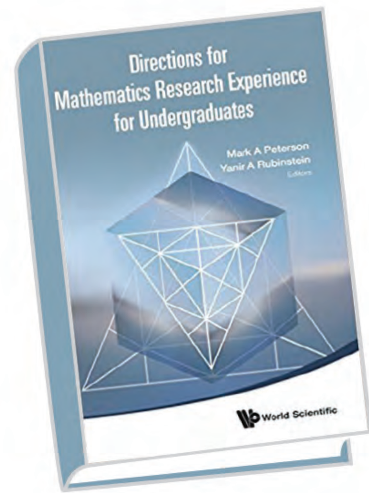
Directions for Mathematics Research Experience for Undergraduates



A Review by Tamás Forgács

Directions for Mathematics Research Experience for Undergraduates
M. A. Peterson, and Y. A. Rubinstein, eds.
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Undergraduate research in mathematics as a concept is only about a half a century old. In the early years it was draped in a shroud of skepticism fueled by the belief that research had to be conducted at leading institutions by experts in the field, not by undergraduate students between semesters at a "summer camp." It would take decades for this shroud to lift. Lift it would, however, due to the sustained quality of student research and to an enlightened understanding of its possibilities.

The National Science Foundation (NSF) has now funded Research Experiences for Undergraduates (REU) sites in mathematics for over twenty-five years at a fairly consistent level (about fifty active sites a year). In fact, in the words of the National Science and Technology council, "The REU program is a highlight of the [mathematical sciences] workforce program…and is an exemplary program in its broader impacts." [1] The NSF has supported undergraduate research through many additional programs, including VIGRE, RTGs, CURM and NREUP through the MAA. The November, 2017 issue of the *American Mathematical Monthly* showcases the impact of the enterprise, and is dedicated entirely to undergraduate research.

Platforms for undergraduates to disseminate their work have grown both in number and in capacity. At the annual Joint Mathematics Meetings, students now present 400 posters and give around 200 talks. Several journals specialize in undergraduate research, and most research journals include undergraduate authors.

The now widespread understanding of the benefits has led to increased interest in undergraduate research that has far outpaced the growth in opportunities. Many REUs receive 40–50 qualified applications per available spot. We have to address the issues of scalability of undergraduate research programs, the role of research in the undergraduate curriculum, and the role of colleges and universities in the endeavor and in bearing the associated costs.

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[1] *p. 16*

Figure 1. REUs provide an alternative to the "lonely genius" research model. Selina Foster, Malachi Alexander, Gianni Krakoff, 2016 Knot Theory Group, mentored by Jennifer McLoud-Mann at the UW Bothell REU.

Figure 2. The program includes a full year at their own school and a summer month at an REU site. Back row: Gabriel Coloma, Lily Wittle, Rita Post, Theresa Thimons, Marina Pavlichich; middle row: Luke Wade, Comlan de Souza, Marcell Nyerges (visitor), David Ariyibi, Ben Thomas, Katherine Blake, Marguerite Davis, Erica Sawyer; front row: Nicholas Lohr, Tamás Forgács, Alicia Prieto-Langarica, Lexi Rager, Carmen Caprau.

An Overview of the Book

Directions for Mathematics Research Experience for Undergraduates notes that the success of REUs across a wide variety of institutions means that many undergraduates "now understand better what mathematics really is." REUs have also contributed to change in the culture of mathematics by providing an alternative to the "lonely genius" research model. Many students of early REUs now hold faculty positions at various colleges and universities, and have carried the tradition of collaborative research into the realm of everyday academia.[2]. Many programs currently also offer professional development opportunities. Students learn about writing and presenting mathematics, and about applying to graduate schools and jobs. Today's research experiences take various different forms in addition to the traditional residential summer REUs. For example, students may undertake research projects spanning several semesters and, on occasion, multiple disciplines. Students might be mentored by advanced undergraduate or graduate students and post-docs instead of faculty, and can also enroll in research based (credit earning) courses at their own institutions.

The Contributions

The editors of the volume have brought together a diverse and experienced group of contributors, including administrators at the NSF and at universities, faculty, and graduate student mentors. Each of the contributions is forward looking in its conclusions, often explicitly identifying areas for improvement, and yet laden with optimistic expectations. Donal O'Shea (President, New College of Florida) opens the collection with a historical overview of undergraduate research in mathematics and aptly discusses the enterprise in the context of the politico-scientific arena, calling for a macro level and systemic assessment of undergraduate research programs, lest the venture experience a funding crisis similar to that of the 1980s. As O'Shea argues, it is incumbent on the agents of the enterprise to demonstrate its long-term contributions to the development of mathematics and new generations of mathematicians.

Chapter Two is a contribution from the author of this review on a program at Primarily Undergraduate Institutions, where access to federal funding might be limited, but talent is nonetheless present. The "FURST"program (see Figure 2) also gives an alternative to the traditional REU format in that it is a year-long effort: students work with their own faculty for a calendar year and visit an existing REU site during the summer in order to benefit from the REU site's co-curricular programs, such as guest lectures, student presentations, and professional development workshops. Chapter Three details the structure and achievements of a laboratory course in mathematics by K. Lin and H. Miller at MIT (see Figure 3). It is a wonderful example of a large-scale effort to involve undergraduate students in research projects. The primary emphasis of the program is to allow students to discover mathematics previously unknown to them in a "research-like" process while earning credit towards their degrees.

allow students to discover mathematics

[2] *See J. W. Grossman's "Patterns of Research in Mathematics" in the January 2005 Notices* `www.ams.org/notices/200501/fea-grossman.pdf` *We note, in particular, that while the percentage of papers with two authors has been steadily rising since the 1940s, the percentage of papers with three or more authors has grown non-linearly, from barely 1 percent in the 1940s, to 5 percent in the 1970s to 13 percent in the 1990s.*

Figure 3. The MIT project lab allows students to discover mathematics previously unknown to them in a research-like process while earning credit towards their degrees.

The next two essays are on programs in which faculty involvement is minimal or limited: the Stanford Undergraduate Research Institute in Mathematics (R. Vakil, Stanford, and Y. A. Rubinstein, University of Maryland), and the Berkeley Summer Research Program for Undergraduates (D. Cristofaro-Gardiner, UC Santa Cruz). Both programs involved graduate student research mentors, and tackled problems in research areas that are underrepresented in REUs, such as analysis and geometry.

REUs can bring about social change.

Chapter Six (P. May, University of Chicago) describes a few of the in-house programs at Chicago, one of which is the hugely successful directed reading program, which has built great rapport between the scores of undergraduates who want to learn more mathematics and graduate students who want to mentor them. The program is inexpensive to operate, and is hence reasonably easy to replicate at any school with a sizable graduate student population.

The next two chapters describe how REUs can bring about social change. Carlos Castillo-Garsow (Eastern Washington) and Carlos Castillo-Chavez (Arizona State) write about the nationally acclaimed Mathematical and Theoretical Biology Institute (MTBI), whose primary goal has been to effect social change. The program excels in involving students underrepresented in the mathematical sciences in its operation, four-fifths of whom have completed PhDs since 1996. Half of all MTBI PhD recipients are women. Problem selection at MTBI is entirely student driven and often results in projects that have everyday relevance to students' lives and social change. The authors argue that introducing research modeling experiences early on can bring about improvement in the K–12 mathematics education of students.

W. Y. Velez (University of Arizona) writes about the Arizona model of recruiting students into the mathematics major and minor. He argues that mathematics is so pervasive that essentially any major can benefit from adding math as a minor or a second major. Research experiences come into play in a different light here. Once a school has 600+ majors along with 700 minors, it becomes infeasible to involve them all in a mathematics research project. The answer, says Velez, is to include them in any kind of research project which can use mathematics or statistics, such as projects in biology, chemistry, computer science, finance, economics, or medicine. In fact, Velez argues that the nature of PhD programs in the mathematical sciences has changed so much that students don't necessarily need exposure to mathematics research in the traditional sense.

The last two contributions about programs both describe institutionalized efforts to involve students in research. The Gemstone Honors Program (F. J. Coale, K. Skendall, L. K. Tobin, and V. Hill) at the University of Maryland is a 550-student, four-year long interdisciplinary research experience, which starts with students identifying research questions, and ends with presentations. The program requires a team of mentors, faculty, librarians, and a dedicated program staff, which makes it challenging to replicate at schools with limited resources. The freshman research initiative (J. T. Beckham, S. L. Simmons, and G. M. Stovall) at the University of Texas Austin sees research engagement as a solution to the STEM shortage, and provides students with courses on elements of research and projects in ongoing faculty research.

The volume concludes with a short essay on the importance of macro scale assessment of research experiences by J. Pearl, NSF) and a final chapter by the organizers of the conference on which the anthology is based (G. Davidoff, M. Peterson, M. Robinson, and Y. A. Rubinstein).

What to Expect From Reading this Book

While I am not one of the early pioneers of undergraduate research, I have been around various incarnations of undergraduate research programs for about a decade, and expected to know about most of what would be included in this collection. I was wrong in that expectation, and have certainly learned a lot not only about some great efforts and research programs throughout the nation, but also the ways they adapt to their rather diverse situations. Differences between participating student bodies, faculty commitments, institutional constraints, program goals and philosophies all manifest in programs with different attributes and characteristics. (Figure 4 is an example of one-on-one mentoring at a private liberal arts college during the academic year.)

Despite the differences, I found that almost all had something relevant to say about programs at my own institution. In this sense, the collection transcends the traditional institutional division lines (private, public, large, small, research, undergraduate, etc.) and has something to offer for readers in every realm of academia. The collection challenges the reader to think about how

Figure 4. In an example of institutionally supported one-on-one mentoring, Elvis Kahoro and Stephan Ramon Garcia work on a number theory project at Pomona College.

to implement and improve undergraduate research experiences, what such experiences mean to students and faculty, and how such experiences can take a permanent place in the modern preparation of undergraduate mathematics and STEM majors. The book is an open invitation to learn about what has worked and what hasn't in the context of undergraduate research. It is a great source of inspiration, and has the potential to ignite initiatives with long-lasting benefits to students and faculty nationwide.

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ABOUT THE AUTHOR

Tamás Forgács' research focuses on the zero distribution of entire functions and related problems in complex analysis, analytic number theory, and operator theory. When he is not doing math, he enjoys hiking in the Sierra Nevada mountains and fiddling with cars.

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