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Original Article

The Effects of Evolution Education: Examining Attitudes toward and Knowledge of Evolution in College Courses

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Abstract: The present study examined changes in university students' attitudes toward and knowledge of evolution measured by the previously validated Evolutionary Attitudes and Literacy Survey (EALS) in response to curricular content. Specifically, student responses on the survey were compared across an evolutionary psychology course, an introductory biology course with significant evolutionary content, and a political science course with no evolutionary content. To this end, 868 students were assessed at a large Midwestern U.S. university prior to and following completion of one of the three courses. A multiple group repeated measures confirmatory factor analysis (CFA) was conducted to examine latent mean differences in self-reported Evolution Knowledge/Relevance, Creationist Reasoning, Evolutionary Misconceptions, and Exposure to Evolution. A significant and notable increase in Knowledge/Relevance, as well as decreases in Creationist Reasoning and Evolutionary Misconceptions, was observed for the evolutionary psychology course, whereas the biology course demonstrated no change in Knowledge/Relevance and a significant increase in Evolutionary Misconceptions. The implications of these findings for evolution education are discussed.

Keywords: education, misconceptions, creationist reasoning, Evolutionary Attitudes and Literacy Survey, confirmatory factor analysis, evolutionary psychology

Introduction

Now over 150 years old, Charles Darwin's *On the Origin of Species* and his accompanying theory of evolution still face substantial criticism and denial from individuals across the western world, but in particular the United States. The U.S. is ranked second to last, only surpassing Turkey, in an examination of 34 prominent countries across the world for public acceptance of evolution (Miller, Scott, and Okamoto, 2006). Moreover, between 1985 and 2005 the American public's acceptance of evolution has

decreased from 45% to 40% (Miller et al., 2006), and a recent Gallup study reported that 44% of Americans found the creationist view "God created man as is 10,000 years ago" closest to their view on human origins (Newport, 2008). Currently, nearly one-third of Americans do not agree with an evolutionist or creationist perspective (Kampourakis and Strasser, 2014).

Evolution faces opposition from a variety of sources, including young-earth creationism (Segraves, 1977; Whitcomb and Morris, 1961) and intelligent design (Meyer, 1999) movements. Many of these criticisms appear to stem from religious beliefs (Miller and Toth, 2014; Scott, 2004), lack of exposure to evolution (Clores and Limjap, 2006; Lombrozo, Thanukos and Weisberg, 2008), and political ideologies (Patterson and Rossow, 1999). Collectively, these oppositions resulted in many historical and current debates about the theory of evolution being taught in public schools. The topic of evolution in high school classrooms is generally avoided by teachers and, accordingly, receives only a small percentage of instructional time during the school year (Rutledge and Mitchell, 2002), even though both the National Association of Biology Teachers (NABT) and the National Science Education Standards (NSES) view evolutionary theory as fundamental to middle and high school science education (Evans, 2005). In addition, a recent national study of nearly 1,000 high school biology teachers revealed that the majority of teachers (60%) were cautious in either advocating evolution or creationism, and only a third of these surveyed instructors presented evolutionary theory in concordance with national recommendations (Berkman and Plutzer, 2011).

Moreover, it is not clear that high school biology instructors differ from their non-science colleagues in attitudes toward evolution education. With some concern, Osif (1997) reported that both high school biology and English instructors held similar views on the importance of evolution education, with only two-thirds of the respondents claiming evolutionary theory was essential to biological education. Thus, increased biological education (e.g., a biology degree versus an English degree) did not appear to influence a teacher's attitudes toward evolution education. These results are further supported by Nehm, Kim, and Sheppard (2009), whose comparisons of high school biology teachers to non-science high school teachers from the state of New York revealed that the teachers did not differ in their attitudes toward evolution. Nearly half of the teachers in each group supported instructional time devoted to creationism.

Collectively, these results may suggest that for high school science teachers, instructors with bachelor's degrees in non-science areas (e.g., English) versus degrees in Biology do not differ in their attitudes toward evolution. Mere exposure to biological material during one's degree in higher education may have little to no effect on attitudes toward evolution. Might our college courses play some role in school teachers' (and therefore children's) negative attitudes about the theory downstream?

Evolution education in college

At the university level, examinations of evolutionary knowledge have largely been among samples of biology or non-biology majors. For biology majors, knowledge about evolution has been shown to increase among first-year students after a semester of introductory biology taught with an active-learning teaching style, but misconceptions about evolution remained for 70% of the students (Nehm and Reilly, 2007). Johnson and Peeples (1987) reported significant increases in understanding science from freshmen to

senior undergraduate biology majors, but student attitudes toward evolution remained largely neutral. Ingram and Nelson (2006) did find increases in positive attitudes toward evolution in senior biology majors following a course on evolutionary theory, but the overall effect size was small.

Among non-biology majors, Bishop and Anderson (1990) reported that undergraduates demonstrated increases in evolutionary knowledge after completing a biology course with specific curriculum directed toward evolution, but again these students adhered to common misconceptions. In addition, when biology majors were compared to their non-biology major peers, biology majors demonstrated significantly higher evolutionary knowledge (Alters and Nelson, 2002; Grose and Simpson, 1982; Johnson and Peeples, 1987), but these effect sizes were all small.

If increased evolutionary knowledge was demonstrated only for biology majors, then one could suspect that the significant findings of past research were largely due to a sampling bias that relied on biology majors only. However, these significant increases in evolutionary knowledge for both biology and non-biology-majors demonstrate that the effect is not simply due to students' interest in science, but may also be linked to the biological curriculum the students are exposed to. Unfortunately, thus far these curricula have not successfully eliminated students' misconceptions about evolution.

These patterns of results suggest that despite effectively teaching the content area of individual courses (as measured by course examinations), biology curricula may not be as effective as we would wish in (1) instilling an understanding of its predominant meta-theory, (2) decreasing common misconceptions about it, and (3) enhancing positive attitudes about its relevancy. In light of Dobzhansky's (1973) oft quoted essay, "nothing in biology makes sense except in the light of evolution," are we doing enough in higher education to explicitly impart the utility of theory such that positive attitudes become part of the nation's culture?

Promising non-traditional avenues for evolution education

Perhaps the most promising increases in evolution understanding and acceptance results from David Sloan Wilson's (2005) undergraduate class, "Evolution for Everyone." This course deliberately pursues increasing knowledge and positive attitudes about evolution by demonstrating the theory's relevance and broad application across the sciences, social sciences, and humanities. Evidence suggests that their efforts were largely successful (O'Brien, Wilson, and Hawley, 2009). At the same time, however, O'Brien and colleagues did not compare student outcomes across comparison classes, such as biology or a control group.

Courses on evolutionary psychology may provide an additional promising, yet unexplored, avenue for enhancing evolution attitudes because of its inherent focus on contemporary human psychology and topics especially relevant for and appealing to undergraduates, such as aggression, interpersonal attraction, and morality. The present study includes the following question: Does an evolutionary psychology curriculum enhance positive attitudes towards the theory in ways that are associated with learning?

The present study

The present study seeks to examine several carefully selected university courses (evolutionary psychology, a biology course with significant evolutionary content, and a

political science course with no evolutionary content) for change across the semester on several relevant dimensions of the previously validated long form of the Evolutionary Attitudes and Literacy Survey (EALS; Hawley, Short, McCune, Osman, and Little, 2011). The EALS comprises several higher order factors of interest, including Knowledge/Relevance, Creationist Reasoning, Evolutionary Misconceptions, Political Activity, Religious Conservatism, and Exposure. Hypotheses about each will be described in turn.

Knowledge/Relevance. The construct Knowledge/Relevance, a subscale of the EALS (Hawley et al., 2011) that measures the degree to which one both agrees with basic facts about genetics, evolutionary theory, and the scientific enterprise, and views evolutionary theory as relevant to various fields of study, has been shown to increase in response to specific evolution-focused courses (O'Brien et al., 2009; Wilson, 2005). Thus, the construct Knowledge/Relevance was hypothesized not to change in the political science course, but increase for both biology and evolutionary psychology assuming the instruction was effective.

Creationist Reasoning. The Creationist Reasoning subscale of the EALS is characterized by adherence to intelligent design and young-earth creationist beliefs, distrust of the scientific enterprise, and moral and social objections to evolutionary theory (Hawley et al., 2011). One course objective of evolutionary psychology (as reflected in a widely adopted textbook and, thus, the textbook for the present evolutionary psychology course; Buss, 2007) was to address the fallacies of young-earth creationist and intelligent design beliefs by highlighting the concept of time and the social history of the field together with a careful handling of the philosophy of science and epistemologies. Therefore, a decrease in Creationist Reasoning was hypothesized to be demonstrated among students in the evolutionary psychology course, but not in the biology or political science courses where such topics are not evident in the syllabus or table of contents of the textbook that was adopted in the present classes.

Evolutionary Misconceptions. Evolutionary Misconceptions are false beliefs about evolution, including both Lamarckian (e.g., a trait an organism acquires during its lifetime can be passed down to its offspring) and teleological ideas (e.g., species evolve in order to reach a finite goal). Because past examinations of biology courses have revealed that students continue to adhere to evolutionary misconceptions even after a semester long biology course (Bishop and Anderson, 1990; Brumby, 1984; Jensen and Finley, 1996; Nehm and Reilly, 2007), the construct Evolutionary Misconceptions was not hypothesized to change for students in the biology course, nor the control group of political science. Common misconceptions, however, are explicitly addressed in the textbook adopted for the evolutionary psychology class (i.e., Buss, 2007) and, therefore, were hypothesized to decrease after the evolutionary psychology course instruction.

Not Targeted for Change: Political Activity, Religious Conservatism, and Exposure to Evolution. Political Activity consists of an individual's self-reported degree to which they are politically active, aware, and have political views which influence their daily life and decisions. Religious Conservatism is a complex construct largely characterized by how much an individual identifies themselves as politically conservative in general, how much an individual identifies themselves as politically conservative specifically on social, economic, and foreign issues, how much religion impacts one's daily life and decisions, and the belief that life begins at conception (see Miller et al., 2006). The construct

Exposure to Evolution consists of one's adult self-exposure to evolution-related media (e.g., web sites, videos, and publications) and one's youth exposure to evolution (e.g., including visiting natural history museums).

None of the three selected course curricula specifically sought to change students' political or religious orientation or activities. Thus, the constructs Political Activity and Religious Conservatism were not hypothesized to change after any of the three courses. Finally, because the construct Exposure to Evolution consists of youth exposure to evolution, the construct was not hypothesized to change among young adult college students enrolled in the three selected courses.

Materials and Methods

Participants

The biology class sample consisted of 437 undergraduates representing 31 majors, including 179 (40.96%) men, 191 (43.71%) women, and 67 (15.33%) participants who did not report gender, enrolled in an introductory course on the principles of organismal biology. Enrollment in this course required students to have previously completed both an introductory chemistry course and a course on the principles of molecular and cellular biology. This class had full enrollment with 483 students. In addition, this class sample was predominantly White (71%) and was largely comprised of first (30.15%), second (33.46%), and third (26.23%) year students. The average age was 20.24 years (*SD* = 3.36). The textbook adopted for this class was *Campbell Biology*, 9th edition (Reece et al., 2011).

The political science sample consisted of 366 students from the introduction to U.S. politics course, with students representing 43 different majors. This course had no prerequisite for enrollment and had a total of 383 students enrolled. The sample consisted of 164 (42.81%) men, 202 (52.74%) women, and 17 (4.44%) participants who did not report gender. The sample was largely White (84.52%), and it consisted of mostly first year (30.92%) and second year (36.55%) college students. Additionally, the average age was 20.04 years (*SD* = 3.26).

The evolutionary psychology sample consisted of 65 students from a course in evolutionary psychology representing 11 majors. Enrollment in the course required previous completion of introductory psychology, as well as three additional credit hours in psychology. The course had full enrollment with 70 students. The sample consisted of 37 (56.92%) men and 28 (43.08%) women, and it was composed of mostly White students (92.96%) and fourth year college students (66.20%). Additionally, the average age was 21.30 years (*SD* = 1.26). The textbook adopted for this class was *Evolutionary Psychology: The New Science of the Mind*, 3rd edition (Buss, 2007).

Measures

The Evolutionary Attitudes and Literacy Survey (EALS; Hawley et al., 2011) is a multidimensional scale that consists of 16 lower order and 6 higher order constructs (i.e., Political Activity, Religious Conservatism, Creationist Reasoning, Knowledge/Relevance, Evolutionary Misconceptions, and Exposure to Evolution) developed to measure the wide array of factors that influence both an individual's endorsement of and objection to evolutionary theory. The construct and predictive validity of the EALS has been demonstrated by a confirmatory factor analysis (CFA) and structural equation models

(SEM), respectively (Hawley et al., 2011). This appropriately validated measure can potentially improve empirical examinations of the effectiveness of evolution education and attitudinal change, especially in conjunction with modern statistical methods.[1]

The long form of the EALS (http://eals.org; Hawley et al., 2011; cf. the short form; Short and Hawley, 2012) consists of 104 items, most of which respondents rated the degrees to which they agreed or disagreed with each statement on a 7-point Likert scale (1 = "strongly disagree," 4 = "neither agree nor disagree," 7 = "strongly agree"). The EALS measures 16 constructs that distill into 6 higher-order constructs representing Political Activity, Political/Religious, Creationist Reasoning, Knowledge/Relevance of Evolution, Evolutionary Misconceptions, and Exposure to Evolution (see Table 1 for sample items).

Table 1. Sample items from the EALS

Construct	Sample Items
Political Activity	
	To what degree are you political?
	To what degree do your political views influence your daily life?
	To what degree do your political views influence your decisions?
Religious Conservatism	
	To what degree does your religion influence your decisions?
	Life begins at conception.
	In general how liberal/conservative are you on Economic issues (welfare, taxation, free market policies, etc)? [A]
Creationist Reasoning	
	Present animal diversity can be explained by the Great Flood.
	The theory of evolution has contributed to racism.
	The data used to support evolution is untrustworthy.
Knowledge/Relevance	
	Humans share a majority of their genes with chimpanzees. [B]
	The theory of evolution helps us understand human origins.
	Mutations can be passed down to the next generation.
Evolutionary Misconceptions	
	Characteristics acquired during the lifetime of an organism are passed down to that individual's offspring.
	Evolution means progression towards perfection.
	Evolution is a linear progression from primitive to advanced species.
Exposure to Evolution	
	I've watched evolution related videos on the web (e.g., Ted.com, YouTube).
	I have visited natural history museums on field trips or with family.
	I've watched nature shows that discussed evolution (e.g., PBS/Nova, Discovery, National Geographic)

Note. [A] From Carney, Jost, Gosling, and Potter (2008); [B] From Miller et al. (2006)

[1] For the present work, the EALS is preferable over other published measures because it is more comprehensive, has an established structure, and has been empirically validated (cf. Changes in Attitude about the Relevance of Science scale [CARS]: Siegel and Ranney, 2003; The Conceptual Inventory of Natural Selection [CINS]: Anderson, Fisher, and Norman, 2002; and the Measure of Acceptance of the Theory of Evolution [MATE]: Rutledge and Warden, 1999).

Data collection

During the first week of the semester and prior to students being exposed to course material, each course instructor emailed all students and asked them to complete an online survey outside of class time via an easy-to-access link that was posted on their course website. Participants were informed that the purpose of the study was to examine their attitudes about and knowledge of evolution, and they were asked to complete the survey after providing their consent. Participants were thanked upon completion and were provided with a negligible amount of extra credit in their course for their participation. Participants were then contacted again 14 weeks later during the last week of course instruction to complete the relevant content of the survey again (that is, demographics were collected only once). Over 90% of enrolled students in each course completed at least one of the two waves of measurement. This study was approved by the Human Subjects Committee–Lawrence Campus, the federally recognized institutional review board for the University of Kansas, and all participants were treated in accordance with the "Ethical principles of the psychologists and code of conduct" (American Psychological Association, 2002).

Plan of analyses

Overall, each group had only a moderate amount of missingness (25% for the political science course, 26% for the biology course, and 2.5% for the evolutionary psychology course). Missing data were handled via full information maximum likelihood (FIML) estimation within Mplus version 7.0 (Muthén and Muthén, 2012). Age, gender, ethnicity, mother's education level, father's education level, year in college, and openness to experience were included as auxiliary variables for FIML estimation (Enders, 2010).

Measurement model. First, an appropriate CFA null model for longitudinal data was specified by having each manifest variable load onto its own unique latent variable that is orthogonal to all other latent variables, equating the indicator loadings and means across time, and fixing the intercepts and residual variances to 0 (see Widaman and Thompson, 2003).[2] Next, a CFA measurement model demonstrating the relationships between the measured (e.g., manifest) indicators (i.e., the items) and the latent constructs was specified with 12 latent constructs, including the six higher-order EALS constructs (e.g., Knowledge/Relevance of Evolution, Creationist Reasoning, Evolutionary Misconceptions, Political Activity, Religious Conservatism, and Exposure to Evolution) for the pre-course (i.e., Time 1) and post-course (i.e., Time 2) assessment. In order to have an identified model, at least three parceled indicators (see Little, Cunningham, Shahar, and Widaman, 2002) were used for each construct. The parceled indicators were created by calculating the mean for the set of items in each of the 16 subscales of the EALS. All six of the Time 2 constructs were indicated with the same pattern of parceled items as those constructs measured at Time 1 prior to course instruction, which indicates that the structure of the scale did not change over time. Because the same items were measured across two time points, each Time 1 indicator had a correlated residual estimated for the corresponding Time 2 indicator. All models were identified by the effects-coding (each constructs' items are fixed such that their average loading equals 1.0) to maintain the scaling metric of the

[2] For a full explication of the CFA for the survey, see Hawley et al. (2011) for the long form, Short and Hawley (2012) for the short form, and http://eals.org for a user's guide.

indicators (see Little, Slegers, and Card, 2006). Completely standardized factor loadings for each parcel and across each course can be found in Table 2 for Time 1 and Table 3 for Time 2 assessments.

Table 2. Time 1 model parcels and completely standardized factor loadings

		Completely Standardized Factor Loading		
Construct	Parcel	Political Science	Biology	Evo Psych
Political Activity				
	Political Activity P1	.888	.887	.810
	Political Activity P2	.897	.921	.897
	Political Activity P3	.919	.897	.939
Religious Conservatism				
	Religious Activity	.825	.771	.649
	Conservative Self-Identity	.565	.582	.526
	Attitudes Toward Life	.628	.657	.701
	Intelligent Design Fallacies	.342	.436	.698
	Young-Earth Creationism	.480	.472	.536
	Relevance	-.213	-.370	-.319
Knowledge/Relevance				
	Relevance	.643	.502	.533
	Genetic Literacy	.897	.883	.758
	Evolutionary Knowledge	.765	.819	.772
	Knowledge of the Scientific Enterprise	.699	.773	.760
Creationist Reasoning				
	Intelligent Design Fallacies	.688	.603	.317
	Young-Earth Creationism	.526	.536	.448
	Moral Objections	.681	.717	.464
	Social Objections	.724	.763	.635
	Distrust for the Scientific Enterprise	.840	.870	.921
Evolutionary Misconceptions				
	Evolutionary Misconceptions P1	.545	.642	.743
	Evolutionary Misconceptions P2	.781	.632	.626
	Evolutionary Misconceptions P3	.642	.458	.572
Exposure to Evolution				
	Self-Exposure P1	.880	.910	.861
	Self-Exposure P2	.847	.789	.779
	Youth Exposure to Evolution	.602	.647	.788

Table 3. Time 2 model parcels and completely standardized factor loadings

Construct	Parcel	Completely Standardized Factor Loading		
		Political Science	Biology	Evo Psych
Political Activity				
	Political Activity P1	.885	.906	.862
	Political Activity P2	.927	.937	.930
	Political Activity P3	.947	.932	.873
Religious Conservatism				
	Religious Activity	.841	.804	.655
	Conservative Self-Identity	.564	.576	.519
	Attitudes Toward Life	.667	.653	.691
	Intelligent Design Fallacies	.265	.462	-.481
	Young-Earth Creationism	.299	.521	.076
	Relevance	-.179	-.404	-.201
Knowledge/Relevance				
	Relevance	.723	.484	.722
	Genetic Literacy	.846	.888	.671
	Evolutionary Knowledge	.878	.840	.917
	Knowledge of the Scientific Enterprise	.639	.799	.818
Creationist Reasoning				
	Intelligent Design Fallacies	.766	.578	1.426
	Young-Earth Creationism	.724	.490	.828
	Moral Objections	.834	.781	.346
	Social Objections	.750	.807	.404
	Distrust for the Scientific Enterprise	.843	.921	.745
Evolutionary Misconceptions				
	Evolutionary Misconceptions P1	.620	.712	.946
	Evolutionary Misconceptions P2	.735	.789	.621
	Evolutionary Misconceptions P3	.625	.557	.615
Exposure to Evolution				
	Self-Exposure P1	.879	.951	.925
	Self-Exposure P2	.884	.850	.714
	Youth Exposure to Evolution	.701	.605	.694

Model invariance testing. Both course and time invariance were tested simultaneously in the current study.[3] First, configural invariance was established by specifying the same estimated parameter paths for each group. Second, weak invariance was established by equating the factor loadings across each group so that only one factor loading was estimated for each construct. Next, the item intercepts were equated across groups to establish strong invariance. Both the weak and strong invariance model constraints were deemed tenable if RMSEAs from each model were within the RMSEA confidence interval for the less constrained model. The change in CFI for each nested model was also examined because it is robust to model complexity and sample size (Cheung and Rensvold, 2002).

Once strong invariance was established, homogeneity of variances was tested across time and course. A chi-square (χ^2) difference test between the χ^2 from the strong invariance model (e.g., free variance between groups) and the χ^2 from the homogeneity of variances was conducted to determine if model fit significantly worsened from the additional constraints. Finally, latent mean invariance tests were performed to examine potential mean differences across courses and time. First, the latent means for each construct were equated across courses to test for a course main effect (e.g., $A_{\text{Political Activity, Poli Sci}} = A_{\text{Political Activity, Bio}} = A_{\text{Political Activity, Evo Psych}}$). Next, latent mean invariance across time for each construct was tested by equating the latent mean of each construct for Time 1 and Time 2 observations (e.g., $A_{\text{Time 1 Political Activity}} = A_{\text{Time 2 Political Activity}}$). All constrained means models were compared to the strong invariance model via a χ^2 difference test to determine if equality constraints were tenable.

Results

CFA measurement model

Overall, the measurement model CFA demonstrated acceptable fit, $\chi^2(2178, N = 868) = 3779.25$, $p < .0001$, comparative fit index (CFI) = .93, Tucker-Lewis fit index (TLI) = .92, RMSEA = .05, 95% CI [.048, .053]. Modification indices were examined in order to ensure the CFA produced the best fitting model. These indices were relatively low with a $\Delta\chi^2 < 10\%$ of the overall chi-square, and lacked theoretical support. Therefore, the current measurement model was maintained.

Course and time invariance

Table 4 displays the model fit statistics from the simultaneous test of time and course invariance. The loadings across the three courses and two time points were equated for each construct for the weak invariant model. Weak factorial invariance was met with no significant change in model fit, with the RMSEA from the weak factorial model fit within the 90% RMSEA confidence interval for the configural invariant model. Also, the change in CFI was less than .01 (Cheung and Rensvold, 2002) and the change in TLI was less than .01. Similarly, equality of the indicator intercepts was met with the strong invariant model, with the RMSEA, CFI, and TLI meeting the same criteria listed above for the weak invariant model.

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[3] Establishing invariance across time demonstrates the constructs are similar across both assessments (Widaman, Ferrer, and Conger, 2010), whereas course invariance demonstrates the constructs are similar across courses (Brown, 2006). Additional comparisons can be made once invariance is established.

Table 4. Fit indices for model invariance testing

Model	χ^2	*df*	$\Delta\chi^2$	Δdf	*p*	RMSEA	RMSEA 90% CI	NNFI	CFI	Constraint Tenable
Null Model	54323.13	2709	---	---	---	---	---	---	---	---
Configural Invariance[1]	3778.25	2178	---	---	---	.050	.048–.053	0.915	0.928	---
Weak Invariance[1]	3989.30	2268	---	---	---	.051	.049–.054	0.912	0.923	Yes
Strong Invariance[1]	4371.45	2343	---	---	---	.055	.052–.057	0.900	0.919	Yes
Homogeneity of Variances[2]	4452.32	2373	80.87	30	<.001	---	---	---	---	No
Latent Mean Invariance[2]	4771.10	2373	399.65	30	<.001	---	---	---	---	No

Note. [1] Evaluated with RMSEA Model Test; [2] Evaluated with χ^2 Difference Test; Each nested model contains its constraints, plus the constraints of all previous, tenable models; Course and Time invariance was tested simultaneously.

Table 5. Test of the equality of variances

Model	χ^2	*df*	$\Delta\chi^2$	Δ *df*	*p*	Constraint Tenable
Intercept Invariance (Baseline model)	4371.45	2343	---	---	---	---
Equality of Variances	4452.32	2373	80.87	30	<.001	No
Course	4430.88	2367	59.43	24	<.001	No
Time	4416.38	2361	49.93	18	<.001	No
Political Activity	4372.87	2346	1.42	5	.92	Yes
Religious Conservatism	4372.56	2346	1.11	3	.78	Yes
Knowledge/Relevance	4379.17	2346	7.72	3	.05	Yes
Creationist Reasoning	4393.39	2346	21.94	3	<.001	No
Political Science	4379.34	2344	7.89	1	<.01	No
Biology	4378.15	2344	6.70	1	<.05	No
Evolutionary Psychology	4378.75	2344	7.30	1	<.05	No
Evolutionary Misconceptions	4386.46	2346	15.01	3	<.002	No
Political Science	4371.50	2344	0.05	1	.82	Yes
Biology	4385.79	2344	14.34	1	<.001	No
Evolutionary Psychology	4372.06	2344	0.61	1	.43	Yes
Exposure to Evolution	4373.27	2346	1.82	3	.61	Yes

Homogeneity of variances

Strong invariance across both time and courses allowed for additional comparisons to be made. One advantage to examining mixed designs with multiple group repeated measures CFA is the ability to test assumption, such as homogeneity of variances, and examine possible differences. Table 5 displays the tests of homogeneity of variances across course and time. The test of homogeneity of variances was significant, $\Delta\chi^2(30) = 80.87$, $p < .0001$, indicating that the variances between constructs did differ across courses and/or time. Further examination revealed significant differences existed with both course, $\Delta\chi^2(24) = 59.43$, $p < .0001$, and time, $\Delta\chi^2(18) = 49.93$, $p < .001$. Because variance equality constraints across courses and time were not tenable, tests were conducted to determine where significant differences existed.

Tests for equality of variance across time were conducted for each of the six EALS constructs. Political Activity, Religious Conservatism, Knowledge/Relevance and Exposure to Evolution were found to be homogenous for each course across time. Conversely, significant differences in construct variances between Time 1 and Time 2 were present for Creationist Reasoning and Evolutionary Misconceptions. Creationist Reasoning variance significantly increased from Time 1 to Time 2 for both the political science course ($\Psi_{PoliSciT1} = 0.56$, $\Psi_{PoliScT2} = 0.72$, $\Delta\chi^2[1] = 7.89$, $p < .01$) and the biology course ($\Psi_{BioT1} = 0.64$, $\Psi_{BioT2} = 0.79$ $\Delta\chi^2[1] = 6.70$, $p < .05$), but significantly decreased for the evolutionary psychology course ($\Psi_{EvoPsyT1} = 0.45$, $\Psi_{EvoPsyT2} = 0.27$, $\Delta\chi^2[1] = 7.30$, $p < .01$). Evolutionary Misconceptions variance significantly increased from Time 1 to Time 2 only for the biology course ($\Psi_{BioT1} = 0.47$, $\Psi_{BioT2} = 0.86$, $\Delta\chi^2[1] = 14.34$, $p < .05$.

Testing the hypotheses

After course and time invariances were established, the hypothesized differences were examined by testing the equality of the latent means. Table 6 includes the unconstrained latent means and standard deviations for each course, and Table 7 includes the omnibus test (i.e., overall test) of latent mean invariance, as well as additional follow-up tests exploring mean differences within course and time.

Table 6. Estimated latent means (*SD*)

	Political Science		Biology		Evo Psych	
	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
Political Activity	3.31 (1.59)	3.28 (1.51)	2.75 (1.42)	2.89 (1.55)	2.99 (1.20)	2.98 (1.13)
Religious Conservatism	2.32 (1.28)	2.31 (1.26)	2.29 (1.25)	2.26 (1.25)	1.68 (0.80)	1.62 (0.78)
Knowledge/ Relevance	4.87 (1.03)	4.97 (1.09)	5.58 (1.07)	5.65 (1.19)	5.81 (0.81)	6.16 (0.79)
Creationist Reasoning	2.55 (1.28)	2.54 (1.34)	2.21 (1.34)	2.14 (1.40)	1.93 (0.78)	1.55 (0.66)
Evolutionary Misconceptions	3.87 (0.96)	3.89 (0.99)	4.17 (1.00)	4.52 (1.25)	3.35 (1.04)	2.92 (1.11)
Exposure to Evolution	2.24 (0.77)	2.26 (0.78)	2.58 (0.79)	2.66 (0.86)	2.60 (0.69)	2.75 (0.65)

Table 7. Test of the latent means

Model	χ^2	*df*	$\Delta\chi^2$	Δ *df*	*p*	Constraint Tenable	Effect Size[1]
Intercept Invariance (Baseline model)	4371.45	2343	---	---	---	---	---
Latent Mean Invariance	4771.10	2373	399.65	30	<.0001	No	---
Course	4742.56	2367	371.11	24		No	---
Time	4461.32	2361	89.87	18	<.0001	No	---
Political Activity	4376.36	2346	4.91	3	.18	Yes	---
Religious Conservatism	4377.38	2346	5.93	3	.12	Yes	---
Knowledge/Relevance	4393.99	2346	22.54	3	<.001	No	---
Political Science	4378.38	2344	6.93	1	<.01	No	0.13
Biology	4375.09	2344	3.64	1	.06	Yes	---
Evolutionary Psychology	4383.43	2344	11.98	1	<.001	No	0.51
Creationist Reasoning	4407.13	2346	35.68	3	<.001	No	---
Political Science	4371.59	2344	0.14	1	.71	Yes	---
Biology	4376.09	2344	4.64	1	<.05	No	-0.09
Evolutionary Psychology	4382.96	2344	11.51	1	<.001	No	-0.63
Evolutionary Misconceptions	4413.86	2346	42.41	3	<.001	No	---
Political Science	4371.59	2344	0.14	1	.71	Yes	---
Biology	4402.15	2344	30.70	1	<.001	No	0.42
Evolutionary Psychology	4382.96	2344	11.51	1	<.001	No	-0.47
Exposure to Evolution	4381.24	2346	9.79	3	<.05	No	---
Political Science	4371.58	2344	0.13	1	.72	Yes	---
Biology	4375.95	2344	4.50	1	<.05	No	0.11
Evolutionary Psychology	4376.61	2344	5.16	1	<.05	No	0.25

Note. Reported negative effect sizes indicate a significant decrease from Time 1 to Time 2, whereas positive effect sizes represent a significant increase from Time 1 to Time 2. [1] Effect size is latent *d*, where $d = (\alpha_{2j} - \alpha_{1j}) / \sqrt{\psi}_{pooled}$

The omnibus test of latent mean invariance was significant, $\Delta\chi^2(30) = 399.65$, $p < .0001$, as well as the main effect for course, $\Delta\chi^2(24) = 371.11$, $p < .0001$, and the main effect of time, $\Delta\chi^2(18) = 89.87$, $p < .0001$. Because both main effects were significant, simple main effects for each construct were examined within time. If the simple main effect of a construct within time was significant (i.e., significant differences in latent means existed between Time 1 and Time 2 for each construct), then the effect was examined within each course to determine where the differences existed. The results for the six EALS constructs are described below.

Knowledge/Relevance. The test of latent mean invariance across Knowledge/Relevance of Evolution was significant, $\Delta\chi^2(3) = 22.54$, $p < .001$. Thus, each course was examined for possible mean differences across time. Contrary to our hypothesis, Knowledge/Relevance of Evolution did not significantly differ across time in the biology course, $\Delta\chi^2(1) = 3.64$, $p = .06$, but, unexpectedly, significant differences did emerge for the political science course ($A_{Time\ 1} = 4.87$, $SE = 0.05$; $A_{Time\ 2} = 4.97$, $SE = 0.06$), $\Delta\chi^2(1) = 6.93$, $p < .01$, though the effect size was small ($d = 0.13$). Knowledge/Relevance changed for evolutionary psychology course in a positive direction, as expected ($A_{Time\ 1} = 5.81$, $SE = 0.10$; $A_{Time\ 2} = 6.16$, $SE = 0.10$), $\Delta\chi^2(1) = 11.98$, $p < .001$. The effect size for evolutionary psychology was moderate ($d = 0.51$).

Creationist Reasoning. Creationist Reasoning did not significantly differ across time for the political science course, $\Delta\chi^2(1) = 0.14$, $p = .71$. Creationist Reasoning did significantly differ across time for the evolutionary psychology course, with pre-course Creationist reasoning ($A_{Time\ 1} = 1.93$, $SE = 0.10$) significantly greater than post-course Creationist Reasoning ($A_{Time\ 2} = 1.55$, $SE = 0.08$), $\Delta\chi^2(1) = 11.51$, $p < .001$. There was a moderate effect size ($d = -0.63$) for this significant difference. In addition, the biology course had a small ($d = -0.09$), but statistically significant decrease in Creationist Reasoning from Time 1 ($A_{Time\ 1} = 2.21$, $SE = 0.06$) to Time 2 ($A_{Time\ 2} = 2.14$, $SE = 0.10$), $\Delta\chi^2(1) = 4.64$, $p = .03$.

Evolutionary Misconceptions. Evolutionary Misconceptions did not significantly differ across time for the Political Science course, $\Delta\chi^2(1) = 0.14$, $p = .71$. Conversely, Evolutionary Misconceptions did significantly decrease over time for evolutionary psychology ($A_{Time\ 1} = 3.35$, $SE = 0.13$; $A_{Time2} = 2.92$, $SE = 0.14$), $\Delta\chi^2(1) = 11.51$, $p < .001$. The effect size here was moderate ($d = -0.47$). Evolutionary Misconceptions significantly increased for the biology course ($A_{Time\ 1} = 4.17$, $SE = 0.05$; $A_{Time\ 2} = 4.52$, $SE = 0.06$), $\Delta\chi^2(1) = 30.70$, $p < .001$, and had a moderate effect size ($d = 0.42$).

Political Activity, Religious Conservatism, and Exposure to Evolution. The test of latent mean invariance across time for Political Activity was not significant, $\Delta\chi^2(3) = 4.91$, $p = .18$. Political Activity did not change from pre-course to post-course assessment for the biology, political science, or evolutionary psychology course. The test of latent mean invariance across Religious Conservatism was not significant, $\Delta\chi^2(3) = 5.93$, $p = .12$. Religious Conservatism did not change from pre-course to post-course assessment for the biology, political science, or evolutionary psychology course.

Self-reported Exposure to Evolution did not significantly differ across time for the political science course, $\Delta\chi^2(1) = 0.13$, $p = .72$. However, Exposure to Evolution did significantly increase for both the biology course ($A_{Time\ 1} = 2.58$, $SE = 0.04$; $A_{Time\ 2} = 2.66$, $SE = 0.04$), $\Delta\chi^2(1) = 4.50$, $p < .05$; $d = 0.11$, and the evolutionary psychology course ($A_{Time\ 1} = 2.60$, $SE = 0.09$; $A_{Time\ 2} = 2.75$, $SE = 0.08$), $\Delta\chi^2(1) = 5.16$, $p < .05$; $d = 0.25$.

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 curricular elements to determine if the topic coverage was effective in changing some of the complex constructs influencing attitudes toward—and knowledge of—evolution.

Several important patterns emerged that bear centrally on the issue. First, there was no significant change in students' Political Activity or Religious Conservatism prior to or following a semester long course in biology, political science, or evolutionary psychology. No change was expected because none of these courses contained curriculum specifically designed to increase students' political participation, conservative beliefs, or religious activity, and, as such, no change was observed.

Changes in knowledge and misconceptions

For our present purposes, we were most concerned with change across time within each course irrespective of their starting points on any of the constructs of interest. In other words, does completion of a given course change students' attitudes toward or knowledge of evolution regardless of where they initially stand?

Knowledge/Relevance. Knowledge/Relevance of evolution consists of understanding basic genetic principles related to evolution (e.g., humans and chimpanzees share a majority of their DNA), the theory of evolution, the scientific method, and whether the theory of evolution is relevant both in the sciences and humanities. Significant positive change in Knowledge/Relevance of evolution was observed for the evolutionary psychology course, but—contrary to our hypothesis—no change was observed in the biology course. One important implication of these results is that significant gains in student knowledge and relevance of evolutionary theory may be possible if educators devote instructional time to a comprehensive examination of evolutionary theory (see also O'Brien et al., 2009; Wilson, 2005). For example, Nehm and Reilly (2007) observed greater increases in knowledge of evolution upon completing a biology course that was taught with an active-learning style (e.g., group discussions, paired problem solving), where the theory of evolution was incorporated in the curriculum throughout the semester, versus a traditional lecture-style biology course that primarily addressed the theory of evolution at the beginning of the semester. In addition, Tran, Weigel, and Richmond (2014) reported that undergraduate students enrolled in an upper-level biology course showed significantly higher knowledge and lower misconceptions between pre- and post-course assessments when weekly 50-minute small group discussions occurred throughout the term, with evolution as a central tropic for three of the discussions and a common theme throughout the term. Similarly, the evolutionary psychology course continually integrated evolution throughout each topic covered (recurrently invoking, for example, sexual selection, parental investment, reciprocal altruism, and inclusive fitness), which may explain the notable increase in knowledge/relevance for the course. Introducing evolutionary theory at the top of the course while noting in passing its importance to the field may not be as effective as explicitly demonstrating its relevance across the semester.

Active learning styles enhance engagement and have been shown to enhance knowledge acquisition (Nehm and Reilly, 2007). The topic of engagement may be relevant for evolutionary psychology. The biology course does not list human behavior as a topic covered, whereas the evolutionary psychology course not only is predominantly about human behavior, but additionally includes topics relevant to students' everyday lives (e.g., romantic love, parenting, alliances and friendships, and within-family favoritism). Such topics of personal interest generally lie well outside the scope of the biology course surveyed. As for evolutionary psychology, the discipline quickly relates to everyone in the room.

There may be, however, additional unexplored contributing factors. For example, student enrollment in the biology course was over six times larger than the evolutionary psychology course, which may have influenced curricular effectiveness. However, previous research reported class size was not related to student learning for courses in biology or psychology (Cheng, 2011). Thus, class size alone probably does not explain the differences. Furthermore, the examined biology course had a prerequisite of molecular and cellular biology, whereas the evolutionary psychology course required completion of introductory psychology and another psychology course of the student's choosing. Even though evolutionary psychology students were, on average, older than the biology students (by 1.06 years), we have no reason to suspect that being a year younger in age, or even academic career, should result in no gain in evolutionary knowledge upon completing a biology course. In fact, the present results are counter to previous increases in knowledge found after completing a biology course (Bishop and Anderson, 1990). Perhaps the evolutionary psychology students were simply more motivated to learn. The course is an elective (versus the biology course being required for biology majors), and though enrollment was capped at 70, many more attempted to get in, which speaks to its popularity.

Misconceptions. Evolutionary misconceptions include false understandings of natural selection (e.g., natural selection is a random process) and beliefs that evolution can lead to perfection. Previous research has noted that misconceptions are pervasive and can remain even after completing a biology course (Bishop and Anderson, 1990; Brumby, 1984; Jensen and Finley, 1996; Nehm and Reilly, 2007), yet misconceptions significantly decreased in the present study for the evolutionary psychology course. Conversely, not only did the biology students' misconceptions significantly increase on average from the beginning to the end of the semester, but they also significantly increased in variability from the beginning to the end of the semester. This increase in both the mean and variability indicate that biology students not only reported more misunderstandings of the theory of evolution, but were also less consistent (i.e., possibly more uncertain) in their agreement with false statements about evolution.

These findings are certainly important for educators, as it again suggests that one's knowledge of basic scientific principles does not eliminate intuitive and incorrect understandings about evolution. In fact, the salience of misconceptions in science is not unique to the biological sciences. McCloskey (1983) found similar misconceptions/errors in physics. The majority of students still held onto their false intuitions about basic physical concepts even after they had completed a course on introductory physics. Similar to McCloskey's (1983) physics reasoning, students may have solidified incorrect intuitions about evolution prior to curricular exposure and simply assimilated the new material to fit

their existing framework of understanding. These evolutionary misconceptions were even shown to persist among science graduate students (Gregory and Ellis, 2009).

Finally, it could be argued that misconceptions in physical sciences are low stakes; for example, what are the consequences of believing larger objects fall faster than smaller ones or misunderstanding the trajectory of swung objects (McCloskey, 1983)? Additionally, what are the consequences of mistaking how water evaporates from plants? In contrast, the "stakes" of failing to correct misconceptions about evolution in regards to human psychology may arguably be higher, and for that reason evolutionary psychology textbooks generally take great care to dispel myths such as genetic determinism and racial superiority.

Creationist Reasoning. Creationist Reasoning is characterized by adherence to intelligent design and young-earth creationist beliefs, including distrust of scientific findings as well as morally and socially objecting to evolutionary theory. Students from evolutionary psychology had a significant decrease in both mean Creationist Reasoning and variability from the beginning to the end of the semester. Evolutionary psychology students not only adhered less to young-earth creationist and intelligent design beliefs, but were also more homogenous in their disagreement with these fallacies. Biology students also had a small, yet significant decrease in mean Creationist Reasoning, but interestingly increased in their variability by the end of the semester. Although biology students on average decreased in creationist reasoning, the increased variability may indicate more uncertainty in their disagreement with the above fallacies. These results further support the claim that simply being exposed to the theory of evolution in a scientific course may not sufficiently lower creationist reasoning, and that more course instruction and resources (such as textbooks) that specifically address these false beliefs of the earth's age, distrust of science, or genetic determinism are needed.

Exposure to evolution. The construct Exposure to Evolution measures the degree to which an individual viewed materials related to evolution as an adolescent and as an adult. No change in Exposure to Evolution was hypothesized, but a significant positive increase was observed for both the biology and evolutionary psychology course. This increase may have been due to students viewing the completion of their course as increased exposure, or the courses may have peaked interest in evolution. Interestingly, although Exposure increased in the biology course, Knowledge/Relevance did not significantly change, but Misconceptions significantly increased. Once again, these results may imply that mere exposure to the theory of evolution is not sufficient in demonstrating increased knowledge.

Limitations and future directions

The present work is the first comparison of evolutionary psychology to biology curriculum to explore whether differences in learning outcomes exist. Future work must explore whether differences are widespread, and if so, what causes them. As the first work of its kind, the present study has a number of limitations that warrant discussion.

To start, only students at a large Midwestern university were examined. It is possible that our effects are due to regional differences. Additional comparisons of other university samples across the nation are needed. At the same time, it is difficult to imagine the mechanism that would affect change in knowledge and attitude structures in the Midwest but not in other regions. In fact, demographic variables have been shown to have

less to do with evolutionary attitudes than did personality variables such as openness to experience (Hawley et al., 2011).

Although individuals from the U.S. may be unique in their lack of acceptance of evolution, an international increase in creationism has also become a concern for European educators (Blancke, Boudry, Braekman, De Smedt, and De Cruz, 2011). Future research should not be limited to only examining U.S. students. For example, a recent study by Ha, Haury, and Nehm (2012) reports one possible mechanism that moderates the relationship between knowledge of evolution and acceptance in pre-service science teachers in South Korea is the construct feeling of certainty. Individuals who felt more confident in their knowledge about evolution displayed higher acceptance of evolution (Ha et al., 2012). Future international research is needed to explore whether our current findings of course differences in change of knowledge and acceptance are observed elsewhere and if Ha et al.'s (2012) suggested mechanism for change in acceptance is cross-culturally supported.

Perhaps more importantly, in the present study we only had single courses taught by sole instructors. That is, our documented effects may not be due to course content per se, but rather individual differences associated with the instructors. Certainly, more evolutionary psychology courses must be examined across institutions. At the same time, however, similar courses at other universities (e.g., O'Brien et al, 2009) showed similar patterns of change using the beta version of the EALS.

Finally, the instructor of the present evolutionary psychology class is a co-author of the EALS, the attitude and knowledge instrument we employed here. Although the EALS was constructed after the course content was established, the present work cannot rule out unequivocally any demand characteristics and biases associated with individual identity. Although this latter concern may in principle account in part for the positive changes documented in the evolutionary psychology class, it cannot account for the *lack of change* or *change in a negative direction* for the biology course. Thus, we do not believe that this is a sizeable factor accounting for differences in our observed rates of change.

At the same time, the study has a number of notable strengths. It is the first of its kind to measure attitudes and knowledge with a single validated measure as far as we know. Therefore, it is also the first of its kind to do multi-group comparisons across curriculum content and change over time.

Conclusions

The results from the present study offer some encouragement to evolution educators, provide more insight into the effects of college courses on attitudes toward and knowledge of evolution, and again demonstrate the need for additional improvements in evolution education. This study implies that it would be false to assume that students fully understand evolutionary theory upon completing a course in biology. Past research (Nehm et al., 2009; Osif, 1997) further implies that even sufficient undergraduate training in biology to become a high school biology teacher may not be enough to increase relevance of evolution education, or to decrease support for instructional time devoted to creationism. Unfortunately, the undergraduate science curriculum, in particular biology, may have been the final formal training in evolutionary theory for both these previously examined science and non-science secondary educators (Glaze, Goldston, and Dantzler, 2014; Nehm et al., 2009; Osif, 1997), and possibly even today's high-school science instructors.

If we are striving to both promote evolution education and reduce creationism in the classroom, the current study's results further suggest that we first should examine more closely the evolution training that future instructors receive during their higher education and the outcomes of such training. Certainly, if undergraduate education is the last training received by future science instructors, then more attention to evolution training in higher education is needed. Ultimately, the current study was the start of many necessary examinations of understanding how the completion of various collegiate science courses that involve evolution may influence university students' attitudes and literacy in evolutionary theory. Although we cannot provide incontrovertible proof that curriculum content was the cause of our observed differences, we urge educators and researchers to recognize that a greater focus on evolution in higher education is needed to enhance pro-science culture change, in both the future science educators we are training and the future generations of youths they will instruct.

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