The Lecture Machine: A Cultural Evolutionary Model of Pedagogy in Higher Education

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ABSTRACT

The benefits of student-centered active-learning approaches are well established, but this evidence has not directly translated into instructors adopting these evidence-based methods in higher education. To date, promoting and sustaining pedagogical change through different initiatives has proven difficult, but research on pedagogical change is advancing. To this end, we examine pedagogical behaviors through a cultural evolutionary model that stresses the global nature of the issue, the generational time that change requires, and complications introduced by academic career trajectories. We first provide an introduction to cultural evolutionary theory before describing our model, which focuses on how cultural transmission processes and selection events at different career phases shape not only who teaches in higher education, but also how they choose to teach. We leverage our model to make suggestions for expediting change in higher education. This includes reforming pedagogy in departments that produce PhD students with the greatest chance of obtaining tenure-track positions.

INTRODUCTION

Student-centered pedagogy leads to greater learning outcomes for students on average, compared with strict lecture. However, in spite of the evidence in favor of active learning, changing the pedagogical practices of faculty is a difficult task with no simple solutions (Gess-Newsome *et al.*, 2003; Henderson *et al.*, 2011; Henderson and Dancy, 2011). Neither providing data nor engaging faculty in teaching workshops has proven sufficient to effect widespread pedagogical change among faculty toward active learning (Sunal *et al.*, 2001; Ebert-May *et al.*, 2011; Henderson *et al.*, 2011; Andrews and Lemons, 2015). Diverse strategies to improve pedagogical training are ongoing, including targeting graduate student professional development (Gardner and Jones, 2011; Reeves *et al.*, 2016), postdoctoral professional development (Knight *et al.*, 2010; Ebert-May *et al.*, 2015; Carroll *et al.*, 2016), and departmental and institutional cultures (Kezar, 2013; Corbo *et al.*, 2016).

To date, these efforts maintain focus on localized change, including the adoption of improved pedagogy among specific individuals, departments, or institutions. These local efforts are integral to enacting change in academia, but are often performed without consideration for how the outcomes may have impacts beyond the local context. However, change efforts may have longer-term impacts that can spread beyond the local context. Using cultural evolution theory as a lens, we zoom out to view academics as a global population of individuals who have pedagogical beliefs and practices that can evolve over time based on structural and normative processes that are part of an academic trajectory. This analytical lens has the potential to lead to more effective strategies for change by illuminating the potential of different change strategies for affecting a larger population of instructors.

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In this essay, we construct a conceptual model of cultural change in academia that we offer as a starting point for using cultural evolution as a lens for pedagogical change. This model takes into account the generational and interconnected nature of academia. We focus on two processes that repeatedly occur throughout an academic career trajectory that can influence pedagogical evolution: social transmission and selection through career transition events (including transitions out of academia). By social transmission, we mean the beliefs, practices, and various artifacts of others that individuals acquire within the social and institutional contexts they experience throughout their careers in academia. By selection, we mean that certain individuals are filtered out of the academic pipeline of becoming a tenured professor, either by their choice or involuntarily. Because the specifics of these processes likely differ for each phase of an academic career and type of institution, we explore dynamics at each sequential career phase in two types of institutions: research-intensive and teaching-focused institutions.

Our model does not provide a new change strategy; rather, it provides a new lens to understand how change occurs at a larger scale in an effort to inform ongoing and future change efforts. In doing so, our model may be useful for 1) understanding historical constraints on pedagogical change, 2) developing testable hypotheses related to pedagogical change, and 3) inspiring future modeling efforts that more formally assess the impacts of potential pedagogical change efforts.

To familiarize readers with this framework before presenting our model, we first provide a brief overview of cultural evolutionary theory.[1] After this overview, we introduce our model, focusing on how past and current selection and transmission dynamics perpetuate the pervasiveness of lecture. We conclude by suggesting ways that this model could help inform when and where change strategies may have the greatest impacts, and we suggest future directions for further research.

CULTURAL EVOLUTION: A BRIEF OVERVIEW

Cultural Evolution Is Cultural Change Over Time

By definition, the modern-day field of cultural evolution[2] is simply cultural change over time. Culture is defined separately by many different disciplines. Here, we use a specific definition of culture, based in cultural evolutionary theory. Culture is "*information capable of affective individual behavior that they acquire from other[s]… through teaching, imitation, and other forms of social transmission*" (Richerson and Boyd, 2005, p. 5). By this definition, culture is information, and this information can influence behaviors, beliefs, and use of technology. Because people learn this information from one another, their interpretation and performance of cultural information shapes how that information is passed on to other actors and can establish group and institutional level social norms. We employ this definition of culture here, because it can be a useful way to operationalize the role of culture in a bird's-eye view (or population-level view) of educational systems. At the same time, we recognize that alternative definitions of culture exist and may be better suited to other types of study: for example, researchers focused on the problems of agency and phenomenology relative to the power structures of race, class, and gender in academia will naturally embrace a different construct to describe the role of culture. As discussed in more detail later, we embrace this informational definition of culture, because it allows us to draw parallels between biological and cultural evolution.

In what follows, when we discuss "pedagogical culture," we mean information about pedagogy that can be socially transmitted, including, for example, methods of instruction and assessment, teaching philosophies, and institutional-level rules and criteria. This last area can include the role of teaching evaluations in tenure and promotion and expectations for relative effort toward teaching versus research. All of this cultural information shapes behavior, and it can be shared, measured, and studied across individual people, as well as at the level of the population as a whole.

Using cultural evolutionary theory, we conceptualize cultural change as change in the frequencies of different cultural variants over time. Cultural variants are different versions of information (e.g., information that more time is required to prepare student-centered instruction than lecture-based instruction vs. information that the time requirements are equal) and are analogous to genetic evolution's "alleles"—different versions of a gene. However, unlike alleles, cultural variants need not be discrete or transmitted faithfully to continue replicating. This is because individuals can invent, repair, and revise the cultural variants they learn from others (Henrich *et al.*, 2008). As a result, we can develop models that track changes in the frequencies of cultural variants in a population as if they replicate like genes and spread like pathogens.

Culture Evolves by Natural Selection and Transmission

Similar to genetic traits, cultural variants can evolve by natural selection, as well as by other evolutionary processes, such as drift. This occurs when cultural variants meet the requirements for natural selection: they exhibit variation, this variation is transmissible, and the contents of the variants have consequences to their own replication. In some cases, a cultural variant's survival and reproduction depends on the success of its host. This parallels genetic evolution: if an individual who harbors a cultural variant dies without spreading the variant, the representation of that cultural variant decreases in frequency. However, there are some key differences between cultural and genetic systems. A particularly important difference is that cultural variants can spread to many individuals, not only to genetic offspring. The closest biological parallel to this is infectious diseases, which spread horizontally[3] between unrelated individuals and reproduce themselves at the expense of the "host" or infected

[1]Cultural evolution is a large and growing field, and our minimal introduction neglects many critical and insightful topics. For readers interested in learning more about cultural evolution, some of our favorite introductory readings into the topic include *Not by Genes Alone* by Richerson and Boyd (2005), *Cultural Evolution* by Mesoudi (2011), and "The Evolution of Cultural Evolution" by Henrich and McElreath (2003).

[2]Modern cultural evolutionary theory recently emerged in the late 20th century, largely through the use of mathematical models adapted from population genetics and other fields. This modern theory is unrelated to early attempts to apply evolution to culture, including unilineal theories of culture suggested in the late 1800s.

[3]We use the word "horizontal" to describe any nonvertical (parent to offspring) spread of cultural variants. However, convention in cultural evolution more precisely defines horizontal transmission as a variant's transmission within members of the same generation and oblique transmission to mean transmission from nonparental individuals from the parental generation (Cavalli-Sforza and Feldman, 1981).

individual (Cavalli-Sforza and Feldman, 1981; Richerson and Boyd, 2005). This means that culture can spread even when the human host produces fewer or no offspring: for example, the practice of celibacy can persist, even though its practitioners leave no genetic descendants, because other individuals may learn about and choose to adopt a celibate lifestyle.

A CULTURAL EVOLUTIONARY MODEL OF PEDAGOGY

In this section we first provide a broad introduction to our model before discussing the selection and transmission events that shape the pedagogical cultural variants that persist among faculty. We begin by outlining how selection and transmission operate on the population of academic trainees and faculty across the trajectory of an academic career. In this context, natural selection on pedagogical practices is most severe at major transition events from one career phase to another, when aspiring academics either continue their careers within academia or seek other employment. These major events include graduate school admissions, academic hiring, and tenure evaluation processes. Importantly, our model is neutral with respect to whether any personal or societal values placed on career paths are superior to others—our model concerns only the impact that these events have on the prevalence of different types of pedagogical techniques, such as lecture, among the population of practicing academics.

These same career phases also mark shifts from receiving to providing training and mentorship, wherein training and mentorship form the main mechanisms of cultural transmission of professional skills and values, including pedagogical teaching techniques. By cultural transmission, we mean individuals within academic institutions adopt and update their cultural variants, such as use of lecture, based on personal experience and social interactions throughout their academic careers. Training-as-transmission occurs within the specific context of each person's disciplinary, institutional, and social environments (Corbo *et al.*, 2016) and may be influenced by social learning heuristics (general cognitive rules that may benefit the learner), such as "copy the prestigious," "copy the successful," or "copy the majority" (Henrich and Gil-White, 2001; Henrich and McElreath, 2003). Overall, these transmission dynamics mean that the cultural variants held by an individual are likely to reflect that individual's past and continuing academic training.

We apply the mechanisms of selection and transmission within the context of an academic's "life history"—undergraduates become graduate students, who become tenure-track professors, who become tenured professors. When people leave academia at any of these points, whichever pedagogical methods they practiced lose a representative individual. This individual-level process can have population-level effects on the prevalence of various pedagogical methods. Because the contexts and consequences of selection and transmission vary across institutions, our model considers how pedagogy may evolve in a system that includes both research-focused and teaching-focused institutions.[4]

In cultural evolutionary models such as this one, individuals are assumed to be self-interested actors. This assumption is a methodological tool that allows the model to focus on population-level analyses. We therefore do not include a direct analysis of the many processes that go into meaning-making for particular individuals, because our focus is to gain insight from viewing the system, including its biases, from a bird's-eye view. We therefore assume that actors can make choices and have agency, but also that they are strongly influenced by their environments. In exchange, we gain the analytical power to look at systemic biases and population-level patterns. Cultural evolutionary approaches are not unique in adopting this level of analysis. For example, studies of systematic biases in hiring, retention, tenure, and promotion of women and people of color necessarily zoom out to view the systemic effects and patterns of bias (or, in contrast, inclusivity) that can result from repeated interpersonal interactions (Williams *et al.*, 2014).

We present a verbal description of our model with a corresponding visualization of movement of individuals from undergraduate to tenured professorship, taking into account the flow of actors between different types of institutions (Figure 1). In our model, there are research-focused institutions that grant PhDs and teaching-focused institutions, which do not grant PhDs. Our model assumes that a PhD is necessary to obtain a tenure-track position at both kinds of institutions and that PhDs are only available from PhD-granting institutions. The visualization includes general estimates of the sizes of the populations of undergraduates, graduate students, tenure-track, and tenured faculty at both PhD-granting and non–PhD granting institutions (Snyder *et al.*, 2016) in order to establish a sense of scale regarding the population we aim to characterize.

Our model outlines the prevailing wisdom in academia that selection acts primarily on research-based traits (Fleet *et al.*, 2006; Wilson, 2010). In other words, we assume that academics in the present system advance through career phases primarily by means of their publication and funding records and not based on their teaching practices. To analyze how this selection may affect the frequency of pedagogical behaviors, such as lecture, and the amount of one's efforts placed into teaching, we represent pedagogical variants held by individual academics that are assumed to underlie these behaviors using color-coded circles with different border thickness (Figure 1). In this way, we simultaneously track two components related to pedagogy: 1) allocation of one's effort into teaching, which we assume trades off with effort into academic duties, such as research (e.g., time spent writing a grant cannot also be spent meeting with students or preparing course materials), and 2) an individual's pedagogical behavior, which we simplify to be either teacher-centered pedagogy or student-centered pedagogy. We assume that effort toward instruction does not necessarily correlate with student-centered pedagogical approaches (i.e., individuals can still use lecture but exert high effort toward instruction). We also assume that early-career individuals who have not received as much pedagogical training or experience are, on average, more flexible in both their effort level and in the pedagogical variants they embrace, and we represent this increased flexibility through the color tint. For example, most undergraduates likely do not have a fixed opinion about their preferred teaching techniques (and are thus colored white), but senior faculty are more likely on average to feel strongly about the

[4]For the purpose of this essay, we consider research-focused universities as those granting PhDs, and teaching-focused institutions as those that primarily train undergraduates and require a PhD as a prerequisite for serving as an instructor. This omits colleges where a PhD is not always required to teach from our model. We do this to keep an already complex model more tractable, and we acknowledge the major role community colleges serve in higher education.

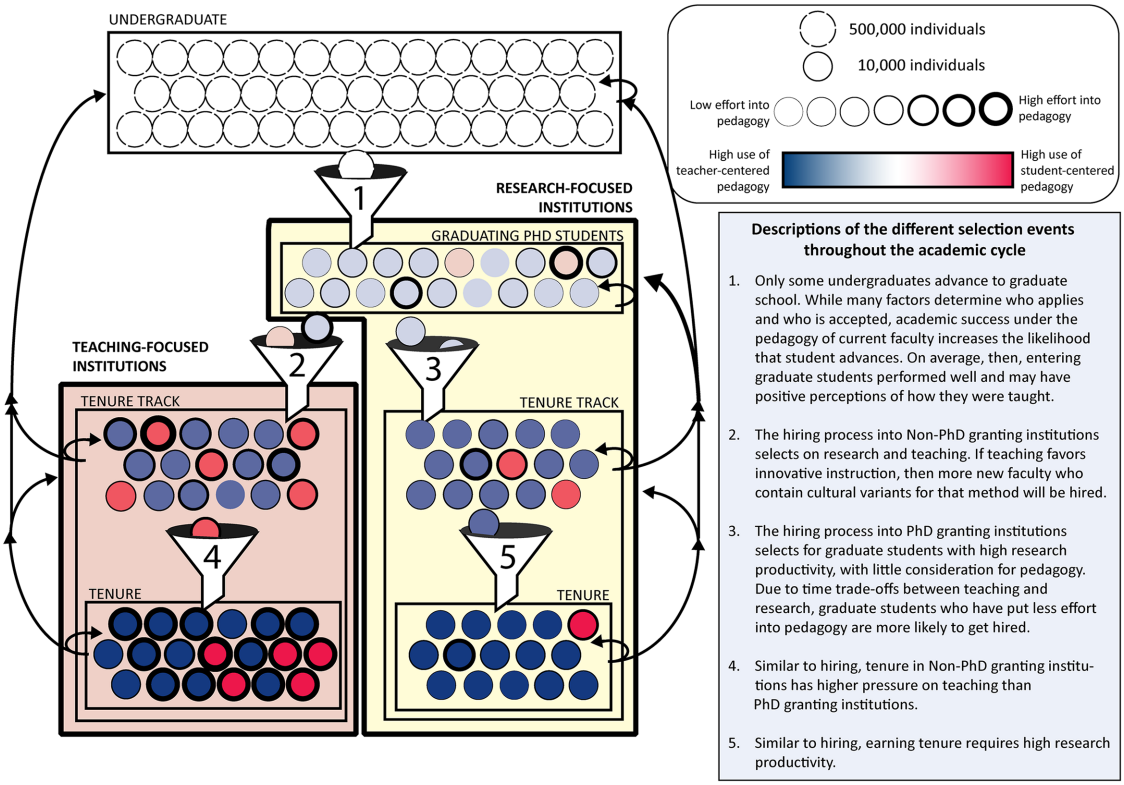

FIGURE 1. A visual representation of our cultural evolutionary model. Circles represent individuals who move through the academic pipeline. The size of each circle represents an estimate of the number of enrolled undergraduates, graduating PhD students, and working tenure-track and tenured faculty at PhD-granting and non–PhD granting institutions (Snyder *et al.*, 2016). Individuals accumulate cultural variants tied to pedagogy as they move through the pipeline, indicated by black arrows. Individuals advance based on criteria that weigh pedagogical practices to varying degrees. The color of each circle represents the likelihood of that individual teaching a certain way, with the color dependent on their accumulated cultural variants. Thus, if one color is at a higher frequency in the tenured faculty compartment, it represents a state where most tenured faculty practice that pedagogical behavior. The border thickness of each circle represents how much effort that individual allocates into pedagogy, which comes at the expense of effort that could be allocated to research. The proportions of pedagogical variants and effort are meant for illustration only, and do not reflect collected empirical data. Black arrows indicate cultural transmission.

methods they have used over the course of several decades (and are thus a darker shade). Academic career phases are separated by selection events, represented by filters. Cultural transmission occurs at each phase of an academic career, with those pathways represented by black arrows.

We simplify our model to keep it tractable in thinking about a system with many moving parts. As the statistician George Box once said, "All models are wrong but some are useful" (Box, 1976); we constructed our model as a tool that may be useful in advancing pedagogical change efforts, and not necessarily to present a completely accurate replication of the academic system. For example, we consider only tenure-track positions in our current model, but suggest later in this essay how nontenured faculty, a large contingent of the academic system, may fit within our framework. Similarly, we omit postdoctoral training periods from our current model, but address how these experiences may change model dynamics in the section on future considerations. Our model is meant to be adaptable for historical, contemporary, and potentially predictive uses, and we expect that some of the assumptions may need to be modified depending on the context of interest. Here, we choose to present the model as a historical account of lecture, with suggestions for how contemporary circumstances are, or are not, eliciting change.

In constructing our model, we make many assumptions. We support our assumptions through empirical work where possible and rely on conventional wisdom when systematic or undisputed evidence is lacking. We argue that our modeling framework could be useful even if some, or many, of our assertions prove to be inaccurate. This is because our unique contribution is a cultural evolutionary framework for pedagogical change. This framework is still relevant, even if details within our description below contain inaccuracies; pedagogical cultural variants are subject to change over time, and cultural evolution is a framework for investigating this change. We consider our modeling framework a useful road map for identifying parts of academic processes that may warrant further research and a lightning rod for future debate. Engaging with this evolutionary framework by considering how changes to parameters would change the trajectory of pedagogical culture is arguably the most productive way to use our model. In fact, using this modeling framework to make predictions requires one to change the current assumptions. For example, using our framework to conceptualize how changing hiring practices might alter pedagogy

requires changing assumptions about hiring practices. Thus, we encourage readers to consider how changing our assumptions might alter the cultural evolution of pedagogy and recognize that further research will help create a more accurate portrayal of the system we describe.

Transmission: Undergraduates Learn to Learn via Lecture

Our model starts with the undergraduate population. Historically, most undergraduates have learned content based on lectures, meaning that adopting learning techniques that are effective for learning from lecture has been critical for the academic success of undergraduates. Experiences in undergraduate classrooms are therefore an early experience of enculturation (Figure 1, arrows into "Undergraduate"). An undergraduate experience that includes primarily lecture classrooms may lead to undergraduates who passively adopt beliefs that college professors are supposed to lecture. While this experience is not the sole determinant of how these students may teach in the future if they later become instructors, studies have shown that one's own learning experiences can often inform future teaching decisions (Richardson, 1996; Phelps and Lee, 2003; Kensington-Miller *et al.*, 2013; Cox, 2014; Oleson and Hora, 2014).

The type of pedagogy that undergraduate students experience depends, of course, upon the transmission source: their instructors. These instructors gained their pedagogical techniques from previous generations of instructors, who learned from previous generations of their own instructors, and so on. A continued tradition of teaching undergraduates via straight lecture perpetuates an early normative belief into the population of potential future graduate students that lecture is both the preferred and accepted way to teach. If pedagogy differs between institutions, and this early experience proves to be important, we may find differences between professors who earned their undergraduate degrees from institutions or departments that implement more lecture-based pedagogies compared with those that use more student-centered practices.

Selection: Graduate School Admissions

Out of the large number of undergraduates in the U.S. system of higher education, only a small subset will apply to and be accepted into graduate school. Undergraduate grade point average (GPA) is a major predictor of admission into graduate school (Salvatori, 2001; Mullen *et al.*, 2003; Bedard and Herman, 2008). If the historical state of undergraduate instruction has been almost exclusively lecture, then graduate student cohorts historically represent populations who performed well in this lecture-dominated pedagogical context. This should create an ongoing selection process: admissions procedures favor students who succeeded in lecture classrooms and may lack personal reasons to dislike lecture. Simultaneously, this process would select against students who struggled in lecture classrooms, but may have otherwise flourished in a pedagogical context that uses more student-centered techniques. If the teacher-centered pedagogical practices and an importance placed on GPA have long been standard in higher education, we surmise that ongoing selection has created generation after generation of graduate students selected to be favorable toward lecture on average. This selection can be visualized as a filter (Figure 1, filter 1): only students who succeed in a lecture-based learning environment pass through to graduate studies. This perpetual selection for students who succeeded in lecture classrooms immediately increases the tendency for lecturing in the future generation and is in line with the often-cited phrase "it worked for me" (Lortie, 1975).

Transmission: Graduate Students

Many instructors in higher education get their first formal experience teaching in graduate school. This teaching experience occurs while they are also learning the professional standards of their disciplines (Corcoran and Clark, 1984), which may include both explicit and implicit guidelines on the relative importance of research and teaching (Brownell and Tanner, 2012). Both formal and informal mentorship can shape which cultural traits graduate students adopt during this career phase (Figure 1, arrow into "Graduating PhD Students"). These traits can include conceptions about how to teach in a college classroom, appropriate time management, and even which career paths are worthwhile to pursue (e.g., nonacademic, teaching focused, or research focused). Historically, graduate student professional development has not focused on the use of student-centered teaching practices or the importance of developing a strong teaching identity (Luft *et al.*, 2004; Tanner and Allen, 2006; Gardner and Jones, 2011; Brownell and Tanner, 2012). Instead, the values most frequently transmitted during graduate training emphasizes the "publish or perish" imperative and the importance of research. In this environment, extensive teaching experience may even be perceived as evidence of failure to obtain research-based funding, and research is prioritized over teaching, as a rule.

For graduate students who do not receive training in teaching, the default approach to teaching may be to mimic a professional research talk, resulting in teaching via lecture. This is likely the representation of teaching that graduate students see modeled in their professors and research mentors when they are communicating their research results at meetings and likely when they are teaching their undergraduate courses. Our model reflects this: we assume most mentors stress the importance of research over pedagogy (Robinson and Hope, 2013) and disproportionately transmit lecture as a pedagogical method. This may happen through direct training, by direct transmission of resources such as lecture slides, syllabi, or exam questions for a lecture-based classroom, or indirectly through the countless lectures experienced throughout a graduate education. Again, the variants transmitted to graduate students depend upon the transmission source, so we see transmission of the same lecture-based pedagogy at the graduate level that we see at the undergraduate level.

Selection: The Tenure-Track Job Market

While graduate school produces newly minted PhDs who vary in the effort they are likely to place on teaching, as well as their use of lecture or student-centered teaching, hiring procedures ultimately determine who becomes a tenure-track professor. With very few tenure-track faculty jobs available, and an increasing number of PhD-holding job candidates, selection at this career phase is severe and primarily based on research achievements (Golde and Dore, 2001; Wright and Vanderford, 2017). This not only culls PhDs who lack the potential for a highly productive research career, but it likely incentivizes

graduate students to publish at the expense of gaining teaching experience.

Tenure-track hiring processes at research-focused institutes place a greater emphasis on research products than teaching experience (Fleet *et al.*, 2006), meaning hiring likely selects for individuals with high research productivity, possibly at the expense of putting any selective pressure on pedagogy (Figure 1, filter 3). We suspect that very few job candidates fail to obtain jobs at research-focused institutions because they either lecture or use student-centered active-learning pedagogies. However, *indirect* selection can occur if the most qualified job candidates (based on research outcomes) teach differently on average than the larger population of candidates. For example, if research productivity is associated with a candidate's propensity to use lecture, then hiring decisions prioritizing productive researchers would inadvertently and concurrently select for lecturers. While there are studies that investigate the relationship between the quality of one's research and teaching, they do not focus on instructional behaviors. Instead, this work typically examines the relationship between one's research productivity as measured by publication record and teaching performance, which is typically measured through student evaluations (Hattie and Marsh, 1996; Seagram *et al.*, 1998; Malcolm, 2014; Gilmore *et al.*, 2015; Cadez *et al.*, 2017). However, student-assessed quality does not directly capture instructional method or the amount of effort one spends on pedagogy. Thus, we assume that a scarcity of time and energy means that graduate students who invest in research at the expense of teaching are more likely to get jobs. We further assume that first-year faculty who lack experience teaching in graduate school, often due to receiving research fellowships, may default more strongly to their undergraduate experiences or to their experiences presenting research in the form of a seminar-style talk. They may also be more likely to rely on classroom resources from mentors and new colleagues and to copy behaviors of these same peers when the time does come to teach.

Hiring practices differ based on the kind of institution (Fleet *et al.*, 2006); applicants to teaching-focused institutions are advised to emphasize their teaching experience, although these institutions still may require impressive publication and funding records (Deardorff *et al.*, 2001). No studies have systematically analyzed whether teaching styles differ between teaching-focused and research-focused institutions, but we expect that different emphases on pedagogical scholarship in hiring decisions across institutions make teaching-focused institutions more susceptible to changes in the pedagogical behavior and effort among newly hired faculty (Figure 1, filter 2). While we expect overall differences, the variation between these two kinds of institutions may be limited for a couple of reasons. First, teaching-focused institutions draw from a pool of job candidates who were trained at research-focused institutions, resulting in a mismatch between the training received by job candidates and the more intensive pedagogical requirements of teaching-focused institutions (Golde and Dore, 2001). Job candidates may lack formal training in college pedagogy or may feel a need to maintain a strong research identity based on their graduate school training, which may dampen effort toward teaching. This mismatch has inspired calls for reformed pedagogical training for doctoral candidates (Golde and Dore, 2001). Second, the evaluation criteria set by hiring committees may not select for student-centered practices, due to either a lack of emphasis on these methods or the inability of evaluation metrics to capture teaching style. For example, single-day teaching demonstrations, student evaluations, or colleague evaluations may not accurately reflect the pedagogical behaviors of a potential job candidate.

Transmission: Teaching before Tenure and Promotion

Faculty are under duress to meet tenure and promotion requirements. This involves deciding how much effort to allot to teaching versus research, often with the added weight of having to prepare new courses. Institutional pressures surrounding a faculty position set the incentives for faculty (Henderson and Dancy, 2007). This means that faculty must learn how to appropriately balance time and effort between research and pedagogy to meet the expectations for tenure and promotion in their departments, as well as at the university level (Hardré *et al.*, 2010; Savkar and Lokere, 2010; Robert and Carlsen, 2017). Departments may provide guidelines for faculty—such as 40% research, 40% teaching—but such ratios are abstract administrative expectations and usually not tied to how much time faculty will need to spend on research to meet tenure standards. While some research suggests that extrinsic institutional incentives drive faculty to emphasize their focus on research (Leslie, 2002; Light *et al.*, 2009; Anderson *et al.*, 2011; Bradforth *et al.*, 2015), other evidence suggests that faculty may be more motivated by intrinsic motivations (Robert and Carlsen, 2017; Shortlidge *et al.*, 2017). During the pre-tenure phase, academics at research-focused institutions are further incentivized to continue prioritizing research and grants. In part, this is because the minimum required teaching performance for tenure and promotion is typically much lower than the bar for research accomplishments. When junior faculty ask for guidance on teaching, it is likely to be treated as a problem to minimize, rather than an achievement or output to produce (Anderson *et al.*, 2011; Harland and Wald, 2017).

New faculty must teach and must choose a method for doing so. While pre-tenure faculty rely largely on their own experiences, personal opinions, and beliefs when making pedagogical decisions (Feldman, 2000; Andrews and Lemons, 2015; Lund and Stains, 2015), other sources, including advice and resources from colleagues (Figure 1, arrows from tenured faculty to tenure-track faculty), can also influence pedagogical decisions (Oleson and Hora, 2014). Given that most faculty join departments in which their colleagues are more likely to use teacher-centered instruction, pre-tenure faculty are likely to receive collegial advice related to how to teach through lecture, and may even receive lecture-based materials from their predecessors for existing classes. Advice on how to allocate time and effort to teaching and research is likely to vary greatly by departmental and institutional requirements, but likely trends toward how to minimize teaching effort in terms of time. Even if pre-tenure faculty do receive advice from colleagues who use evidence-based teaching approaches, this does not guarantee instructional change. Pre-tenure faculty must weigh that advice against other sources; potentially prestigious colleagues who have successfully climbed the career ladder to full professor while lecturing may have more impact on new faculty than their early-career faculty counterparts and may counteract efforts toward pedagogical change.

The situation is likely similar for pre-tenure faculty at teaching-focused institutions, where we also assume a historical tradition of lecture. Faculty advice about how to teach likely transmits via suggestions about teacher-centered practices wherever they are pervasive. However, if these institutions have different requirements for tenure and promotion, then new faculty will be in an environment in which they also receive advice that conforms to higher effort toward pedagogy, independent of whether that pedagogy is teacher or student centered. This is likely not the case in all teaching-focused institutions, though, as many of these institutions still require high research productivity from their faculty.

Research to understand the impact colleagues have on faculty pedagogy is underway, including studies examining faculty networks. Work to understand faculty communication networks reveals that discipline-based education researchers engage with more faculty regarding pedagogy than their peers, with some evidence that they influence teaching behaviors within their own departments (Quardokus and Henderson, 2015; Andrews *et al.*, 2016; Ma *et al.*, 2016). However, a more comprehensive understanding of how these channels influence the pedagogical methods of colleagues will be key, especially given evidence that, when instructors do adopt evidence-based instructional practices, they often do so with low fidelity (Dancy *et al.*, 2016; Stains and Vickrey, 2017) and therefore may not be teaching effectively even when they embrace alternatives to lecture.

Selection: Earning Tenure and Beyond

Tenure requirements vary by institution and department, with research-intensive PhD-granting institutions requiring research products, such as publications, successful trainees, and grants awarded (Gardner and Veliz, 2014). The same is true for post-tenure promotions, but we focus on earning tenure in this model, because the result of failing to earn tenure often means the end of a person's academic career at that institution; failure to advance at a later phase merely means no additional promotions. As in the hiring process, there is little selection on pedagogical practices, and the selection that does exist on pedagogy is usually weak at best (Boyer, 1990). Effectively, there is no positive selection to promote instructors who use student-centered teaching practices—and there may even be negative selection against those who perform well on teaching if it comes at the cost of research products. Although we expect most faculty to achieve tenure (Figure 1, filters 4 and 5), and thus consider this selection event one of the weakest, this stage nonetheless sets external expectations for faculty achievements and behaviors.

Given differences in hiring criteria between teaching-focused and research-focused institutions, we expect tenure and promotion systems at teaching-focused institutions to place greater stress on teaching accomplishments compared with those at more research-intensive institutions. While one might suspect that a heightened emphasis on pedagogy at teaching-focused institutions would motivate professors to adopt evidence-based instructional practices, evaluations for tenure tend to use student feedback and colleague evaluation of in-class teaching methods (Hughes, 2014). These forms of evaluation do not necessarily capture the method of teaching or reward evidence-based practices, giving one reason to believe that tenure evaluations will not motivate or select for more student-centered teaching practices, especially when student evaluations of teaching are the primary measure of teaching effectiveness. Concerns about the use of student evaluations to capture instructor effectiveness are common (Spooren *et al.*, 2013), as student feedback is notoriously biased and often more sensitive to variables other than student learning gains, such as instructor likability (Shevlin *et al.*, 2000; Emery *et al.*, 2003; Uttl *et al.*, 2017). In fact, instructors have noted dips in student evaluations upon implementing student-centered practices, suggesting that the reliance of institutions on these subjective metrics may incentivize faculty to maintain teacher-centered practices. Peer observations may similarly be problematic if faculty tasked with the evaluations are unfamiliar with student-centered practices and are unable to assess those strategies within the classroom, ultimately penalizing innovative teachers, even at teaching-focused institutions.

How Lecture Reproduces in a Population of Academics

We have laid out arguments for how the pedagogical practices used in higher education are shaped by transmission and selection events acting on individual academics who use them, with a focus on historical forces leading to a high frequency of lecture-based instruction. Critically, the way the academic system is structured makes PhD-granting institutions more influential on pedagogical culture than teaching-focused institutions that do not produce PhDs. Professors at PhD-granting institutions get to "reproduce" by training graduate students. Some of the trained graduate students fill tenure-track jobs, and many may practice lecture as they were trained, thus indoctrinating their students in the same methods, whether consciously or not. Professors at teaching-focused institutions, which we suggest may be more prone to pedagogical change toward evidence-based instructional practices, are unlikely to see their pedagogical techniques "replicate" throughout the system, because they do not produce PhD students who can further spread those practices. While these professors are responsible for the training of undergraduates, their undergraduate students who go on to graduate school must do so at research-focused institutions, where they are subject to the forces of selection and transmission that likely favor lecture.

Disparities in influence also exist within and between PhD-granting institutions. All newly minted PhDs come from a research-focused institution, but the most competitive candidates typically are trained by advisors or in labs with strong records of funding, high research productivity, and well-established reputations. Thus, high-powered research professors likely have a disproportionate effect on the academic culture by "replicating more of themselves," including their own cultural variants, most effectively. Indeed, PhDs from highly prestigious schools are more likely to obtain coveted tenure-track positions, often at other influential universities (Clauset *et al.*, 2015; Headworth and Freese, 2015). This consolidation of influential power over the academic system can result in a continuous reinforcement of culturally learned practices such as lecture and a value system that prioritizes research over teaching.

For these reasons, we fear that interventions focused on individual departments or particular institutions may fail to enact change in the broader system of higher education. Suppose that many faculty recognize the value of student-centered pedagogy and that some subset of faculty prefer it over lecture. Even if

this is true, the structure of an academic trajectory 1) creates multiple hurdles through career points at which individuals are likely to be penalized for teaching effort and 2) includes cultural transmission pathways dominated by the most frequent pedagogical practices, historically lecture. The exception to these claims may be in teaching-focused institutions, where hurdles are less likely to penalize teaching effort. However, the reproductive dynamics of academia hinder innovations from spreading from teaching-focused institutions at the same rate as research-focused institutions, because they do not directly produce PhDs.

Leveraging Our Model for Change

Our model offers a road map for thinking about how cultural evolution occurs in academia and can help highlight pathways for changing pedagogical culture. Specifically, the model reframes the goal of pedagogical change to a more global view of academic culture that stems from processes at the individual and departmental level, including cultural transmission and career-based selection on the population of potential instructors. Emphasizing this global view means evaluating the downstream changes that emerge from local interventions that then spread throughout the larger academic system. This kind of impact may take years to materialize and occur beyond the immediate goals of change initiatives, in part because it relies on the career paths and training of individual academics.

Will a proposed initiative lead to systemic change or be limited to local departmental or institutional improvements? We can use our model to identify pedagogical change initiatives that are likely to create impact beyond their proximal targets. Three potentially novel suggestions emerge by using our model. The underlying rationale behind all three of these suggestions is that R1 institutions represent a critical lynchpin for faculty pedagogical change and that with limited time and resources, efforts should be focused on R1 institutions. First, pedagogical training initiatives should target PhD students and postdocs who are likely to become professors at R1 institutions. Second, initiatives should target professors who train graduate students at top R1 institutions. Finally, more channels for collaboration and learning between professors at teaching-focused and research-focused institutions should be prioritized.

Graduate students and postdoctoral scholars are the source population for all future tenure-track faculty. Universities that provide graduate students and postdoctoral scholars with pedagogical training are not only improving the quality of their own undergraduate classrooms (Reeves *et al.*, 2016), but they are also providing pedagogical training to the individuals who represent the future population of faculty and pedagogical culture. Pedagogical training for graduate students and postdocs may be particularly productive if training programs specifically target individuals who want to become tenured faculty. Some existing initiatives fit this suggestion. Institutional Research and Academic Career Development Awards (IRACDA) aim to train postdocs in pedagogical skills at minority-serving teaching institutions while they are conducting research at R1 institutions. This federal investment ties pedagogical outcomes to research aims for a population of individuals who are likely to obtain tenure-track positions. By reaching individuals who are amenable to pedagogical training and likely to advance to influential parts of their careers, this program may have downstream effects on the academic system beyond its recent success (Faupel-Badger and Miklos, 2016). Similarly, the FIRST IV program aims to train academics while they are still amenable to learning new pedagogical methods (Knight *et al.*, 2010; Ebert-May *et al.*, 2015). However, these programs do not specifically target individuals who are likely to pursue careers at R1 institutions, where we argue faculty will have the most influence on changing the teaching practices of the next generation. A novel approach could be to specifically target individuals who are on track to become faculty at R1 institutions.

There is a large inequity in which departments and institutions produce tenure-track faculty, with a majority of faculty coming from the same top 25% of institutions (Clauset *et al.*, 2015). While this inequity is potentially troublesome for collective scholarship, it represents a potential lynchpin for systemic change. If faculty in departments producing the bulk of competitive job candidates were to adopt student-centered teaching practices, they might continually "replicate" those practices into their graduate student offspring. While faculty change is difficult, an "outside-in" strategy that involves administrators and faculty to evince cultural change across multiple departments might be a powerful way to motivate change (Corbo *et al.*, 2016). Our model suggests that enacting change at the most prestigious research-focused academic departments and institutions, which produce the bulk of future faculty, would expedite systemic change across academia. Some interventions are already focusing on research universities. For example, the Center for the Integration of Research, Teaching and Learning Network (CIRTL) integrates this strategy as part of its mission to reform undergraduate science, technology, engineering, and mathematics education (Austin *et al.*, 2008; Micomonaco, 2011; Center for Integration of Research Teaching and Learning, 2017).

At teaching-focused institutions, there is greater value placed on instruction. This creates a potentially greater chance that interventions in teaching styles will succeed within the institutions themselves. Further, the focus on instruction makes these institutions potentially important sources for new evidence-based teaching methods to arise. However, because these institutions do not directly produce PhDs who go on to faculty positions, there is no channel for spreading pedagogical culture through graduate student replication. We advocate for an increase in alternative mechanisms for the transmission of culture from teaching-focused to research-focused institutions. We are not suggesting that advancements in pedagogy are the sole responsibility of teaching-focused institutions, but instead that structuring more channels for faculty from teaching-focused institutions to communicate with faculty at research-focused institutions would be mutually beneficial. Teaching-focused institutions may gain additional access to research and resources through collaboration, while faculty at research-based institutions would gain the often hidden knowledge from teaching experts in relevant fields, who have put in the time and effort to develop effective teaching strategies.

Further Considerations

As previously noted, we simplify our model for the sake of tractability. Various aspects of the academic system are currently and purposely unincorporated in our model. However, we

invite readers to consider how one can add complexity into the framework we have laid out. As an example, our model omits non–tenure track faculty (lecturers, adjunct professors, etc.). Indeed, part-time faculty make up more than 50% of all faculty appointments in the United States (American Association of University Professors, 2017) and thus represent an important population, especially for undergraduate education and enculturation. Incorporating this population into our model may alter some expectations, but this would depend on whether non–tenure track faculty have different cultural variants from tenure-track faculty, whether these faculty train graduate students, the amount of interaction that occurs between these faculty and tenure-track faculty, and other factors related to selection and transmission in our model. In addition, including a postdoctoral stage to our framework may alter model dynamics, as they represent an extra phase of selection and transmission. However, our prediction is that the typical research focus of postdoctoral training would not alter the systematic pull toward lecture outlined earlier.

Our framework could be modified to include greater complexities of academia, and this would be useful if researchers do so with a particular question in mind. For example, a consideration of the accumulation of freely available curricular artifacts supporting student-centered instruction, such as those found on CourseSource (Wright *et al.*, 2013), or the implementation of communities of practice (Wenger, 1998) would need to take these specific transmission pathways into account. Likewise, our model lumps a diversity of pedagogical techniques into a single variable we are calling student-centered pedagogy. To understand how specific pedagogical practices evolve, researchers should consider the particular fit between a practice and the academic system. For example, course-based undergraduate research experiences (CUREs) provide a wealth of benefits to students (Auchincloss *et al.*, 2014; Brownell and Kloser, 2015) and can simultaneously benefit the research interests and goals of faculty (Shortlidge *et al.*, 2015; Cooper *et al.*, 2017). Modifying our model to account for reduced conflict between research and teaching effort might change model dynamics. Namely, CUREs may be particularly transmittable in research-focused institutions, insofar as they align with research-oriented goals.

Cultural evolutionary models have similar scopes and goals to population genetics models. As such, they purposefully simplify some details about the intricate and complex processes that underlie the patterns that are the focus of study. Indeed, Darwin was able to develop the theory of natural selection without knowledge of the processes of genetic inheritance (Darwin, 1859). However, our understandings of evolutionary processes and patterns become richer and more complex with a deeper understanding of inheritance mechanisms (Fisher, 1930; Huxley, 1942). Similarly, our wide lens on cultural change may be strengthened in the future by incorporating concepts from other theoretical approaches that have been used to study individual and group-level change (Bourdieu, 1986; Pentland, 1995; Strauss and Quinn, 1997; Martin, 2001).

CONCLUSION

We re-envisioned pedagogical change through a cultural evolutionary model in which change depends on connected processes of cultural transmission and selection across an academic career trajectory. This model underscores that even change initiatives that successfully result in positive faculty change may still fail to make a dent in the broader academic culture. However, it simultaneously suggests that successful interventions may have impacts that go beyond the local contexts these interventions aim to influence. Focusing energy and resources to change pedagogical beliefs and practices among faculty who produce the plurality of future professors may be a critical strategy moving forward. If 100% of graduate trainees from the most prestigious institutions graduated with training and experience in using evidence-based instructional practices, sweeping change toward evidence-based pedagogy in undergraduate education at a large scale might not be too far behind.

Our model is only a first step, but it has the potential to inspire future work in several ways. First, our model simplifies a complex academic system. The simplifying assumptions enable discussion of the model, but fleshing out particular problems and variations that we have not included here may help generate new hypotheses and lead to new data that further inform cultural change in academia. For example, knowing to what extent prestigious research faculty and discipline-based education researchers influence the pedagogical decisions of newly hired assistant professors would inform dynamics in our model and potential policy as it relates to pedagogical change.

Second, our model is descriptive and conceptual. Formal evolutionary models could be used to evaluate whether our assumptions would result in the population dynamics we described earlier. A previously published agent-based model exploring the evolution of "bad science" in research examined potential impacts of interventions aimed to improve research standards (Smaldino and McElreath, 2016). A more formal model of pedagogical culture might do the same and could give a quantitative estimate of the strength of selection at different career phases and in different fields of study.

Finally, our model has practical applications in its current form. Its main purpose is to help move the needle toward greater use of evidence-based instructional practices. Change on this scale is a slow and multi-generational process, a fact established by existing work to reform pedagogy in academic departments. Our cultural evolutionary framework is productive in thinking about how to accelerate change in these dynamic systems, by leveraging forces of selection and transmission at key points when they wield the greatest influence on population-level outcomes. Future work based on this framework may help initiate change at a larger scale.

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