The "Math Prefresher" and The Collective Future of Political Science Graduate Training[1]

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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 are useful for political science. The prefresher's benefits, however, go beyond the technical material taught: it develops lasting camaraderie with their entering class, facilitates connections with senior graduate students, opens pathways to mastering methods necessary for research, and eases the transition to the increasingly collaborative nature of graduate work. The prefresher also shows how faculty across a highly diverse discipline can work 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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[1] The political science math prefresher was originated in Harvard University's Department of Government in 1994 by Gary who continues to organize it. (Steve Ansolabehere and Jim Snyder, then at MIT, and Gary originally hoped to host one prefresher for both programs, but differing university schedules made this infeasible). Shiro and Yon Soo taught the prefresher in the same department this past summer. Our sincere thanks to the distinguished scholars who, as senior graduate students, taught in and contributed to the ongoing development of the Harvard math prefresher over the last quarter century: David Kane (*years of service:* 1995, *present employment:* Harvard), Jeffrey B. Lewis (1995, UCLA), Curtis S. Signorino (1996-1997, University of Rochester), Kenneth F. Scheve (1997-1998, Stanford), Eric Dickson (1998-2000, NYU), Orit Kedar (1999, Hebrew University of Jerusalem), James Fowler (2000-2001, UCSD), Kosuke Imai (2000-2001, Harvard), Daniel J. Epstein (2002-2003, Texas Tech), Ben W. Ansell (2003-2004, University of Minnesota), Ryan T. Moore (2004-2005, American University), Michael Kellermann (2005-2006, United States Naval Academy), Eleanor Neff Powell (2006-2007, University of Wisconsin-Madison), Jennifer (Katkin) Bachner (2007-2008, Johns Hopkins), Patrick Lam (2008-2009, Thresher), Viridiana Rios (2009-2010, Harvard), Jennifer Pan (2010-2011, Stanford), Chiara Superti (2011, Columbia), Konstantin Kashin (2012, Facebook), Andrew Hall (2012, Stanford), Soledad Prillaman (2013, Stanford), Stephen Pettigrew (2013-2014, University of Pennsylvania and NBC), Anton Strezhnev (2014-2015, NYU), Mayya Komisarchik (2015-2016, University of Rochester), and Connor Jerzak (2016-2017, Harvard). We also appreciate instructors who have shared their experiences from other programs: Bryce Corrigan (Cornell), Michael Decrescenzo (University of Wisconsin-Madison), James Fowler (UCSD), Stephen Gent (UNC Chapel Hill), Adam Glynn (Emory), Justin Grimmer (Stanford), Mark Hansen (Chicago), Dorothy Kronick (University of Pennsylvania), Jeffrey Lewis (UCLA), Jacob Montgomery (Washington University St Louis), Andrew Rosenberg (Ohio State), David Siegel (Duke), Yuki Shiraito (Michigan), Ahmer Tarar (Texas A & M), Teppei Yamamoto (MIT), and Congyi Zhou (NYU).

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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 benefits have not been widely discussed in the discipline, perhaps because faculty advisors design prefreshers primarily for their own departments. 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. We also 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 student and faculty as one enters a graduate program. 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 outlines 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 do not track individual student performance. 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 scientists and know how to use

[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.

behavioral incentives to turn the anxiety we all remember prior to starting graduate school into motivation and action (!), but the level of effort is still each student's individual choice.

Having fellow graduate students lead or assist the sessions helps the prefresher program further convey the collective experience of graduate school, how students should begin to rely on and help each other, and some of the new types of relationships they need to establish with faculty. Moreover, building camaraderie and the feeling of safety in numbers during the math prefresher makes graduate school seem less threatening, and it remains important for their entire graduate career by helping to build a community of scholars for each one of us. Learning to work together makes everyone more productive.

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 tailor the material and the structure the group exercises to make the experience more inclusive and accessible. A well thought-out prefresher before helps make the whole class and all individuals in it better by working together.

The practice of collaboration and drawing upon each other's comparative advantages prepares students well for the rest of their graduate school career. This is a rare industry where helping competitors helps ourselves (as suggested by the rising trend in coauthored publications), 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. Tailoring content towards research in the discipline is what distinguishes the political science math prefresher from other introductions to math.

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 a political science program into a technical degree program. So we design the prefresher to motivate students, 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 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 (apart from the fact that the subfield of political methodology is now the second or third largest subfield 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 helpful in conveying the go-deep style of learning necessary for research. Foundational math material sets the path for deep engagement with methods in doing rigorous research in their chosen substantive fields.

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 (and 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 to a deep partnership for the good of the broader discipline (King, 2014: p.167), a tremendously important development.

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 explicit 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 informal survey of prefreshers in 25 Political Science Ph.D. programs, we found that some programs emphasize mathematical preparation in analyzing game theoretical models (Texas A & M, New York University), 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 interspersed over the summer (Duke). Some programs teach calculus and programming separately (University of Wisconsin Madison), some teach it with the same instructor, and two programs each offer two separate prefreshers, one before the first year and the other before the second. Reading materials range from a set of published exercises (Moore and Siegel 2013, Kropko 2015) to having no set text 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, probability theory, instead of simply previewing the the material students encounter in the first semester methods class (such as MIT, UCLA, and Emory). The informality of the math prefresher makes experimentation, and adaptation to local circumstances, particularly seamless.

Who teaches the Math Preferesher?

Senior graduate students are the sole instructors in most of the programs we have surveyed (such as Harvard, Michigan, and OSU), with the remaining programs taught by faculty accompanied with graduate students serving as teaching assistants (Stanford, Washington University in St Louis, University of Pennsylvania, and Duke). Senior graduate students also have a major role in

most programs continually re-examining and renewing the content each year, which provides additional flexibility and productive 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 typically also provide the first introduction students have 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

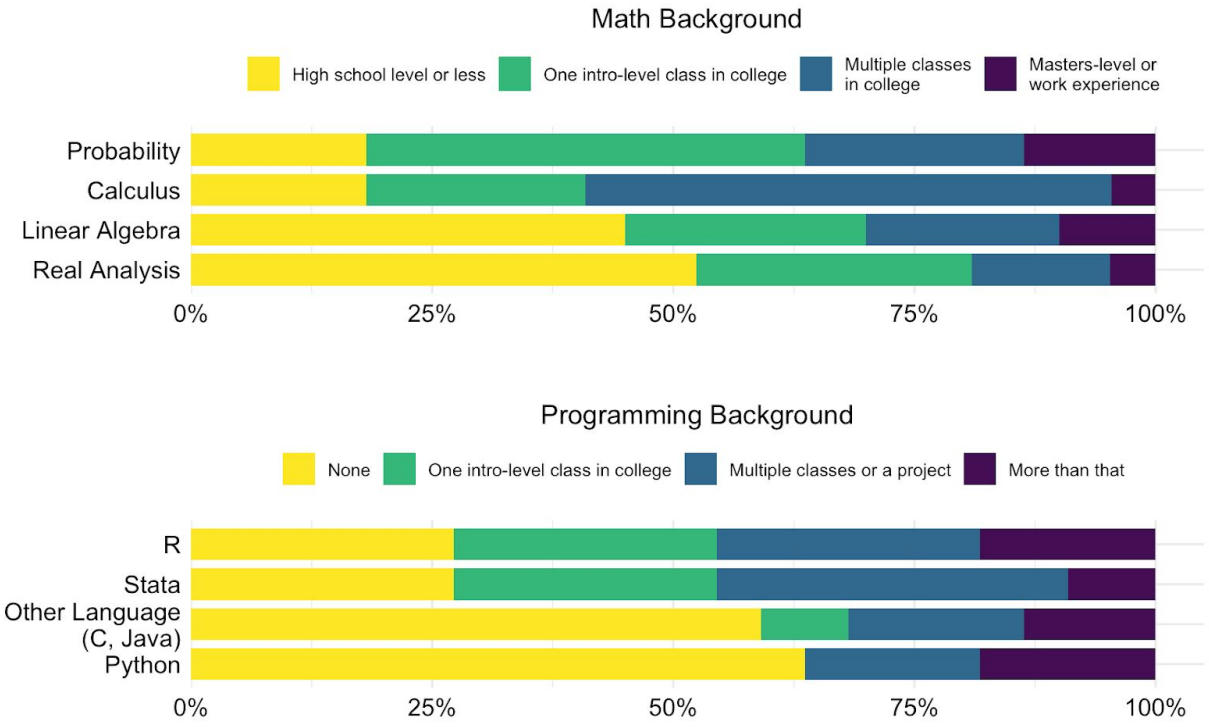
The math prefresher has benefited from competition and cooperation across political science departments copying, competing with each other, and innovating to improve their own programs. We propose to build on this productive interaction by introducing infrastructure for all departments to tap into, contribute 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. This site includes the syllabus for our most recent program, an entire book manuscript we created and adjusted over time with new teaching materials designed especially for the prefresher, a set of computational tools, and a link to a github repository we set up to make it possible for other programs to use, modify, or contribute back to our materials. This material is available to all 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 see the different models 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 so we can continue to learn from each other. 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 as well.

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. 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



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