Do Street Level Bureaucrats Enhance Policy Responsiveness?
Classroom-Level Implementation of State Standards for Teaching Evolution

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The Politics of State Curriculum Standards

While nearly all states have established local school districts with significant financial and curricular discretion, education remains a state-level responsibility. Critical decisions about what to teach are made by state school boards, who in nearly every state establish curriculum *content standards.* Standards codify what the state believes students should learn in a certain class. These standards allow states to promote curricular coherence across districts and in many cases are accompanied by state-wide exams, (currently mandated by No Child Left Behind for reading and mathematics).

Developed by the legislature, school board, and education department, considerable time and effort goes into the writing and periodic revising of content standards in each state. They are enacted with the expectation that they will influence what is taught in the state's classrooms. And the process of writing these standards periodically becomes politically charged. What is the proper balance between diversity and the perspectives of the nation's founders? Which is more effective in teaching reading: phonics or whole language? Should math education focus on the memorization and repetition of mathematical operations or allow students to discover their own paths to correct answers? Should sex education emphasize abstinence and to what degree? And – the subject of this paper – how should high school biology classes explain the diversity of species and the origins of human life? By any measure, the creation of these policies is political. The outcomes matter to teachers, parents, interest groups and ordinary citizens.

Yet, these content standards are soft policies that have few sanctions for those who would ignore them. Once written, discretion is exercised at many levels. Content standards may have their most far reaching consequences by driving decisions within school districts about which textbooks to adopt as well as drive textbook publishers' decisions of what to include, thereby giving the standards of states with centralized text book decisions influence beyond their borders. Standards, however, do not dictate what is covered in a specific class; at best they can structure district-wide and individual teacher curricular decisions. Instructors can appeal to standards

when teaching subjects--like sex education or evolution-- that are likely to engender negative parental or community response. Ultimately, however, adhering to state content standards is a *choice* made by individual classroom teachers. Standards represent one potential influence on teachers but are they among the more important ones?

This paper seeks to answer this question with respect to one of the more controversial curricular choices in the contemporary United States: evolutionary biology. Specifically, we address the effectiveness of the evolution standards now in effect in the American states by presenting results of a national survey of 939 high school biology teachers. This is the first national survey that focuses on the teaching of evolution and it allows us to see how teachers in different states, operating under different standards and testing regimes, actually teach evolution and its alternatives in American public schools.

We view teachers as street-level bureaucrats (Lipsky 1980). As such, they are formally agents of their state governments and local school boards and therefore responsible for implementation of state standards. Yet they enjoy particularly broad discretion and standards are one of several competing claims on teachers' conduct. The standards themselves may have more bite if they are coordinated with high stakes assessment tests. In that case, failure to adhere to state standards can have consequences for the school district, the school, and the students – ultimately reflecting poorly on the teacher. Teachers are also professionals and are likely to be pulled in the direction of professional norms and expectations – perhaps especially when standards are minimal. Yet teachers also work in specific communities whose citizens can bring pressures either for or against the teaching of evolution. Finally, teachers' individual beliefs and values may enter into their choices in the classroom.

Evolution in the Classroom

The debate about whether or not evolution should be taught, or whether evolution should be taught alongside alternative explanations, is complex with deep roots. Michael Ruse writes of Darwin's Origin of Species that "The *Origin* was one of the most significant and controversial work of the age—of any age—most particularly because the book was seen to challenge long-held views about religion, specifically the Christian religion and its claims about creation and about the nature of God, of humans, and of our relationship to God" (2005, 1). Evolution has particular resonance in the Evangelical Christian's world-view. Michael Lienesch (2007) argues that antievolutionism was central to Fundamentalism's early identity and especially important in

the political social movement that it would become. The 1925 *Scopes* trial was the national event that it was because of the importance of the evolution issue to the early formation of Evangelical Christianity in America (Smith 1998). Teachers' decisions about whether and how to teach evolution are made within this historical context.

The issue persists and presents a challenging environment for contemporary science teachers. An "important element of evangelicalism is tension with a secular society that evangelicals perceive as antithetical to their values" (Campbell 2006, 106). Schools, according to many religious conservatives, are a source of immense danger to them and their children (Apple and Oliver 1996). The teaching of evolution in particular is perceived as a direct threat, so it is not hard to see how state and school district support of evolution would mobilize and antagonize them. Anti-evolution forces are persistent and motivated, and the fact that scientists and others are intent on squashing the creationist movement at every opportunity only reinforces this feeling of threat (Binder 2007). Repeated losses have (ironically) led creationism itself to evolve in response to the changed (legal) environment: creationism, young-earth theories, creation-science, and at least some characterizations of intelligent design can all be understood as modifications in response to court decisions.

But the issue is not only important to Evangelicals. Scientists fight vigorously in courtrooms because they believe the issue is central in the rhetorical realm of *public science* "where scientists present 'rhetoric, argument, and polemic [designed] to provide the public or influential sectors thereof that science is worthy of receiving attention, encouragement and financing" (Gieryn, Bevins and Zehr 1985, 392). As the physicist Leonard Susskind writes, "there is more at stake than biology textbooks…A well respected scientific community can be a major inconvenience if one is trying to ignore global warning, or build unworkable missile-defense systems, or construct multibillion-dollar lasers in the unlikely hope of initiating practicable nuclear fusion" (2006, 26). Scientists' efforts in cases like the recent trial in Dover, Pennsylvania, often in alliance with groups like the ACLU that oppose the introduction of religion into public spaces, often involve "ridiculing, stigmatizing, and silencing" anti-evolution supporters (Binder 2007). Ruse describes the conflict as involving "two violently opposing camps" (2005, 2).

The situation for teachers can be very stressful (Grifith and Brem 2004). Among students, both creationists and fully committed evolutionists are likely to see evolution as having

largely negative implications (Brem, Ranney & Schindel 2003). The increased salience of religiously based conflict in American politics (Layman and Carmines 1997; Layman 1997) filters down to the local level informally and through the "stealth" school board candidates intent on promoting a religious agenda (Deckman, 2004).[1] It is, therefore, understandable that some teachers shy away from the subject, while others in their commitment to strong science or to personal beliefs about human origins plow ahead.

Surveys conducted in different states do show that most biology courses at least include evolution and that creationism is almost as likely to be presented negatively as positively, if at all. For example, 229 randomly selected Indiana biology teachers were surveyed in 2004, and eighty percent of those who responded indicated that they made something more than a "brief mention" of evolution in their classes (Donnelly and Boone 2006). This is not far from the percentage of teachers who responded to surveys conducted by Moore and Kraemer (2005) of Minnesota science teachers at national conventions, as well as similar questions on older studies with different sampling strategies in South Dakota and Ohio.[2] More recently, Berkman, Pacheco and Plutzer (2008) found that 25% of the nation's public high school biology teachers spent at least some class time on creationism or intelligent design, with the group evenly divided between those who presented it in a critical light and those who presented these as valid, scientific alternatives to Darwinian evolution. Federal courts have been consistent in their rulings that states and school boards cannot require the teaching of creationism or other alternatives to evolution, no state directly discusses creationism or intelligent design in its standards, and few textbooks used outside of private religious schools legitimize these approaches, so these findings are not unexpected.

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[1] The position has taken on clear partisan implications as President Bush (Bumiller 2005) and nearly all the original candidates for the 2008 Republican presidential nomination have weighed in with their belief that American school children should be exposed to alternative, non-scientific perspectives.

[2] Moore and Kraemer (2005) conducted surveys of and Minnesota teachers only at the National Science Association Convention and National Life Science Teacher's Conference, both in Minnesota, in 2003. He finds that eighty-eight percent of the biology teachers self-selecting to attend this conference include evolution; a survey of similar questions of Minnesota conducted with a different sampling strategy in 1995 found that sixty-nine percent included evolution. Moore also found that twenty percent of the biology teachers at the conferences also included creationism. A 1989 study in South Dakota showed that creationism was taught in 16.3 % of classes, but in nearly half of the cases it was presented in an unfavorable light (Tatina 1989). A 1987 study in Ohio (Zimmerman 1987) showed that 87 percent include evolution and 15.2 percent included a favorable treatment of creationism.

Of course, the mere inclusion of evolution in a biology class, and the exclusion of favorable treatment and creationism or ID as valid scientific alternative, is the bare minimum of what scientists and science educators expect. Three respected national organizations have provided model curricula: The National Research Council's 1996 *National Science Education Standards* (NSES), the National Science Teachers Association's (NSTA) 1992 *Scope, Sequence, and Coordination* project, and the American Association for the Advancement of Science Project's 1989 *Science for All Americans.* These curricula, and their supporting rationale, all "provide evidence that evolution has attained its status as a unifying theme in science" (Skoog and Bilica 2002, 449). Adherence to NSES standards requires that teachers not just include evolution but treat it in some depth and present it as central to the study of biology. Teachers committed to teaching biology as the NSES or the National Science Teachers Association (NSTA) recommend would use "evolution as a major unifying concept of science" (in Chuang 2003).

If evolution were truly the organizing theme for high school biology classes teachers would spend considerable time on it (Skoog and Bilica 2002; Donnelly and Boone 2006). The best evidence, again from studies in different states, suggests that this is not the case for most teachers. Teachers actually approach the subject in different ways leading to differences in how evolution is presented, the role it plays in the overall biology curriculum, and how much classroom time it occupies. Griffith and Brem (2004) looked in depth at 15 Arizona biology teachers and placed each into one of three categories; one-third were *Scientist Teachers* with a deep "love of science" who believed that evolutionary theory is "essential to any biology curriculum" (796).[3] Teachers classified as *Selective* or *Conflicted Teachers*, however, approached the subject differently. *Selective Teachers* "take classroom and community harmony very seriously" and therefore restricted the content of their classes during the evolution unit by avoiding the topic of human evolution altogether, avoiding other content likely to raise controversy, strategically timing their lessons, and including disclaimers to avert conflict between the lessons and students' religious beliefs (800). *Conflicted Teachers*, concerned about

[3] Griffith and Brem (2004) used a combination of surveys, focus groups, open-ended interviews and a visualization exercise where respondents create a lesson in evolution and a control subject. Their categories are based on clinical models of stress and their analysis examines how teachers in each group experience stress about evolution and cope with it.

the consequences of teaching evolution, hold somewhat stronger feelings that they must teach the subject but clearly did not give it the pride of place that the *Scientists* did.

Studies based on larger samples than the Arizona one assess the treatment of evolution through the number of class periods or hours spent on it. Donnelly and Boone's (2006) study of Indiana teachers, for example, finds that sixty-four percent claimed to treat evolution as a central organizing principle while the average teacher spent two weeks on the topic. They also found substantial variation among teachers with a range of between one to sixty days spent on it. However, a 2002 Indiana study found that teachers may spend far less time, with one-third indicating that they spend fewer than three days on the topic (Rutledge and Mitchell 2002). Only twenty-nine percent of teachers in a Louisiana study (Aguillard 1999) say evolution should be integrated into the whole class and most teachers in the state allocate only two to five class periods to it—roughly the same as saying two to five hours--with sixty percent of the teachers spending five or fewer days on it. Zimmerman's 1987 study of Ohio teachers also finds that teachers spend much less time than in Indiana, seven and half class periods, while Moore and Kraemer's Minnesota (2005) study finds that fifty seven percent of teachers there devote at least six classroom hours to evolution.

Comparison across these state surveys is difficult because they are conducted at different times, often (but not always) with different question wording. Some employ scientific sample survey methods while others sacrifice generalizability in favor of higher cooperation rates, such as Moore and Kraemer's surveys of teachers attending conventions and professional meetings. But they do suggest that few teachers embrace evolution as the central organizing theory of their course or are spending enough time on it to make it a central theme. And while it is difficult for us to assess whether any number of class periods is "a lot" or "not very much," we can say with confidence that previous studies show significant variation, even within states with the same standards. Our survey of teachers differs from all those reviewed here because it is a national sample and allows systematic exploration of both standards and teacher-specific explanations of how standards might be expected to matter.

Contemporary Content Standards for High School Biology

States use their content standards, in many cases accompanied by state-wide examinations, to promote curricular coherence across districts. Developed by the governor, state legislature, school board, and education department, standards articulate state policy about the

facts, concepts, theories and methodologies all students should learn. As noted above there are several models from national organizations that have been developed and made widely available for states and local school boards to adopt for their standards.

The more closely that states adhere to the NSES standards the more evolution will be emphasized (Skoog and Bilica 2002). The NSES identifies evolution as one of the five "unifying concepts and processes" that provide the "big picture of scientific ideas. It further enumerates eleven benchmarks (e.g., natural selection, biological adaptation) for states and textbook editors to use in determining the content for high school biology. In the area of evolution many of these state standards fall far short of NSES expectations; in Lawrence Lerner's oft cited report card, "six states rate an unsatisfactory D and thirteen an F or worse, their standards being essentially useless for purposes of teaching evolution" (Lerner 2000, 287).

Other states rate far better in Lerner's analysis, as well as in independent rankings by Skoog and Bilica (2002). Another review of state science standards published in 2005 found little change in the quality of evolution standards (Gross 2005). The variation is not surprising. The politics of evolution are often conflictual. The alignment of groups and parties on the evolution debate closely resembles those found on debates concerning same-sex marriage, abortion, and other contemporary issues. As with these other morality issues (Smith 2002; Mooney and Lee, 2000; Mooney 2000), state governments are responsive to public opinion in developing their standards, with much weaker treatments of evolution apparent in the standards of states with high numbers of evangelicals and where public opinion is more strongly opposed (Gibson 2004; Berkman and Plutzer 2006). Federal courts have greatly restricted the discretion available to states, but within the space available to them they have adopted very different policies representing not necessarily the best science, but rather the median voter (Berkman and Plutzer 2006).

Why teachers may ignore state standards

To what extent are these state science standards responsible for the quality of instruction students receive on evolution? Randy Moore (2002a) reviews 21 studies in 15 states that were conducted between 1983 and 2002, including some of those cited in the previous section. He compares the results in each of the state-specific studies with the quality of standards in each of the fifteen states and concludes that "although standards for teaching science have been touted as important for the reform of science education, they often mean little in biology classrooms.

Indeed, surprisingly large percentages of biology teachers throughout the US endorse creationism, question evolution, and even teach creationism in their courses, regardless of the state's standards for evolution education" (380). He looks at some older Indiana studies, conducted in 2000 and 2002 (Rutledge and Warden 2000, Rutledge and Mitchell 2002) and notes that even in this state with "some of the best evolution education standards in the nation" forty-three percent of its biology teachers avoid or "briefly mention" evolution, and at least twenty percent reject or are undecided about the scientific validity of evolution.

As noted above a more recent analysis of Indiana teachers finds that many of its teachers emphasize evolution much more than that, while the variation within the state seems, at first blush, to suggest a minimal role for standards. But the Indiana study is actually instructive about the importance of standards because it demonstrates how they make a difference for individual teachers; standards are important, argue Donnelly and Boone (2006) so long as teachers accept them: "Teachers attitudes toward the evolution standards in particular are strong predictors of their evolution teaching practices." When teachers choose to allow standards to guide the amount of time spent on subjects they spend more days on the subject.

Thus, one key linkage between the high quality Indiana standards and what occurs in the classroom appears to be teacher's attitude toward them. We suggest that this attitude encompasses three distinct components: whether the teacher knows the content of the standards, whether the teacher accepts the idea of standards generally and the evolution standards in particular, and whether the teacher believes the standards are enforced through state-wide examinations that align student learning with the standards. But what we cannot know from a single state study is what happens when teachers accept standards but the standards are not as well developed as those in Indiana.

Our design allows us to do precisely this, to assess the impact of different quality standards at the level of the individual teacher. Teachers' attitude toward standards is one characteristic of teachers that mediates the effect of standards on instruction. There are others as well: the extent to which a teacher understands evolution, accepts evolution, and teaches in a community unlikely to accept evolution. Each of these influences the extent to which a teacher emphasizes evolution, both independently and in interaction with the quality of state standards.

Seniority

A second important characteristic of teachers is their seniority. Those with substantial seniority have the least incentive to follow standards written by experts in the state capital and, most especially, to embrace new reforms (Berends 2000). This is due to three related reasons. First, experience often comes with tenure, providing a buffer from principals or others who would seek to promote the state's curricula. Second, high seniority teachers have a great deal of time and effort invested in their lesson plans and approach to teaching. They have little incentive to come in line with standards if those contradict the way they have been teaching for decades. Third, teachers with high seniority were professionally socialized in a different era; in contrast, new content standards are likely to reflect to latest trends in pedagogy which only younger teachers would have been exposed to in college. For all these reasons, we expect teachers with the least seniority to adhere most closely to the state's content standards.

Teacher Knowledge and Understanding of Evolution

Many teachers lack either a full understanding of evolution or confidence in their knowledge of it. When Rutledge and Mitchell (2002) asked Indiana teachers to draw concept maps of evolutionary theory some could draw elaborate ones showing full recognition of evolutionary mechanisms and natural selection. Others, however, held misconceptions and tended to depict evolution as "only a theory" of "low scientific status" supported by "little evidence" or even "only a hypothesis." They conclude that "teachers are not comfortable teaching evolution because it is controversial and they don't feel they have a sufficient understanding of evolutionary principles and the compelling nature and scientific validity of the supporting evidence" (Rutledge and Mitchell 2002). Zimmerman's 1987 study of Ohio teachers found that most could not give a correct answer about what evolution is. Moore (2004) finds that teachers often do not know the legal issues about the place of evolution and alternatives in the classroom.

On the other hand, teachers who have a fuller understanding because they had a course on evolution in college or more credit hours in biology are more likely to treat evolution as organizing principle, use hands on activity to teach it, and to ask to apply natural selection to real life situations (Donnelly and Boone 2006). Teachers who understand evolution are also less likely to feel stressful about teaching evolution (Griffith and Brem 2004), which probably explains whey they will spend more time on it (Aguillard 1999).

We expect that our analysis too will show that more knowledgeable teachers, including those who feel confident in their knowledge or have more college-level coursework will spend more time on evolution. But we also expect that standards can prove especially valuable for teachers who lack a full understanding of evolution because they offer students a curriculum and content that they may have difficulty developing themselves. Indeed, Donnelly and Boone (2006) identify this as one reason teachers find standards useful. Better standards enable the less-knowledgeable teachers to introduce evolution into the classroom.

Belief in evolution

Closely related to knowledge of evolution is a teacher's personal belief in it. Teachers who accept the validity of evolution, either because they understand it well or because it does not contradict their religious beliefs, are less likely to be conflicted (Griffith and Brem 2004) and more likely to spend more time on it (Aguillard 1999; Tatina 1989; Rutledge and Mitchell 2002). Moore and Kraemer's (2005) interviews with science teachers suggests that self-identified creationists included only the Christian story of creation in their classrooms, and that approximately one in five biology teachers either does not know that the teaching of creationism in science classes of public schools is unlawful, or feel that their beliefs in creationism justify breaking the law (Moore 2004). Of course, strong standards, especially those backed by examinations, will make it more difficult for teachers to avoid the topic of evolution because of their beliefs, especially compared with teachers in states with weaker standards.

Community Context

Teachers confront implementation decisions about how to teach evolution in a variety of community contexts. With respect to evolution, the opinions of community residents will vary from those who are supportive of model curricula such as the NSES to those that are hostile to the teaching of any evolution in public schools. Teachers report pressure to drop evolution from their classes or to teach creationism (Moore 2002; Donnelly and Boone 2007) from residents, church leaders, administrators, and local school board members. Some fear that "chronic pressure" from creationists "thwart their attempts their attempts to teach evolution" because it leads adminstrators to discourage any teaching that might bring controversy (Griffith and Brem 2004). There is little evidence, however, of counter pressure to teach evolution (Tatina 1989).

We anticipate that teachers in more socially conservative communities will feel the most pressure to shy away from evolution. But teachers should be able to appeal to standards when

introducing subjects, like evolution, likely to engender negative parental or community response (Donnelly and Boone 2007). Even if standards are not directly important, Moore writes, "they are nevertheless important because they provide support for teachers who *do* want to teach evolution. Such standards can be used by these teachers to offset or neutralize protests from creationist students, parents, and administrators who want creationism to be taught (or evolution not to be taught) in science classes" (380). The quality of the standards should also be important. Teachers under comparable pressure in a state with strong standards should devote more time to evolution than a teacher in a state with weaker standards.

Data and Methods

The data for this paper come from a survey of high school biology teachers conducted between March 5 and May 1, 2007 (for details, see Berkman, Pacheco and Plutzer 2008, section on Materials and Methods). A total of 939 respondents completed the multi-modal (mail and internet) study for a response rate of 48%. Teachers completed a six page survey containing questions about the content of their most recently taught biology course, more specific questions about the teaching of evolution in particular, and a variety of background questions.

The data set contains teachers from 49 states (no teachers from Wyoming) and the District of Columbia and is generally representative of the population of inference. The data analyzed in this paper are weighted to adjust for small differences in size of school and the school's racial and ethnic diversity. However, the substantive conclusions are the same when we employ unweighted data. For details on weighting and an assessment of coverage bias, see supplemental text S1 in Berkman et al. (2008).

Dependent Variables

Teachers were asked to indicate the number of hours they devoted to human evolution, ecology, human health/disease, general evolutionary processes, and to creationism or intelligent design. This paper focuses solely on the responses to the questions concerning human and general evolution. The reports of instructional time are reported in the upper panel of Table 1. The answers concerning human and general evolution were combined to get a summary measure of the number of hours devoted to evolution and this shall be our primary dependent variable. The distribution of this variable is reported in the lower panel of Table 1. This shows that on average, teachers devoted about 14 class hours to evolution (of which about 30% concerned human origins) but also that there was enormous variation across teachers. We also shall employ

a simple indicator of whether human evolution is taught at all – as Table 1 shows, 83% devoted at least an hour to this topic while 17% did not cover it at all.

Table 1. Descriptive Statistics on Coverage of Evolution

Thinking about how you lay out your Biology course for the year, please indicate how many class hours you typically spend on each of the following areas.

	Human Evolution	General Evolutionary Processes	Total devoted to human & general evolution (a)
Not Covered	17.4 %	1.9 %	1.3 %
1-2 hours	35.4	8.9	2.2
3-5 hours	24.8	25.3	8.6
6-10 hours	12.0	26.1	33.8
11-15 hours	5.1	17.7	19.1
16-20 hours	3.2	12.5	11.0
20 hours or more	2.1	9.1	22.6
	100.0	100.0	100.0
N	*919*	*911*	*908*

(a) Combined column calculated by first converting human and general evolution responses to category midpoints (22 hours used for last category) and summing these.

Summary statistics for responses converted to hours, using midpoints (and 22 for last category)

	Mean Hours	Std. Dev.	Min	Max	N
Human Evolution	4.2	4.9	0	22	919
Gen Evolutionary Processes	9.5	6.3	0	22	911
Combined	13.7	8.9	0	44	908

Measuring State Standards

Our primary independent variable is based on measures that code the rigor of state science standards concerning evolution. The most recent survey of state standards was published in 2005 (Gross 2005). This study graded science standards generally with a separate grade for evolution standards and, as noted above, found little change in standards from earlier studies. But many of the states were coded on the basis of now outdated standards; since the

publication of that study at least 16 states have changed their standards from the ones Gross evaluated. Therefore, we conducted on our survey of state science standards in effect at the time of our survey.

To do this we used two undergraduates comfortable and familiar with basic biology and evolution. We found standards on the websites of state departments of education. Each student read the standards for each state several times, focusing on the biology or life sciences guidelines for grades 9-12. We use their overall assessment of the state standards on three criteria: overall treatment of evolution, whether evolution is the guiding theme for the biology curriculum, and the thoroughness of the standards.

To determine the overall treatment of evolution coders first read through the standards to determine whether evolution is mentioned at all, in its own section, or in multiple sections. Once they found evolution—either in its own or in multiple sections—coders determined whether the treatment of evolution was detailed or cursory.[4] These codes were then combined into a scale with the following values:

1. evolution is not mentioned in the standards
2. evolution in its own brief and cursory section

2.5 evolution is mentioned in one or multiple bullet points with cursory detail

3. evolution is mentioned in its own section, although briefly or in a few sentences

3.5 evolution is mentioned in its own section, in multiple sections or in bullet points in support of other course goals

4. evolution is mentioned in its own section with a few phrases or sentences
5. evolution is mentioned in its own section with a few or multiple phrases
6 . evolution is mentioned in its own section with some detail
7. evolution is mentioned in its own section in some to great detail
8. evolution is mentioned in its own section with great detail
9. evolution is mentioned in its own section in great detail throughout the course curriculum

[4] There was high agreement among the coders over whether evolution could be found in the standards at all, and whether it was in its own or in multiple sections (r=.85); there was somewhat less agreement on the secondary question of whether it could be described as cursory, in a few sentences, or very detailed (r=.53).

Coders also evaluated the overall treatment of evolution as the unifying theme of the course. Here the coders used a five point scale[5] to complete the phrase, *Overall, evolution appears to be…*

1. The unifying theme for the biology/life sciences curriculum
2. One of several unifying themes for the biology/life sciences curriculum
3. A major topic whose treatment is comparable to the cell, heredity, or ecology
4. A smaller topic, given less emphasis than others such as the cell, heredity or ecology
5. An afterthought or very minor topic

Finally our coders ranked the extent to which the standards left teachers discretion to teach as they wished. For each state they used a 1 to 4 scale to complete this sentence: *On a scale from 1 to 4, the standards for biology/life sciences as a whole…*[6]

1. Are sufficiently specific and detailed to ensure that teachers will have to cover evolution.
2.
3.
4. Are sufficiently vague that a teacher could choose not to cover evolution at all.

After the coders completed their work one of the principle investigators looked for discrepancies between the two coders. When discrepancies were found, the PI substituted his independent judgment. Overall there was strong agreement among the coders (see notes 6,7,8). When the coders did not disagree by more than 2 points we used an average of their scores. The scores for each of the three questions were converted so all ran in the same direction with higher scores indicating more thorough treatment of evolution.

Overall, the three scores are highly correlated indicating that they are all indicators of the same construct. We standardized all three rankings (mean of zero, standard deviation of one) and combined them into a single scale that measures the rigor with which evolution is addressed in the state standards. High scores indicate states whose content standards address evolution in detail, identify evolution as a major theme, and which provide very specific guidance to teachers

[5] Agreement between the coders was r = .51.

[6] Intercoder reliability was r = .72.

on the specific topics that students are expected to learn. The scale has an estimated reliability (Cronbach's alpha) of 0.88.

Although all valid measures must be reliable, not all reliable measures are valid (Bohrnstedt 1983). To assess the validity of the scale, we undertook several additional analyses. First, we looked to see if our rankings were positively correlated with similar rankings made by other scholars. The Gross report mentioned above (Gross et al. 2005) used a coarse four category rating system of standards. In spite of the less precise measurement and the fact that many states had changed their standards, we find the two ratings correlated at a level of r = 0.36. Second, we also examined the correlation with Lerner's older (2000) ratings. The Lerner rankings, like ours, are highly detailed and based on multiple indicators; Lerner's summary score correlated with our measure at r = 0.46. As a result of the positive correlations with similar, but dated, rankings done by other teams of researchers to measure the same construct, we feel confident in the validity of our coding scheme.

Do Standards Matter?

Our initial exploration appears in the top panel of Table 2. Here we regress the hours devoted to evolution (both human and general) on our measure state content standards treatment of evolution. The slope of 0.95 is statistically significant but substantively small. An increase in rigor of a standard deviation would result in roughly an additional hour devoted to evolution over the course of a school year. This confirms observations by Moore (2000a) that standards do not seem to matter.

However, we have noted that we believe that standards will matter more for some teachers than others. So we proceed by exploring conditional effects of state content standards. The first of these factors that we will explore is the seniority of teachers. We argued earlier that teachers with longstanding tenure should be the least impacted by state curricular goals and panel B of Table 2 shows precisely this. Seniority is an ordinal variable with five categories. It is centered for this analysis (the mean of 3.95 is subtracted from the original score to create a new measure having a mean of zero). As a result, the slope for content standards now represents the impact of standards on teachers with average seniority (roughly 20 years of teaching experience). The slope is about the same as estimated earlier.

The interaction terms is negative and statistically significant and this tells us that as one moves up the seniority scale, state standards have less and less of an impact on the time devoted

to evolution. For those with more than 20 years of experience, the effect of state science standards is essentially zero (.085 – 1.02 = -0.17). But for the newest teachers, those with 0-2 years of teaching experience, standards have a very large effect (0.85 + (3 x 1.02) = 3.98). That is, a standard deviation increase in standards rigor results in new teachers devoting four additional hours to evolution.

Table 2. Regression of total hours spent on human and general evolution on index of evolution standards (N=890)

A. Bivariate model (N=908)

	B	SE	t	p
Standards Index 2007	**0.95**	0.36	2.62	.01
Intercept	13.70	0.36	37.89	.00
Adjusted R2	0.01			

B. Interaction with seniority (N=894)

	B	SE	t	p
Standards Index 2007	**0.85**	0.35	2.39	.02
Seniority (centered)	-0.61	0.41	-1.50	.14
Standards X seniority	**-1.02**	0.36	-2.85	.00
Intercept	13.75	0.36	37.94	.00
Adjusted R2	0.03			

Reported Knowledge of Standards

One reason standards may not matter is that teachers might not fully understand them. Our survey suggests substantial gaps between state content standards and teachers' reports of what they contain. Take, for example, Illinois. The state most recently updated its science standards in 1997-1998. Lerner (2000), Skoog and Bilica (2001) and our coders all agree that the Illinois standards do not mention human evolution. Yet of the 49 Illinois teachers completing our survey, roughly half reported that their state content standards did, in fact, include human evolution. Only a third were correct in characterizing the standards as having no mention of human evolution while the remainder were either unsure or believed that evolution was included. Similarly, more than a quarter of the Texas teachers we surveyed erroneously report that their state content standards include human evolution.

To see if *perceptions* of standards matter more than the standards themselves, we asked each teacher, "So far as you know, do your state's science standards include evolution?" Forty five states have standards that unambiguously include evolution and 94% of the teachers in these states correctly reported this with 4.5% saying they were unsure and 2% incorrectly saying the standards did not discuss evolution. However, as Table 3 shows, reported knowledge is related to teaching practices with those reporting that their state does not mandate the teaching of evolution spending far less time on the topic. Indeed, the two sections of the table are virtually identical, again suggesting little impact of standards generally.

Table 3. Hours devoted to general and human evolution by perception of state standards.

So far as you know, do your state's science standards include evolution?	Five states whose standards do not specifically mention evolution			45 states whose standards do mention evolution		
	Mean	Std. Dev.	Freq.	Mean	Std. Dev.	Freq.
Yes	14.1	9.8	74	14.0	8.9	741
No *	9.6 *	4.3	10	8.2 *	7.1	32
Not sure	13.1	9.5	9	11.4	8.5	32
Total	13.6	9.4	93	13.7	8.9	805

** Significantly less than the "yes" category at the .01 level*

More specifically, those answering "yes" were asked to indicate if their state's content standards included *human* evolution. Although the actual standards were unrelated to actual classroom instruction, we see in Table 4 that perceptions of standards make a very large difference.

Of course, it is possible that teacher answers to our questions are determined in part by their own biases. The answers could be partly rationalizations for their own classroom conduct (they come to believe that state standards are in fact aligned with the way they teach). We cannot assess this with the data we have available. However, these results help to reconcile two apparently conflicting conclusions in the empirical literature. Moore found no cross-state effects

from evolution while we find only limited effectiveness , but like Donnelly and Boone's (2007) we find that perceptions of standards at the teacher level appear to guide classroom instruction.

Table 4. Coverage of human evolution by perception of state standards.

	Mean hours on human evolution	Std. Dev.	N
Standards do not include human evolution	3.0	4.4	286
I am not sure	4.7	5.3	45
Standards do include human evolution*	4.8	5.0	557
Total	4.1	4.9	822

** Statistically different from teachers who do not believe standards include human evolution at the 0.01 level*

	Percentage reporting some coverage of human evolution	
	Pctg	N
Standards do not include human evolution	68.7 %	293
I am not sure	76.8	48
Standards do include human evolution*	91.7	576
Total	83.5	916

** Statistically different from teachers who do not believe standards include human evolution at the 0.01 level*

Assessment Tests

Content standards may be more likely to be implemented when a state has a required assessment test whose content is aligned with the standards. As with the standards themselves, the teacher's knowledge about the assessments may also play a central role in how they allocate classroom time to various topics. We investigate these two possibilities in this section.

According to a careful analysis by Editorial Projects in Education (2007), thirty one states had aligned science examinations at the high school level during the 2006-2007 school year. We also asked teachers if their state had an assessment test that covered high school biology. Interestingly, we see here a certain amount of confusion on the part of teachers. In states with such a test, 14% of teachers told us that they did not. In some states (e.g., New York, Michigan)

100% of the teachers correctly told us that there was such a test. But in Illinois and Wisconsin, more than a third incorrectly reported that there was no such test. Among teachers in states without an aligned assessment test, more than half told us that they did, in fact, have one. As in the case of standards, we see some evidence that the attitudes toward the standards may play more of a role than the exam itself – and this is especially true of teachers with less seniority. Table 5 shows the four relevant regression models.

Table 5. Regression of total hours spent on human and general evolution on index of evolution standards and objective and subjective measures of state assessment

	All teachers (N=908)			Teachers with less than 20 years of seniority (N=565)		
A. State has general science test	B	Robust SE	p	B	Robust SE	p
Standards Index	-0.19	1.40	.89	-1.36	1.87	.47
State *has* a science assessment	-0.29	0.85	.74	-0.78	1.27	.54
Index X Assessment	1.25	1.45	.39	2.64	1.93	.18
Intercept	14.03	0.73	.00	15.02	1.11	.00
Adjusted R2	0.01			0.02		
B. Teacher perceptions of testing						
	B	Robust SE	p	B	Robust SE	p
Standards Index	0.05	0.72	.95	-0.54	0.78	.49
Teacher says state has assessment	-0.51	0.85	.55	0.06	1.10	.96
Index X Teacher report	**1.40**	0.83	.09	**2.43**	0.98	.02
Intercept	14.20	0.74	.00	14.17	0.92	.00
Adjusted R2	0.02			0.03		

The equation in the top panel shows that the existence of the exam has neither a main effect nor an interaction with content standards. This is true regardless of seniority. But we see a small impact of perceptions in the lower panel for all teachers (one tailed p = .04) and a more pronounced effect when teachers with more than 20 years of seniority are removed from the analysis. Teachers spend more time on evolution when their state has rigorous standards *but only if* they are under the impression that their students will take an assessment exam covering high school biology. For lower seniority teachers, this effect is substantively meaningful, with a

one standard deviation increase in standards rigor associated with about two additional hours of evolution instruction (-.54 + 2.43 =1.89 hours) when the teacher thinks there is a test. We failed to discern any corresponding effect concerning human evolution.

Individual Characteristics

To this point, we have examined the standards and assessment environment, along with simple indicators of teacher's knowledge and understanding of them. We now examine factors that can have a strong influence on teacher's curricular preferences and their qualifications for teaching a biology course with a rigorous treatment of evolution.

We first examine teacher's general background characteristics. The top model in Table 6 reports a regression model including our index of state standards, seniority and their interaction, plus teacher sex, graduate degree, whether they completed a "specific college level course in evolution," and the number of credit hours they have completed in the biological sciences (the contrast category is 24 or fewer credits).

We see that now that we have controlled for other characteristics, seniority has a small, positive effect. We also find that women devote slightly less attention to evolution. The most striking results, however, are the impacts of college coursework. Those who completed 25-40 credit hours (29% of the sample) devoted two additional hours to evolution compared to those with fewer credits (6% of the sample). Those with more than forty credits (64%) taught nearly three hours more than those with only minimal coursework in biology. In addition, the completion of a specific course on evolution (by 43% of the sample) is associated with an *additional* 3.4 hours. Since these are additive effects, the impact of having substantial training in the subject matter makes an enormous difference in the class time devoted to the subject.

In the lower panel of the table we explore whether the two key background variables – coursework in biology and specifically in evolution – interact with state standards. We expect that standards are more important for those with limited qualifications because standards provide a roadmap for the curriculum and an impetus to cover topics even if the teacher lacks expertise. The model fails to confirm this. None of the interactions are significant. When we eliminate those with 20 or more years of experience (right hand panel) we see hints in this direction with all three interactions negative, but none significant. However, the seniority x standards effect is now not distinguishable from zero.

Table 6. Regression of total hours spent on evolution on teacher background characteristics

A. Additive model of background scharacteristcs

	All teachers (N=870)		
	B	Robust SE	p
Standards index	0.74	0.44	.10
Seniority (centered, -3 thru 1)	**-0.78**	0.37	.04
Standards X Seniority	**-0.91**	0.36	.02
Female	**-1.28**	0.61	.04
Has master's of doctoral degree	0.28	0.84	.74
Had a course in evolution	**3.15**	0.87	.00
Completed 25-40 credits in biology	**2.33**	1.01	.03
Completed 40+ credits in biology	**3.29**	0.97	.00
Intercept	10.22	0.99	.00
R2	0.08		

A. Interactive models of background scharacteristcs

	All teachers (N=870)			Teachers with less than 20 years of seniority (N=558)		
	B	Robust SE	p	B	Robust SE	p
Standards index	1.34	0.85	.12	1.14	0.84	.18
Seniority (centered, -3 thru 1)	-0.78	0.38	.04	-0.91	0.68	.18
Standards X Seniority	-0.92	0.35	.01	-1.15	0.66	.09
Female	**-1.27**	0.60	.04	**-1.89**	0.92	.05
Has master's of doctoral degree	0.27	0.84	.75	1.14	1.07	.29
Had a course in evolution	**3.13**	0.88	.00	**2.05**	0.92	.03
Standards X evolution course	-0.07	0.91	.94	1.47	1.04	.16
Completed 25-40 credits in biology	**2.41**	1.00	.02	**2.59**	1.23	.04
Completed 40+ credits in biology	**3.40**	0.94	.00	**3.12**	1.15	.01
Standards X 25-40 credits	-0.80	0.79	.32	-1.34	1.25	.29
Standards X 40+ credits	-0.52	0.83	.53	-1.27	0.97	.20
Intercept	10.13	0.98	.00	10.38	1.56	.00
R2	0.08			0.10		

When we examine only those teachers with less than ten years of seniority (not reported), we *do* get significant interactions. Thus standards matter most to newer teachers with limited scientific training. They take cues from their standards about how much time to devote to evolution and spend less time on it where standards are cursory and more time where standards are rigorous. Thus, taking all the analyses together, we can say that standards matter most to those newest to the teaching profession and especially to new teachers with limited training in the subject that they teach. And beyond the interaction with standards, the teachers with the

most coursework in biology devote substantially more time to evolution than others. NCLB is set to expire within the year. However one legacy of this policy is new emphasis on teacher qualifications. It would indeed be ironic if the flagship domestic program of George W. Bush – who has advocated balancing evolution with ID and other alternatives – led to a new cohort of highly qualified teachers who devoted more time to evolution.

Having seen that the individual backgrounds of teachers matter, we now examine to see if their subject beliefs matter as well. Here we examine two kinds of subjective accounts. First, we asked each teacher to rate their own knowledge of "the scientific evidence bearing on the validity of evolutionary theory." They could rate themselves as knowing "less about this topic than many other high school biology teachers" all the way up through average, above average and on to "Exceptional, on par with many college-level instructors." Scored 1-4, Table 7 shows that this variable is a strong predictor of time devoted to evolution in the classroom. Each step on the scale is associated with an extra two hours – even after accounting for their actual coursework. This is consistent with arguments based on qualitative studies that expertise is important in part because it engenders confidence in the ability to handle a potentially controversial subject. We also estimated an interaction term to see if standards mattered most for those who are least confident in their self-rated expertise in evolution. The slope is in the expected direction but does not attain conventional levels of significance (one-tailed $p = 0.053$). It *is* significant when we used unweighted data. Thus, we view the finding as suggestive and consistent with the general picture that standards matter most to those who lack training or confidence in their ability to explain evolution or defend their teaching of it.

This model also includes a question about personal attitudes. We asked each teacher a question that was adapted from Gallup polls of the general population.

> ***Now, regardless of what you do in the classroom, we would like to ask about your own personal views.*** *Which of the following statements comes closest to your views on the origin and development of human beings?*
>
> > *Human beings have developed over millions of years from less advanced forms of life, but God guided this process.*
> >
> > *Human beings have developed over millions of years from less advanced forms of life, but God had no part in this process.*
> >
> > *God created human beings pretty much in their present form at one time within the last 10,000 years or so.*

Table 7. Regression of total hours spent on human and general evolution on teacher background characteristics (N=819)

	B	Robust SE	t	p
Standards index	**2.54**	1.38	1.83	.07
Seniority (centered, -3 thru 1)	**-0.82**	0.38	-2.15	.04
Standards X Seniority	**-0.91**	0.40	-2.30	.03
Female	-1.04	0.69	-1.51	.14
Has master's of doctoral degree	-0.48	0.88	-0.55	.59
Had a course in evolution	**1.93**	0.91	2.12	.04
Completed 25-40 credits in biology	1.50	0.93	1.62	.11
Completed 40+ credits in biology	**2.14**	0.88	2.44	.02
Self rating of expertise in evolution	**2.01**	0.42	4.77	.00
Standards X Self rating	*-0.72*	*0.44*	*-1.65*	*.11*
Believe humans evolved; God guided	**2.67**	0.93	2.86	.01
Believe humans evolved; God had no role	**5.31**	1.06	5.01	.00
Intercept	**3.63**	1.16	3.12	.00
R2	0.15			

In the regression model, the last response option – an answer consistent with "young earth" creationism – is the omitted category. This answer was selected by 15% of the teachers, with 33% selecting the "God had no part in the process," response and 52% selecting what may be considered the intermediate category and is sometimes labeled "theistic evolution." The regression estimates show that personal beliefs about human origins play a substantial role in the classroom. Personal beliefs do not seem to interact with standards (not shown) so we cannot say that rigorous standards are especially important for those who might oppose evolution on personal or religious grounds. The table also shows that the effects of coursework are smaller than in the previous model, suggesting that a portion of the coursework effect is mediated by subjective assessments of competence. In particular, extensive course work leads to feelings of competence and expertise which, in turn, results in more attention to the topic of evolution.

Community Context

Lastly, we examine the potential impact of two aspects of the community context. Research on "culture wars" in the United States points to two variables that are related to polarization among the public – Evangelical Christianity and educational attainment. Those with high levels of education tend to be on the liberal side of debates concerning abortion, sexuality, and civil liberties; in contrast, highly religious conservative Christians tend to be on the right on all of these issues. Measuring the community context is challenging but we were able to generate two appropriate variables. The first derives from the US Census and measures the proportion of adults *in the teacher's school district* who have education beyond a bachelor's degree. Our average teacher lived in a school district in which 0.08 of the adults (25 and over) had master's, professional, or doctoral degrees. There is substantial variance, however, with ten percent living in districts with 0.15 or higher.

Our second measure is an estimate of the proportion of all adults *in the teacher's county* (county in which the school is located) who are participants in Evangelical churches. This measure is intended as a valid proxy for social and religious conservatism. This was constructed using county-level data file from the Religious Congregations and Membership Study. The data were collected by the Association of Statisticians of American Religious Bodies and distributed by the Glenmary Institute (see Jones et al. 2002, for a complete report on the methodology). These data are based on a census of religious bodies and reported as a proportion of the adult population in the county. We classify churches as Evangelical based on the taxonomy developed at the American Religious Data Archive (www.thearda.com). Because many predominantly African American denominations did not participate at rates comparable to those of other churches, the variable may be best interpreted as reflecting the predominance of *white* Evangelicals in the county (see Finke and Schietle 2005).

Our model (Table 8) adds the two contextual measures to the teacher qualification model we reported earlier. The estimates show a strong and significant effect of the proportion of evangelicals and no corresponding effect for the number of school district residents with advanced degrees. The parameters suggest that an increase in the proportion evangelicals from .02 (tenth percentile nationally) to .36 (ninetieth percentile) would be associated nearly three fewer hours (2.77) devoted to evolution. These findings tell us that the instruction received by students varies substantially based on the social and cultural environment of the school district.

Table 8. Regression of total hours spent on human and general evolution on teacher background characteristics and social context (N=810)

	B	Robust SE	t	p
Standards index	0.36	0.44	0.81	.42
Seniority (centered, -3 thru 1)	**-0.87**	0.40	-2.20	.03
Standards X Seniority	**-0.90**	0.43	-2.09	.04
Female	-0.83	0.67	-1.23	.23
Has master's of doctoral degree	-0.39	0.75	-0.51	.61
Had a course in evolution	**1.71**	0.92	1.85	.07
Completed 25-40 credits in biology	**1.72**	0.99	1.74	.09
Completed 40+ credits in biology	**2.20**	0.93	2.37	.02
Self rating of expertise in evolution	**1.82**	0.48	3.76	.00
Believe humans evolved; God guided	**2.24**	0.94	2.38	.02
Believe humans evolved; God had no role	**4.15**	0.97	4.28	.00
Evangelical proportion of population	**-8.17**	2.77	-2.95	.01
Advanced degree proportion of population	2.18	8.18	0.27	.79
Intercept	**5.57**	1.57	3.54	.00
R2	0.15			

Finally, we sought to determine if standards mattered more in socially conservative locales. We therefore estimated the interaction of the standards index with the proportion of Evangelicals in the county. The interaction was in the expected direction but is not significantly different from zero. Further exploration showed that the interaction is significant in purely descriptive terms when individual-level measures are excluded from the model. However, as we saw before, teaching practices in Evangelical settings are due to the types of teachers who are hired (or agree to work) in those schools and the effect disappears when teacher qualifications and opinions are accounted for.

Conclusion

In sharp contrast with Moore (2002a) we must conclude that state evolution standards do indeed matter in some specific, but important, circumstances. Our design allows us to do what previous studies could not: compare across teachers in multiple states interviewed at the same time with the same questions. But most importantly, following the approach and findings of Donnelly and Boone (2006), we find that we must account for individual-level differences among teachers to see how standards matter. Our design allows us to move beyond their study

of Indiana teachers to compare teachers operating under different standards. Standards matter in substantively important ways, but to see this we must understand the role teachers play in implementing them.

Implementation of state standards is a classic principle-agent problem. States set out their policy toward the teaching of evolution in the form of standards. These may be long and detailed or short and abstract; we have little systematic understanding of standards other than that they reflect to some extent the values and opinions of state residents and overall capacity of the state's scientific infrastructure (Berkman and Plutzer 2006; Gibson 2004). Some states clearly signal their preference that evolution be presented as central and fundamental to an understanding of biology; others signal their preference that evolution be presented in a disjointed or cursory manner, moving as close to promoting non-scientific approaches as the courts will allow.

The efficacy of state standards is enhanced by the use of examinations. Examinations have the effect of both clarifying the policy intent and restricting the discretion of agents: if a teacher in a state with examinations chooses not to teach to the standards they risk lower scores on a test keyed to the standards, while the examination, over time, clarifies for them exactly what is expected in the standards. If states continue to move toward increasing use of examinations, (in spite of the pending expiration of No Child Left Behind), the overall impact of standards should become greater.

But implementation is the job of thousands of agents around the country. Teachers come into their jobs with their own attitudes and beliefs and widely varying amounts of training; some have advanced undergraduate and graduate coursework in biology and evolutionary theory, and others have far less, their training principally in the pedagogy of science. Their training and beliefs are critical to how standards are implemented at the classroom level: high quality standards will be very important for the teacher who lacks confidence in their understanding of evolution, and these teachers will devote more class hours to evolution than a similarly educated teacher in a state with weaker standards.

Teachers also operate in different political contexts than the principals who wrote the standards. At the local level, the pressure from opponents to evolution can be intense. Evolution is threatening to many Evangelical Christians who can make their preferences known through political channels, like school board elections. They can also bring pressure to bear informally

through contact with teachers or via students who are encouraged to challenge evolution in their classrooms. Yet, it is possible that more conservative teachers are more likely to be hired in more conservative districts, leading to less time being spent on evolution in such locales. It is an open question whether these same teachers avoided evolution classes when in college. If so, requiring them to take such classes might have only minimal impact.

There are multiple policy implications to our findings. Scientists devote considerable time to winning court cases and school board battles. But if their ultimate goal is that evolution be taught well they might be more effective by lobbying for more thorough science education for high school teachers, whether before they are hired or as part of their continuing professional development. Our findings suggest that the NCLB goal of ensuring that all teachers are "highly qualified" for teaching their subject matter will have the effect of increased instructional time on evolution. Our findings also highlight the circumstances in which standards have their strongest effect – suggesting that the resources states devote to standards do have an effect on teachers least likely to implement the preferred curriculum on their own. Finally, we show that examinations may be necessary to ensure that teachers carry out these policies in the face of their own beliefs and lack of knowledge.

All these findings are important as the Congress considers reauthorization of *No Child Left Behind Act* (*NCLB*). To date the federal government has required assessment exams only in math and reading and these have received significant scholarly attention (Darling-Hammond et al 2001; Desimone et al 2005). The expectation under the expiring law was that American middle and high school students may begin testing in science subjects sometime in the near future.[7] The question of whether science standards matter, and whether high-stakes exams are required for them to be effective, will become critically important to the thousands of school districts responsible for teaching biology and other science subjects.

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