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Science Standards, Science Achievement, and Attitudes About Evolution

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Abstract

This article explores the relationships between (a) the quality of state science standards and student science achievement, (b) the public's belief in teaching evolution and the quality of state standards, and (c) the public's belief in teaching evolution and student science achievement. Using multiple measures, we find no evidence of a relationship between the quality of a state's science standards and student science achievement. We also examine the relationship between state-level beliefs about evolution and student achievement. Here, we find a positive and consistent relationship between a state's acceptance of evolution and student science achievement. Our results suggest that the attitudes that the public has toward evolutionary science are strongly related to student science achievement—more so than the quality of state science standards.

Keywords

science education, standards, state policies, evolution, science achievement

Introduction

With the recent push for implementation of the Common Core standards nationally, the long-running and often contentious debate about the utility

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and rigor[1] of standards has intensified (Cobb & Jackson, 2011; Porter, McMaken, Hwang, & Yang, 2011). In addition to a push for national standards in reading and math, the National Research Council and National Academy of Science's *Framework for K-12 Science Education* includes guidance for developing national science standards.[2] Yet, although advocates express that clear, concise, rigorous standards in a subject area will produce higher student outcomes (Scherer, 2001; Trimble, 2003), evidence of such effects is questionable. A few studies claim that a relationship exists (Reville, 2004; Swanson, 2006), but to date, rigorous studies of the practical effect of strong standards have been especially rare (Carmichael, Wilson, Porter-Magee, & Martino, 2010; Lauer et al., 2005).

This is not particularly surprising, as evidence suggests that implementation of standards can vary based on how district leaders interpret and then relay those standards to teachers and then how those teachers reinterpret the district's version based on their own perceptions (Spillane, 2000, 2002).[3] Several studies have also shown that standards play an insignificant role in what teachers are actually teaching in their classrooms (Bandoli, 2008; Berkman & Plutzer, 2011; Fowler & Meisels, 2010; Loveless, 2012; Moore, 2002). And, in the case of science standards, this point may be particularly exacerbated by the contentious issue of evolution (Bandoli, 2008; Berkman & Plutzer, 2011; Fowler & Meisels, 2010). It is reasonable to expect that the actual implementation of rigorous science standards, which typically have hot-button issues like evolution embedded in them, are at least partially disregarded by teachers because of the external signals they receive (Berkman & Plutzer, 2010; Chuang, 2003; Fowler & Meisels, 2010; Moore, 2004; Tatina, 1989; Van Koevering & Stiehl, 1989) During the last decade, for example, despite the fact that the U.S. Supreme Court in 1987 in *Edwards v. Aguillard* ruled that "creation science" is not science and cannot constitutionally be taught in science classrooms, Kansas voters battled over the inclusion of the "e-word" in their state standards. The Dover Area School District in Pennsylvania required biology teachers to teach "Intelligent Design" as an alternative to evolution, and Louisiana passed the first anti-evolution "academic freedom" bill, giving teachers and school boards the legal freedom to discredit scientifically accepted theories, even though both states emphasized evolutionary concepts in their state-mandated science standards (Bowman, 2007; Lerner, 2000a; Moore, 2002; National Center for Science Education [NCSE], 2006). Moreover, some teachers shy away from teaching evolution because they either do not accept evolution or do not understand or feel sufficiently prepared to teach evolutionary concepts (Aguillard, 1999; Aleixandre, 1994; Eve & Dunn, 1990; Griffith & Brem, 2004; Rutledge & Warden, 2000; Shankar & Skoog, 1993). These and other examples suggest that state science standards, particularly those that deal with evolution, may be difficult for teachers to implement.

In this article, we explore the relationship between six distinct evaluations of state science standards, a series of national polls on the public's belief about teaching evolution in schools, and student science achievement on the National Assessment of Educational Progress (NAEP). Specifically, we examine the following questions:

Research Question 1 (RQ1): What is the relationship between the quality of a state's science standards and student science achievement?
Research Question 2 (RQ2): What is the relationship between a state's residents' belief[4] in teaching evolution in schools and the quality of those science standards?
Research Question 3 (RQ3): What is the relationship between a state's residents' belief in teaching evolution in schools and student science achievement?

Background

What Americans Believe About Evolution?

"When I want to read fiction, I don't turn to *Arabian Nights*; I turn to works of biology—I like my fiction wild," proclaimed William Jennings Bryan at a Baptist convention during the 1920s (McPherson & Brinkley, 2001, p. 272). In 1981, 45 years after Bryan's death, Georgia Court of Appeals Judge Braswell Deen, Jr., echoed Bryan's sentiment, claiming that "this monkey mythology of Darwin is the cause of permissiveness, promiscuity, prophylactics, perversions, pregnancies, abortions, pornotherapy, pollution, poisoning and proliferation of crimes of all types" (Moore, Decker, & Cotner, 2010, p. 287).[5] After 14 federal court cases and 14 losses for creationists, creationism still heavily influences the public debate, is aired in many K-12 classrooms, and abets the general public's poor understanding or dismissal of the scientific process known as evolution (Berkman & Plutzer, 2010; Futuyma, 2009; Moore, 2000; Newton, 2010). Despite the increasing amount of evidence supporting evolution (Berra, 1990; Coyne, 2010; Dawkins, 2009; Futuyma, 2009; Kolbe, Leal, Schoener, Spiller, & Losos, 2012; Krings, Taylor, & Dotzler, 2012; NCSE, 2011; Rogers, 2011; Zimmer, 2009), about half of Americans still reject it. Many national polls show that acceptance of evolution by American adults has remained stagnant since the early 1980s. In 1982, Gallup found that 38% of people believed that humans evolved under God's guidance, compared with 44% who believed "God created humans in their present form." In 2010, Gallup reported that 38% still believed that evolution is guided by God and 40% still believe "God created humans in their present form" (NCSE, 2012; Newport, 2010).[6] Taking God out of the question, a 2009 Gallup Poll asked, "Do you personally believe in the theory of evolution, do you not believe in evolution, or do you not have an opinion either way?" Only 39% said they believed in evolution.

Besides asking Americans their general beliefs about evolution and creationism, several polling organizations have also asked whether creationism should be taught in public schools. In 2000, People for the American Way Foundation (2000) reported 79% of the American public backed teaching creationism in schools. In 2004, 65% of respondents to a CBS News/New York Times poll favored teaching both creationism and evolution. In a 2005 Harris survey, 55% of Americans polled favored teaching evolution, creationism, and intelligent design, and a 2006 poll by the Pew Research center found 58% surveyed favored teaching both creationism and evolution in schools (Polling Report, 2011). Several studies have found similar belief patterns among science teachers. Depending on the source, studies suggest that roughly one in four of all biology teachers advocate teaching creationism in schools (Berkman & Plutzer, 2010; Moore, 2002; Nehm, Kim, & Sheppard, 2009; Wiles & Branch, 2008).

Teachers and Their Treatment of Science Standards

Shortly after President Bush signed the No Child Left Behind Act requiring all states to create standards, Moore (2002) questioned whether or not state standards mattered with regard to teaching evolution. To answer this question, Moore compared the Thomas B. Fordham Institute's 2000 A-through-F grading of state evolution standards with published findings on the evolution-related-attitudes and actions of biology teachers in 15 states.[7] He concluded that in most cases, classroom activities and teacher lessons were not aligned with standards for science education. He observed that states with "unsatisfactory or useless standards" corresponded with biology teachers' lack of emphasis on evolution, larger percentages of biology teachers believing creationism should be taught in science class, and substantial numbers of biology teachers actually endorsing creationism in their science classes. At the same time, he also found discomforting teacher attitudes and actions in states that had "satisfactory to excellent" evolution standards. For example, 40% of biology teachers in Minnesota, which received a "B" from Fordham, were not teaching any evolution. Oregon, another "B" state, had 26% of biology teachers teaching creationism. Pennsylvania, an "A" state, had 33% of biology teachers believing that creationism should be taught in science class.

Bandoli (2008), Bowman (2008), Fowler and Meisels (2010), Donnelly and Boone (2007), and Berkman and Plutzer (2011) provide additional evidence that many biology teachers only briefly mention or refrain from teaching evolutionary content regardless of state standard requirements. Using recent high school graduate survey data, Bandoli (2008) compared the evolutionary teaching practices between two neighboring states, one with excellent treatment of evolution in state standards (Indiana) and the other with weak treatment of evolution (Ohio). He found that approximately 30% of students in both states reported that evolution was not covered or mentioned in their high school biology course. Bowman (2008) surveyed college students from eight different states and found that 6% were not taught about evolution, an additional 18% said that evolution was only "briefly mentioned," and 47% said evolution was "somewhat" taught." Only 26% responded that evolution was taught in-depth. Fowler and Meisels (2010) surveyed teachers on the new evolution strands in the Florida state standards and found that 20% of teachers are not comfortable teaching the evolution strands and that 38% of teachers will not use the updated standards to justify teaching evolution. However, 85% of teachers that responded believed they understood enough about evolution to teach it, even though 17% believed students could understand biology without learning evolution. Donnelly and Boone (2007) surveyed 229 Indiana biology teachers and found that although 64.0% used evolution as a central organizing principle in their course, 20% only briefly mentioned evolution content in their biology classes.[8] They further note that "Teachers' attitudes toward the evolution standards in particular are strong predictors of their evolution teaching practices" (p. 252).

This suggests that even when strong standards exist, there is no guarantee that they will be utilized by all classroom teachers. Teachers' prior attitudes toward evolution will continue to play a role. Berkman and Plutzer (2011) found similar results from a national survey of biology teachers. In their survey, only 28% of teachers advocated evolutionary biology, 60% who chose to avoid the controversy, and 13% specifically advocated teaching creationism. Although 87% of biology teachers are not advocating teaching creationism in biology class, Berkman and Plutzer concluded that the 60% of teachers who are avoiding the controversy "fail to explain the nature of scientific inquiry, undermine the authority of established experts, and legitimize creationist arguments, even if unintentionally" (p. 405).

Data

Standards

For this study, we selected a variety of evaluations of standards over a 12-year time period to account for the potential lag between the implementation of standards at the state level and the implementation of standards in the

Table 1. Descriptive Statistics of the Six Evaluations of State Standards.

	Low score	High score	*M*	Median	Grade range
McComas 2009 nature of science evaluation (%)	17	100	72.4	75	K-12
Lerner 2000 evolution standard evaluation (%)	2	100	62.0	73	K-12
Mead 2009 evolution standard evaluation (%)	20	100	73.9	78.5	K-12
Lerner 2000 science standard evaluation (%)	9	100	75.9	82.5	K-12
Gross 2005 science standard evaluation (%)	29	97	61.3	62	K-12
Lerner 2012 science standard evaluation (%)	2	97	46.8	44	K-12

classroom. We use six different evaluations of state science standards, with two specifically evaluating evolution standards (Table 1). Four of the six evaluations were published by the Thomas B. Fordham Institute: Lawrence Lerner's 2000 *State of State Science Standards*, Lerner's 2000 *Good Science, Bad Science: Teaching Evolution in the States*, Paul Gross's 2005 *State of State Science Standards*, and Lerner's 2012 *State of State Science Standards.*[9] We also use William McComas, Caroline Lee, and Sophia Sweeney's 2009 *Critical Review of Current U.S. State Science Standards with Respect to the Inclusion of Elements Related to the Nature of Science*, and Louise Mead and Anton Mates' 2009 *Why Science Standards are Important to a Strong Science Curriculum and How States Measure Up* (Gross, 2005; Lerner, 2000a, 2000b, 2012; McComas, Lee, & Sweeney, 2009; Mead & Mates, 2009).

For the 2000 *State of State Science Standar*ds and *Good Science, Bad Science* studies, Lerner evaluated science standards published before January 2000 for 45 states and evolution standards published before September 2000 for all states except Iowa.[10] In the overall science standard evaluation, Lerner graded on purpose, expectation, and audience; organization; coverage and content; quality; and negatives, such as the treatment of evolution. States could receive up to 79 points (Lerner, 2000b). In *Good Science, Bad Science*, Lerner graded state evolution standards on whether the document contained the "e-word," biological evolution, human evolution, geological evolution, cosmological evolution, historical sciences, creationist jargon, and disclaimers. States could earn 110 points and could lose points for creationist jargon and disclaimers. Lerner converted the final raw score to a percentage for both reports. Some states, such as Illinois and Ohio, had unsatisfactory evolution standards but received a high grade for their overall science standards (Lerner, 2000a).[11]

Paul Gross reevaluated all 50 states' science standards for Fordham's 2005 *State of the State Science Standards.*[12] His rubric consisted of five main criteria: expectations, purpose, and audience; organization; science content and approach; quality; and seriousness; and two minor criteria: inquiry and evolution. States could earn a raw score of 69 points, which he also converted to a percentage.

Nine years later, Mead and Mates published *Why Science Standards are Important to a Strong Science Curriculum and How States Measure Up*. They used Lerner's 2000 evolution evaluation rubric and concluded that 9 states had very good or excellent evolution standards (compared with 10 states in 2000), and 11 states had unsatisfactory, useless, absent, or disgraceful evolution treatment (compared with 19 states in 2000; Mead & Mates, 2009). Since Lerner's 2000 evaluation, 14 states showed some signs of improvement in their treatment of evolution, while 10 states declined in their grade.[13]

In 2009, McComas, Lee, and Sweeney at the University of Arkansas evaluated state science standards with respect to their treatment of the "nature of science." Although not directly related to evolution, some scholars believe a disparity exists between the perceptions of the nature of science and the difficulties some students have in learning evolutionary concepts, and some teachers have in teaching evolutionary concepts (Dagher & BouJaoude, 1997; Farber, 2003; Johnson & Peeples, 1987; Lawson & Thompson, 1988; Lawson & Weser, 1990; Lawson & Worsnop, 1992; Rudolph & Stewart, 1998; Rutledge & Warden, 2000). McComas and his colleagues evaluated state standards based on 12 criteria, such as "there is a distinction between laws and theories" and "scientific knowledge is empirically based." They found that some nature of science ideas were widely included in state standards, such as the role of experiments (86%) and the role of empiricism (96%). Others, such as the distinction between law and theory (54%), were not widely included. McComas's reviewers concluded that there is a strong "nature of science" content found in state standards.

Lerner (2012) recently published Lerner's second *State of the State Science Standards*.[14] For this evaluation, the reviewers looked at how rigorously each state covered physical science, life science, earth and space science, and scientific inquiry and methodology. Only six states earned an "A" for quality science standards whereas 27 received a "D" or "F." The report concluded that even though the most exemplary states do not set high proficiency bars on assessments, do not hold students and teachers accountable for learning, or have not provided teachers with the right instructional tools to improve achievement, standards are still "an important place to start" (p. 7).

Belief in Teaching Evolution

Berkman and Plutzer (2010) provide the second independent variable of interest used in our analysis: The state-level percentage of citizens endorsing the teaching of evolution exclusively.[15] Using multilevel modeling with imputation and post stratification from 9,533 randomly selected respondents in surveys between 1998 and 2005, they created a state-level variable that captures public opinion on attitudes toward teaching evolution exclusively, evolution in conjunction with creationism, or creationism exclusively.[16]

Student Test Scores

We obtained student achievement data from the National Center for Education Statistics' NAEP Data Explorer (Institute of Education Sciences [IES], National Center for Educational Statistics [NCES], NAEP, 2009). We use the 2009 eighth-grade NAEP science and life science, as well as reading and writing mean scale scores by state. For the portion of our analysis that uses a growth measurement, we calculate a gain score using the 2009 eighth-grade NAEP mean science score and the 2005 fourth-grade NAEP mean science score for each state.[17] NAEP as a measure of student achievement has several benefits: NAEP selects students randomly, NAEP selects enough students in each state to make state-level comparisons, NAEP collects background information on students, teachers, and schools, and the NAEP science assessment includes questions about evolution.

NAEP did not have results for Vermont and Nebraska in 2009, so we used their most recent scores—2000 and 2005, respectively. Alaska and Kansas did not have science test scores for any years. As a result, our sample size is 48 for models that incorporate test scores.[18] For ease of interpretation, we standardized the scale scores to have a mean of 0 and a standard deviation of 1.

Covariates

In addition to our independent variables of interest, we employ a set of additional variables to control for demographic influences. Belief in evolution is influenced by religious and political beliefs, and some research suggests that religiously dedicated children perform higher than their less religious peers (Jeynes, 2003; Regnerus & Elder, 2003), and political parties influence school quality and, indirectly, student achievement (DeBray-Pelot & McGuinn, 2009; Wolbrecht & Hartney, 2011). To separate the public's belief in teaching only evolution from other political and religious beliefs, we attempt to control for these confounding factors. To control for religious influences, we use the state percentage of respondents who do not have a religious preference, are atheist, or are agnostic (Newport, 2009).[19] To control for political influences, we use the percentage of respondents who are Republican or lean Republican (Jones, 2009).

To control for economic situations, we utilize 3-year estimates (2008-2010) of the median income of the population 16 years and over from the U.S. Census Bureau (2010) database. To capture student characteristics, we obtained two variables from the NCES Common Core Database: the percentage of students on free and reduced lunch and the percentage of non-White and non-Asian 8th graders (IES, NCES, Common Core Data, 2009). Finally, from the 2007 to 2008 Schools and Staffing Survey, we include the percentage of 7th- to 12th-grade core classes not taught by teachers with a major or certification in that subject (as cited in Almy & Theokas, 2010).

Empirical Strategy

An ordinary least squares (OLS) approach is used to estimate the relationship between state standard quality and student achievement in science (RQ1), state residents' belief in teaching evolution exclusively and state standard quality (RQ2), and state residents' belief in teaching evolution exclusively and student achievement in science RQ3). The estimating equation for RQ1 is,

$$\textit{Science Achievement}_i = \beta_0 + \beta_1 \textit{Science Standard Quality}_i + \mathbf{X}_{CST}\beta_2 + \varepsilon_i,$$

where *Science Achievement* is the mean score on the 2009 NAEP science test at the eighth-grade level for state *i*. The variable *Science Standard Quality* is the percentage score awarded by each of the six state science standard evaluations. The coefficient β_1 represents the relationship between the quality of a state's science standards and science achievement. Because other factors may influence science achievement across states, we also include **X**, which is a vector of characteristics about each state's residents' political and religious preferences (*C*), student characteristics (*S*), and teacher characteristics (*T*), as described previously.

For RQ2, the model is,

$$\textit{Science Standard Quality}_i = \beta_0 + \beta_1 \textit{Evolution}_i + \mathbf{X}_{RPFE}\beta_2 + \varepsilon_i,$$

where *Science Standard Quality* is the score awarded by each of the six evaluations in percentage points for state *i*. The variable *Evolution* is the percentage of people in a state believing evolution (not creationism or both) should be taught in schools. The coefficient, β_1, represents the relationship between belief in teaching evolution exclusively in schools and the quality of a state's science standards. Besides the belief for teaching only evolution, other beliefs and external factors may also influence the quality of a state's standards. In an attempt to control for these factors, we include the same list of covariates described previously.

For RQ3, the estimating equation is,

$$\textit{Student Achievement}_i = \beta_0 + \beta_1 \textit{Evolution}_i + \mathbf{X}_{CST}\beta_2 + \varepsilon_i,$$

where *Student Achievement* is the mean score on a particular 2009 NAEP subject test (math, reading, science, or the life science portion of the science assessment) at the eighth-grade level for state *i*. The coefficient, β_1, represents the relationship between teaching evolution exclusively and student achievement in general science. In addition, we include the same list of covariates described previously.

Results

Science achievement, the quality of state evolution standards, and state's residents' belief in teaching evolution exclusively do not necessarily show a strong relationship when plotted visually (see Figure 1). For example, there are as many states with an "A" for evolution standard quality above the mean of 0 for science achievement as there are below. New York, which is second only to Massachusetts for the number of residents who support teaching evolution exclusively in schools, ranks only average for both student science achievement and quality of science standards. California, which has high evolution standard score and a larger percentage of the population endorsing only evolution in schools, does not perform well on the science NAEP. However, other factors such as race, poverty, and teacher quality also contribute to student achievement, which could potentially strengthen these relationships.

Table 2 shows the results of RQ1: What is the relationship between the quality of a state's science standards and student science achievement?[20] Although the usual suspects of free-lunch and minority indicators are significant across all seven regression models, we find no evidence of any relationship between the quality of a state's standards and student achievement.[21] It appears that regardless of the strength of science standards, it is not a good predictor of student science achievement.[22]

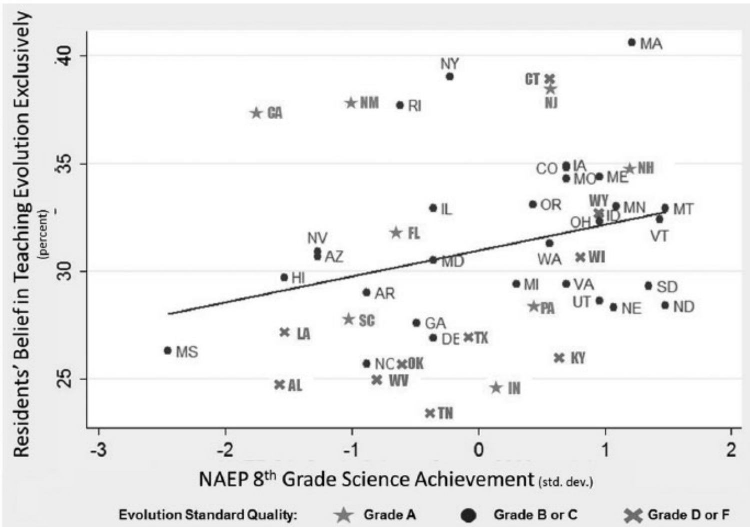

Figure 1. Science achievement, evolution standards, and belief in teaching evolution.
Source. Berkman and Plutzer (2010), Mead and Mates (2009).
Note. NAEP = National Assessment of Educational Progress.

Table 3 displays our results from RQ2: What is the relationship between a state's belief in teaching evolution exclusively and the quality of a state's science standards? For this analysis, each of the six evaluations of state science standards are incorporated into our previously established OLS regression model, only in this case they are treated as dependent variables, while the main independent variable of interest is the percentage of a state's population that believes in teaching evolution exclusively.[23] We did not, however, find any significant relationships between the belief in teaching evolution and the quality of a state's standards.

Table 4 shows our results for RQ3: What is the relationship between a state's belief in teaching only evolution and student science achievement? Each column shows the results for the five NAEP outcomes we tested using this approach. Column I shows a statistically significant and positive relationship between belief in teaching evolution exclusively and overall science achievement. For each percentage point increase in the belief of teaching evolution exclusively, a state's 2009 eighth-grade science score on the NAEP rises by about .06 standard deviations, equivalent to half a mean scale point.

Table 2. Science Achievement and the Quality of State Science Standards.

Independent variables	Dependent variable: NAEP eighth-grade science achievement (2009)					
Fordham science standards 2000 (Lerner)	−.000 (.006)					
Fordham science standards 2005 (Gross)		.002 (.006)				
Fordham science standards 2012 (Lerner)			−.001 (.005)			
McComas' 2009 nature of science standards				.004 (.004)		
Fordham evolution standards 2000 (Lerner)					.000 (.003)	
Mead and Mates' evolution standards 2009						−.000 (.006)
% atheist/non-believer/agnostic	−.009 (.025)	−.005 (.024)	−.007 (.023)	−.007 (.023)	−.008 (.025)	−.006 (.024)
% Republican	.022 (.019)	.025 (.018)	.025 (.017)	.024 (.017)	.025 (.018)	.025 (.017)
% students FRL	−.058*** (.017)	−.057*** (.016)	−.056*** (.016)	−.057*** (.015)	−.057*** (.017)	−.057*** (.016)
% minority (eighth grade)	−.023**(.009)	−.024*** (.008)	−.023*** (.008)	−.023***(.008)	−.023** (.009)	−.023***(.008)
Median income (1000s)	.019 (.313)	−.042 (.317)	.020 (.318)	−.015 (.295)	.014 (.316)	.005 (.299)
% of 7th- to 12th-grade core classes taught by teachers without a major or certification	.002 (.019)	.002 (.018)	.003 (.018)	.002 (.018)	.003 (.018)	.002 (.018)
n	45	47	48	48	46	48
Adjusted R^2	.63	.64	.64	.65	.64	.64

Note. Each column shows results from a separate OLS regression. The independent variables of interests are a series of evaluations of state science standards converted to percentage points. The dependent variable is standardized 2009 NAEP science achievement test scores. Standard errors are given in parenthesis. Data are aggregated at the state level. NAEP = National Assessment of Educational Progress; FRL = free and reduced lunch.

**Statistically significant at the 95% confidence interval. ***Statistically significant at the 99% confidence level.

Table 3. The Quality of State Science Standards and Belief in Teaching Only Evolution.

	Dependent variables					
Independent variables	Fordham science standards 2000 (Lerner)	Fordham science standards 2005 (Gross)	Fordham science standards 2012 (Lerner)	McComas' nature of science standards 2009	Fordham evolution standards 2000 (Lerner)	Mead and Mates' evolution standards 2009
% belief in teaching evolution exclusively	0.004 (0.97)	0.14 (0.80)	−.82 (0.95)	−.54 (1.03)	0.78 (1.46)	0.94 (0.76)
% atheist/non-believer/agnostic	0.13 (0.84)	−.99 (0.70)	−.74 (0.83)	0.43 (0.90)	1.58 (1.25)	0.93 (0.66)
% Republican affiliated	−.90 (0.60)	−.58 (0.47)	−.56 (0.56)	0.22 (0.61)	−.73 (0.85)	−.30 (0.45)
% students FRL	−.97* (0.52)	0.19 (0.45)	0.90 (0.54)	0.24 (0.59)	−1.15 (0.77)	−.75 (0.43)
% minority eighth-grade students	0.35 (0.27)	0.22 (0.23)	0.03 (0.28)	−.16 (0.31)	0.66 (0.41)	0.34 (0.23)
Average median income (1000s)	−0.06 (1.05)	1.30 (0.86)	2.44** (1.02)	0.57 (1.11)	−.08 (1.62)	−.92 (0.81)
% of 7th- to 12th-grade core classes taught by teachers without a major or certification	0.44 (0.61)	0.21 (0.52)	−.05 (0.63)	0.21 (0.68)	0.21 (0.89)	−.41 (0.50)
n	46	49	50	50	47	50
Adjusted R^2	.11	.14	.27	−.13	.16	.14

Note. Each column shows results from a separate OLS regression. The dependent variable is a series of evaluations of state science standards converted to percentage points. Standard errors are given in parenthesis. FRL = free and reduced lunch.
*Statistically significant at the 90% confidence level. **Statistically significant at the 95% confidence level.

Table 4. Student Achievement and the Belief in Teaching Only Evolution.

	Dependent variables				
	I	II	III	IV	V
Independent variables	NAEP 2009 eighth-grade science	NAEP 2009 eighth-grade life science	NAEP 2009 eighth-grade science gain	NAEP 2009 eighth-grade reading	NAEP 2009 eighth-grade math
% belief in teaching evolution exclusively	.060** (.026)	.065** (.028)	.032** (.015)	.045 (.028)	.032 (.028)
% atheist/non-believer/agnostic	−.025 (.023)	−.039 (.025)	.023* (.013)	−.047* (.024)	−.027 (.024)
% Republican	.032* (.016)	.026 (.017)	.021** (.009)	.014 (.017)	.004 (.017)
% students FRL	−.054*** (.015)	−.052*** (.016)	.002 (.007)	−.055*** (.015)	−.078*** (.015)
% minority eighth-grade students	−.025*** (.008)	−.026*** (.008)	.002 (.004)	−.019** (.008)	−.004 (.008)
Median income (1000s)	−.019 (.029)	−.021 (.031)	.000 (.016)	.028 (.031)	−.001 (.031)
% of 7th- to 12th-grade core classes taught by teachers without a major or certification	.007 (.017)	.004 (.018)	−.012 (.009)	.005 (.018)	.004 (.018)
n	48	48	43	48	48
Adjusted R^2	.68	.64	.24	.64	.64

Note. Each column represents results from a separate OLS regression. The dependent variables for all columns except III are achievement by eighth graders on NAEP by subject. Column III is the difference in achievement between the 2009 eighth-grade score and the 2005 fourth-grade score. NAEP scale scores were standardized to a mean of 0 and standard deviation of 1. Standard errors are given in parenthesis. Data are aggregated at the state level. NAEP = National Assessment of Educational Progress; FRL = free and reduced lunch.

*Statistically significant at the 90% confidence level. **Statistically significant at the 95% confidence level. ***Statistically significant at the 99% confidence level.

Column II shows the relationship of the life science portion of the 2009 eighth-grade science NAEP. This portion of the exam has the greatest concentration of evolution questions. Again, the relationship is statistically significant, positive, and of modest effect size. Column III shows a statistically significant and moderate relationship between belief in teaching only evolution and the growth in achievement between fourth graders in 2005 on the Science NAEP and their cohort's 2008 eighth-grade score. For each increase in the percentage of residents who believe in teaching only evolution, a state's eighth graders improve by about .03 standard deviations from their fourth-grade score. Columns IV and V investigate the relationship of the belief in teaching only evolution on math and reading scores. If belief in teaching evolution exclusively is simply a proxy for a state's overall ability, we would expect it to also have strong relationship with math and reading scores. However, we see no statistically significant relationship between belief in teaching only evolution and math or reading scores. This is a particularly strong test of our hypothesis and reinforces the notion that a state's residents' support of only evolution in schools is particularly related to how students perform in science.

Conclusion

As the debate over national science standards runs its course, it is worth questioning to what extent rigorous standards will have an impact. In this analysis, we find almost no evidence that seven different evaluations of state science standards are related to science achievement. This corresponds with other findings on the relationship between math and reading student achievement and the quality of math and reading standards (Goodman, 2012; Whitehurst, 2009). Other researchers have documented that one problem with associating standards with achievement effects is that teachers do not always adhere to standards. In the case of science standards, which have become extremely politicized and are guided by personal and religious beliefs, this may be especially true. In many cases, it seems that a desire to avoid controversy may explain why teachers shy away from teaching evolution. Our clearest finding—that student science achievement is related to the views that the public holds toward evolution—suggests that there is something important about the way the public perceives evolution that translates into greater science achievement for students. Perhaps a general acknowledgment and respect for science among parents and educators has a way of affecting classroom practices and the quality of science education overall. Future research should more closely consider the link between student science achievement and beliefs about evolution held by parents and teachers at a more precise level of aggregation. Additional research might include in-depth interviews that investigate why some teachers are reluctant to teach evolution. In the meantime, the national adoption of rigorous and accurate science standards may lead us in the right direction, but it is unlikely to move student achievement unless ways to garner acceptance and implementation of such standards is understood and facilitated.[20]

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Notes

1. We use the word "rigor" interchangeably with "strong" and "high-quality," because the majority of the evaluations of state standards we review use these terms. In this study, it is not our goal or aim to define these terms in relation to standard quality (as we are not evaluating standards), but instead, we are referring to the many different definitions as outlined in the standard evaluations.
2. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* is serving as the foundation for the 2012 Next Generation Science Standards—the science equivalent of the Common Core Standards (www.nextgenscience.org).
3. Interpretations of "implementation" can also vary between curriculum developers and teachers based on different expectations of what should be implemented. This disparity can also extend to "curriculum," which refers to "curriculum as planned" (state standards) and "lived curriculum" (curriculum as taught in the classroom; Aoki, 1993, p. 261).
4. "Belief in teaching evolution exclusively" or "belief in teaching only evolution," as compared with the belief in teaching both evolution and creationism and/or the belief in teaching only creationism in public school science classes.
5. Judge Deen made these comments to *Time* magazine and not as part of a legal verdict in favor of teaching creationism in schools. The former judge has a personal website evolutionornot.com where he describes himself as a self-proclaimed expert on human origins. His site advocates anti-Darwin viewpoints and promotes academic freedom of students and teachers.
6. In many cases, polling results are sensitive to the exact wording of the question. In 2005, Gallup changed the wording of their evolution question so that instead of asking "God created human beings pretty much in their present form at one time within the last 10,000 years or so" to "God created human beings in their

present form exactly the way the Bible describes it." In 2005, the number of respondents who did not believe in evolution jumped from 45% to 53% whereas the number of those who believed evolution was guided by God dropped from 38% to 31%. In 2006, when Gallup returned to their original pre-2005 question, the responses matched those of 2004 (Bishop, 2006; Miller, Scott, & Okamoto, 2006). For a more thorough selection of polling results over a variety of questions dealing with beliefs about evolution, creationism, and public education, please see http://www.gallup.com/poll/21814/evolution-creationism-intelligent-design.aspx and http://www.pollingreport.com/science.htm

7. The studies Moore compared with Lerner's 2000 evaluation came from 20 different publications between 1983 and 1999 and varied in survey instruments and procedures (Moore, 2002).
8. It is also worth considering that much of the current research relies on teachers to self-report their practices. Teachers may feel pressure to over-report compliance with state standards, or under-report teaching creationism when asked to complete surveys.
9. Since 1998, the Fordham Institute has published three evaluations on the quality of overall state science standards, noting disappointing findings and minimal improvements over the last 12 years (Lerner, 1998, 2012).
10. By 2000, 49 states and the District of Columbia had published science standards. Iowa did not have state standards for any subjects.
11. States receiving a "D" or "F" for evolution standards in 2000 were AK, AR, IL, KY, VA, WI, AL, FL, GA, ME, MS, NH, ND, OH, OK, TN, WV, and WY. States earning an "A" were CA, CT, DE, HI, IN, NJ, NC, PA, RI, and SC.
12. States receiving a "D" or "F" for evolution standards in 2009 were AL, AK, CT, KY, LA, OK, TN, TX, WV, WI, and WY. States earning an "A" were CA, FL, IN, KS, NH, NJ, NM, PA, and SC. In 2012, States earning an "A" were CA, DC, IN, MA, SC, and VA.
13. Lawrence S. Lerner served as lead reviewer, while also reviewing states' K-12 physical science and high school physics standards. Ursula Goodenough reviewed states' K-12 life science standards (including those for high school biology); John Lynch, the K-12 scientific inquiry and methodology standards; Martha Schwartz, the K-12 earth and space science standards; and Richard Schwartz, the K-12 physical science and high school chemistry standards (Lerner, 2012, p. 204).
14. Although the National Assessment of Educational Progress (NAEP) randomly selects different students to participate each year, the gain score represents the same cohort of students as fourth graders and then later as eighth graders, except for any students retained during this time period.
15. As NAEP did not have results for Vermont and Nebraska in 2009, we estimated Pearson's correlation to determine how closely related the scores were between 2000 and 2009 (r = .92) and 2005 and 2009 (r = .97). As the correlation between years was high, we used the most recent scores for Nebraska and Vermont—2000 and 2005, respectively. For our gain-score analysis, our sample size is 46 as we also do not include Vermont and Nebraska.

16. We use the non-religious category instead of using a religious group such as Protestants, Catholics, or Jews because of the mixed support for evolution within these groups (Masci, 2009).
17. We also ran simple bivariate regression models between science achievement and standards that included no control variables. Only one bivariate regression between Lerner's 2012 state science standard evaluation and science achievement showed a statistical, albeit negative, relationship (−.013 where $p < .10$).
18. We also ran all multivariate regression models using the gain score from the 2009 eighth-grade NAEP science score and this cohort's 2005 fourth-grade NAEP science score. Only Mead's 2009 evolution standard evaluation indicated a statistical, but small relationship between standard quality and science achievement gains (.005 where $p < .10$).
19. Using Gross' 2005 classification and a convenience sample of 573 students, Bowman (2008) finds that students "in weak standard states are three times as likely as those in strong standard states to receive instruction that evolution is not scientifically credible" (p. 71). Our analysis, however, does not confirm that this relationship extends to student science achievement.
20. We also ran all models using the percentage change between Lerner's 2000 evolution evaluation and Mead's 2009 evolution evaluation, Gross's 2005 science evaluation and Lerner's 2012 science evaluation, and Lerner's 2000 science evaluation and Gross's 2005 science evaluation. We find no significant relationships between the change in standard quality and states residents' belief in teaching only evolution.

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