The “Math Prefresher” and The Collective Future of Political Science Graduate Training

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Abstract

The political science math prefresher arose a quarter century ago and has now spread to many of our discipline’s Ph.D. programs. Incoming students arrive for graduate school a few weeks early for ungraded instruction in math, statistics, and computer science as they relate to political science. The prefresher’s benefits, however, go beyond the technical material taught: it opens pathways to mastering methods necessary for research, facilitates connections among peers, and, perhaps most importantly, eases the transition to the increasingly collaborative nature of graduate work. The prefresher also shows how faculty across a highly diverse discipline have worked together to train the next generation. We review this program, highlight its collaborative aspects, and try to take the idea to the next level by building infrastructure to share teaching materials across universities so separate programs can build on each other’s work and improve all our programs.


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Introduction

Math prefresher (or “math camp”) programs in political science invite newly admitted Ph.D. students to graduate school a week or two before their official start date to attend classes on math, statistics, computer science, and related technical material designed specially for them. Although differences exist across universities, the usual pattern has students attending lectures in the mornings, doing problem sets together in the afternoons, and having informal lunches with faculty who have differing perspectives across the department. Typically, no grades are assigned. No individual attendance records are kept. Most programs are entirely voluntary, but almost all students choose to attend the entire program, regardless of background or interests. A faculty advisor organizes and guides the program, and senior graduate students or faculty serve as instructors.

The program turns out to have substantial benefits well beyond the specific technical material learned. It has value for pedagogy, showcasing different pathways to learning various methodologies, building camaraderie among the entering class, and forging connections with senior graduate students. Perhaps most importantly, the program eases transition from undergraduates studying mostly on their own to graduate students who learn to work collaboratively. Experience with the math prefresher also highlights a valuable example of how faculty from all parts of a highly diverse discipline have worked together to design an introduction to graduate training. As a result, versions of the math prefresher program have been adopted by political science departments across many universities and some other social science disciplines.

Despite its prevalence as the de facto introduction to a graduate program, these issues have not been widely discussed in the discipline, perhaps because faculty advisors design prefreshers primarily for their own departments only. Based on our 25-year experience and now with interviews with instructors from over 15 different graduate programs, we clarify some of the advantages of the prefresher in helping students transition to collective learning styles and then discuss the role of and reason for math as the substantive content in the math prefresher. Finally, we propose to take the idea behind the prefresher to the next level by building infrastructure to share teaching materials and lectures across political science prefreshers at different universities so all the separate programs can build on each other’s work and improve all our programs.

Graduate School as a Transition to Collective Learning

Graduate school in political science is not merely advanced study. It is not merely more focused study. It is a time of transition to a collective model of teaching and learning, one where collaboration, cooperation, contributions to the broad literature, and connections between
students, the department, university, and profession are increasingly central. For instance, rates of article coauthorship in leading political science journals have grown spectacularly since the 1950s -- with increases from 638% to 1,739%, depending on the journal (see Teele and Thelen, 2017). As the first collective event of graduate school designed for learning, the math prefresher begins this transition.

Although undergraduates have many collective experiences, from residential and extracurricular activities to study groups, their intellectual experience is relatively solitary compared to graduate students. Each undergraduate is evaluated alone and graded individually and frequently. Although graduate students begin with classwork as they did as undergraduates, every step along the way eases them into the broader community of scholars -- beginning with taking orders from the professor to taking the initiative and collaborating with others as colleagues. What matters is that graduate students learn how to do research, become comfortable with teaching others, practice collaboration, begin to understand how to manage a research team, and contribute to a broader literature.

Another important part of this transition is the change in the nature of relations between students and faculty as graduate school begins. Faculty want more connections with graduate students, since graduate students help faculty achieve faculty career objectives as teaching and research assistants, coauthors, and members of the scholarly research community. Also in sheer numbers, the graduate student-faculty ratio is on the order of 20 times smaller than for undergraduates. The collective learning structure of the math prefresher therefore prepares incoming graduate students for deeper engagement and collaboration with colleagues -- faculty and fellow students alike.5

**Fostering Collaboration**

A typical introduction to the math prefresher would outline the specific technical skills it intends to impart to students. However, this endeavor also plays a more fundamental role in introducing students to the transition to collaborative learning and so we begin with these benefits.

To facilitate the transition away from the undergraduate model of evaluation, most math prefreshers issue no grades, and the ones that do make clear that grades will not be tracked in their transcript. At Harvard, we convey that if you want to learn this material, we’ll help; if not, that’s up to you. Motivation comes from the student or not at all. Of course, we are social

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5 Consider also the difference between undergraduates and graduate students from the perspective of faculty. The number of undergraduates is so large per faculty member at most universities that faculty have no choice but to find ways of reducing demands on their time. When demand is greater than supply, the possibilities include (1) raising prices, which is obviously not an option; (2) reducing the quality of the service, which is not a good career move; and (3) rationing, which is used everywhere with undergraduates, such as by restricting access to a few faculty office hours per week.
scientists and know how to use behavioral incentives to turn the anxiety we all remember prior to starting graduate school into motivation and action (!), but lack of student motivation is usually the least of our concerns at this stage of their student experiences.

Instead, an underlying pedagogical goal of the math prefresher is to cultivate lasting collaboration. The transition to collective learning occurs in several steps. First, having fellow graduate students lead or assist the sessions helps the prefresher program convey how students should begin to rely on and help each other. Building camaraderie through identifying each other’s comparative advantages makes graduate school seem less threatening.

The collaborative experience does not merely make everyone feel good; it helps level the playing field for the incoming class. Taking stock of the range of different technical backgrounds of the incoming cohort, instructors can adjust the syllabus to make the experience more inclusive and accessible. A well thought-out prefresher helps make the whole class and all individuals in it better by helping to build a community of scholars for each one of us.

Finally, the practice of collaboration and drawing upon each other’s comparative advantages prepares students well for the rest of their graduate school career and beyond. This is an industry where helping competitors helps ourselves, and this initial experience just before graduate school helps orient students in this productive direction.

**The Role of Math in the Math Prefresher**

Being the first exercise that students encounter in their program, the material taught in the prefresher should be designed for the motivations and interests of beginning political science graduate students. While some political science prefreshers originally mirrored similar programs in economics departments\(^6\), today the distinguishing feature of our prefreshers is that we tailor the content to the political science discipline.

The path to graduate school in political science often involves intentionally forking off to the social sciences or humanities and leaving behind possible careers in mathematics, science, and engineering. Thus, landing in graduate school, and learning that many parts of political science require heavy doses of math, statistics, programming, and other technical material, can feel like a breath of fresh water. This is not a flaw in our student pool; we want students focused on the substance of government and politics and do not want to turn graduate training in political science into a technical training program. So we design the prefresher to motivate students to get

\(^6\) Economics Ph.D. departments may have started similar programs earlier than in political science. Harvard’s Department of Economics probably started math camp around the mid to late 80s, and the University of Chicago Economics department did not have a prefresher at least until the early 90s (Jerry Green, Robert Margo, and Jim Snyder, personal communication).
the background to do their research, given their highly diverse technical backgrounds and substantive interests (see Appendix A).

The math prefresher program eases students into engaging with technical material, including material they may have thought they would never need to know, by orienting them to the importance of different topics in learning to do research in their preferred subject area. And the prefresher, along with the first year graduate methods or formal theory courses, then takes students up the ramp of knowledge so they can eventually produce, or at least engage with, research that makes use of various quantitative methods, or when necessary take technical courses in other departments.

In principle, the prefresher might be able to accomplish some of its collective goals by going deep into specialized knowledge from any one of the political science subfields. But for at least five reasons (in addition to the fact that the subfield of political methodology is now the second or third largest in the discipline), the vast majority of political science prefresher programs focus on quantitative material from math, statistics, and computer programming.

First, the math prefresher is important to the style of learning, not only the content. Graduate school, and the profession beyond, is about going deep, focusing, and learning enough about a specific subject to make a real contribution. Thus, beginning graduate school with, say, a brief introduction to each of the subfields may be useful in the same way as reading the department website might be. But all-introduction-all-the-time is not what graduate school is supposed to be. Focusing on any single subfield may have subsidiary benefits, but math is especially useful to illustrate the go-deep style of learning because it is easier to show the immediate returns to understanding rigorous research in student’s substantive fields with it.

Second, math, statistics, and related material is essential to understanding theories of inference -- using facts you know to learn about facts you don’t know -- which are fundamental to all subfields of political science. For this reason and others, math is used explicitly or conceptually throughout the discipline. Even for students who do not wind up using primarily quantitative methods for their research, learning the building blocks of statistical inference allows them to understand, engage with, and build on empirical research in the vast reaches of the discipline that use those approaches.

Third, technical material requires learning the building blocks of knowledge in a sequence, like foreign languages but unlike most substantive areas of political science, and so helping students see the trajectory of technical courses they will take over the next several years can be helpful when beginning early.
Fourth, math is scary! Everyone knows more than you do (the reverse is true too). This fear is useful for building camaraderie and fostering the likely lifelong connections begun during the prefresher and in graduate school, which students can use to decide among the many possible paths before them. It is especially good to get all that started from the outset.

Finally, the idea that mathematics, statistics, and programming could provide a unifying experience to the diverse array of incoming political science graduate students may seem paradoxical, given that the most fervent intellectual debates in our field have often taken place over a quantitative-qualitative divide. What this perspective misses is that the debate has also been highly productive for both sides. Qualitative researchers, who are typically overwhelmed with field notes, audio tapes, video recordings, speeches, treaties, and archival texts, are now regularly getting help from quantitative scholars who have been developing methods to derive substantively important meaning from this unstructured information in ways no human being could consume on their own. Quantitative scholars now appreciate and learn from qualitative scholars who know far more about any region or event than could be hoped for with quantified variables. And everyone recognizes that every book and article written in political science is qualitative and some fraction of these are also quantitative. The debate will continue for the foreseeable future, but the divide has long since transitioned from siloed subfields, to an open war, and finally to a deep partnership for the good of the broader discipline, all of which is a tremendously important development (King, 2014: p.167).

In fact, the math prefresher has developed because of, not in spite of, these hard-fought debates, where each side has provided tremendous encouragement and assistance to the other. The same scholars who levy the harshest criticisms of quantitative techniques have chosen to institute requirements for political methodology courses in the vast majority of political science graduate and undergraduate programs, to hire mathematically and statistically trained colleagues, and to encourage math prefreshers. The formation and spread of math prefresher programs could not have happened without help from entire departments, including the most qualitative among us.

**What Mathematical Content Should Go in the Math Prefresher?**

Because much of the value of the prefresher comes from the collective aspects of the program, it has advantages independent of the specific type of technical content taught (cf. Anand, 2016). As such, graduate programs have latitude in designing prefreshers to suit diverse incoming classes, the particular knowledge and teaching skills of the faculty sponsors and senior graduate students available to serve as instructors, and the needs and direction of the department and the discipline.

Much of the variation among prefreshers is the result of the development of the political methodology subfield. For example, our own prefresher began in the mid-90s with reading
materials produced in and for statistics, mathematics, and econometrics (e.g., Simon and Blume, 1994). That course outline emphasized optimization and comparative statistics, linear algebra, and computational software for solving math problems. Today, a quarter century later, our focus on mathematics remains but the changes are illuminating. Probability theory and linear algebra appear more prominently as a tool to characterize social phenomena. Statistical programming is taught as a central tool for empirical analysis. Programming exercises are usually arranged in small groups to match those with different levels of prior experience in the same groups to transmit knowledge faster. Students more regularly take advantage of datasets and examples generated by political scientists and specifically tailored for an audience of political scientists (e.g., Imai 2018). These applications now often cover all major subfields in our discipline, and give incoming students exposure to political science studies in addition to instruction in math and programming (e.g., Ober and Pyzyk 2014, Nunn and Wantchekon 2011, Hochschild and Powell 2008, Oneal and Russett 1999, Persson and Tabellini 2000).

Departments also adjust the content of their prefreshers to meet their particular strengths, curricula, and culture. In our survey of political science prefreshers in various Ph.D. programs, we found that some programs emphasize mathematical preparation in analyzing game theoretical models (New York University, Princeton, Texas A & M), others cover concepts from machine learning (UC San Diego), while yet others cover computing and technical word processing (Cornell). Prefreshers in these departments range from one day (UNC) to assignments and online discussion interspersed over the summer prior to an in-person prefresher (Duke, Princeton). Some programs teach calculus and programming separately (University of Wisconsin Madison), some teach it with the same instructor, and yet others programs each offer two separate prefreshers --- one before the first year and the other before the second (MIT, Princeton). Reading materials range from a set of published exercises (Moore and Siegel 2013, Kropko 2015) to coming from no textbook at all. The University of Chicago prefresher (taught for many years by John Mark Hansen) includes students in all social science disciplines but economics, and the one taught for the Princeton Sociology department (by political scientist Brandon Stewart) is supplemented with small group discussions with department faculty employing ethnographic methods.

Finally, in ongoing discussions, some programs emphasize fundamental concepts in proofs and probability theory instead of simply previewing the material students encounter in the first semester methods class (MIT, UCLA, and Emory). The informality of the math prefresher makes experimentation and adaptation to local circumstances particularly seamless.

**Who teaches the Math Prefresher?**
Senior graduate students are the sole instructors in most of the programs we have surveyed (such as Harvard, Michigan, and OSU, Princeton), with the remaining programs taught by faculty accompanied with graduate students serving as teaching assistants (Duke, Stanford, Washington University in St Louis, University of Pennsylvania). Senior graduate students are also involved in re-examining and renewing the content of the prefresher each year, which provides additional flexibility, customization, and innovation. Moreover, their leadership reinforces the collaborative, peer-learning environment that the math prefresher aims to introduce and promote.

The instructor’s responsibilities are not to be taken lightly: in addition to teaching technical material, they also provide students the first introduction to their new graduate programs, help to level the playing field among incoming graduate students, and set the tone for collegiality. Faculty sponsors may also share teaching material and pedagogical insights with the graduate student instructors, which in turn improves their teaching skills. For many student instructors, the math prefresher is the first class they teach in their teaching career.

**Concluding Remarks: A Proposed Collective Future for Cross-Department Training**

The math prefresher has benefited from competition and cooperation across political science departments copying, competing with each other, and innovating to improve their own programs. We propose to build on this productive interaction by introducing infrastructure for all departments to tap into, contribute to, or build off of. For this purpose, we have built a website with all the teaching materials from Harvard’s prefresher, which we have fine-tuned and morphed over the years: [bit.ly/prefresher](http://bit.ly/prefresher). This site includes the syllabus for our most recent program, an entire book manuscript our faculty and graduate student instructors have created with teaching materials designed specifically for the prefresher, and a version-controlled repository that makes it possible for other programs to use, modify, or contribute back to our materials. This material is available to all for free with open source licenses.

In addition to sharing our own teaching material, we have consolidated links to other prefreshers we have found so different programs can stay in touch with each other and so departments can learn from the variety of programs available. This platform makes public a process that has been occurring organically, as new instructors have launched math prefreshers in their departments based on teaching material handed down to them by their advisors and colleagues. We hope these materials make it easier for other programs to improve their prefreshers. On the prefresher website, instructors are welcome to correct, add to, and browse the resources each program and their teaching teams have built over the years. We welcome contributions from, or suggestions for links to, materials from other programs on our site as well. Perhaps this will also help smaller departments without prefreshers to create new programs.
Appendix A: Diversity of Incoming Student Math Background

We give here the results of a survey of two cohorts of students participating in the Harvard Government Ph.D. program math prefresher (n = 39). Figure 1 gives a breakdown of the students’ self-reported mathematical and programming background (in separate stacked bar charts). For the most common tools (Probability, linear algebra, R, and Stata), students break down roughly evenly between having little experience to having substantial experience in college. From our conversations with prefresher instructors and faculty supervisors from other departments, this high level of diversity in technical preparation seems to be a common characteristic of most incoming Ph.D. programs. This poses special challenges for teaching, of course, as well as a motivation for holding the prefresher in the first place. All the more reason why it is helpful if different programs work together to develop more extensive training materials.

Figure 1: Diversity of Student Backgrounds
References


