist Reasoning	4422.537	2346	<.0001	31.264	3	<.001	No	---
Political Science	4391.278	2344	<.0001	0.005	1	0.944	Yes	---
Biology	4391.299	2344	<.0001	0.026	1	0.872	Yes	---
Evolutionary Psychology	4422.505	2344	<.0001	31.232	1	<.001	No	-0.64
Evolutionary Misconceptions	4404.163	2346	<.0001	12.89	3	<.001	No	---
Political Science	4391.685	2344	<.0001	0.412	1	0.521	Yes	---
Biology	4391.563	2344	<.0001	0.29	1	0.590	Yes	---
Evolutionary Psychology	4403.461	2344	<.0001	12.188	1	<.001	No	-0.47
Exposure to Evolution	4396.278	2346	<.0001	5.005	3	0.171	Yes	---

Note. T1 = Pre-Course , T2 = Post-Course
[1] Effect size is latent d, where $d = (\alpha_{2j} - \alpha_{1j}) / \sqrt{\psi_{pooled}}$

DISCUSSION

Currently, a significant portion of the American public, including both teachers and students, are neutral to evolutionary theory and education at best, or fully opposed to this fundamental theory in science education at worst. The present study sought to conduct a modern quantitative examination of the effects of semester long college courses varying in amounts of evolution education to determine if the curricula were effective in changing some of the complex constructs influencing attitudes toward and knowledge of evolution.

Significant change in Knowledge/Relevance of evolution was observed for the Evolutionary Psychology course ($A_{Time\ 1} = 5.80$, $SE = 0.10$; $A_{Time\ 2} = 6.16$, $SE = 0.10$; $d = .52$), $p < .001$, but, surprisingly, no change was observed in the Biology course. Interestingly, evolutionary knowledge increased for the Political Science course (e.g., the control group), but the small effect size indicates that the increase is not of much practical significance ($A_{Time\ 1} = 4.88$, $SE = 0.05$; $A_{Time\ 2} = 4.98$, $SE = 0.05$; $d = .13$), $p < .01$.

Significant change in Evolutionary Misconceptions was observed for the Evolutionary Psychology course ($A_{Time\ 1} = 3.39$, $SE = 0.13$; $A_{Time\ 2} = 2.94$, $SE = 0.14$; $d = -.47$), $p < .001$. Unlike students in the Evolutionary Psychology course, the Biology students did not report significantly more disagreement with these statements at the end of the semester. This finding is certainly important for educators, as it again suggests that one's knowledge of basic scientific principles does not eliminate their intuitive misunderstandings about evolution.

Finally, there was a significant decrease in Creationist Reasoning for the Evolutionary Psychology course ($A_{Time\ 1} = 1.88$, $SE = 0.10$, $A_{Time\ 2} = 1.50$, $SE = 0.08$, $d = -.64$), $p < .001$. Student activities present in the Evolutionary Psychology course, such as critical examinations of evolutionary fallacies, may be some of the necessary instructional methods outside of traditional lectures needed to decrease false views of evolution.

These results demonstrate that it may be misleading to assume that students fully understand evolutionary theory simply by completing a collegiate course in biology. Science educators who aim to increase students' evolutionary knowledge must deliberately go beyond traditional lectures, directly address frequent misconceptions, and frequently demonstrate the relevance of evolution in order to change students' knowledge and attitudes towards this unifying theory.

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