TPSEMath

Transforming Post-Secondary Education in Mathematics

# PREPARING MATH MAJORS FOR CAREERS: REVISING CURRICULUM

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Rutgers Education and Employment Research Center
Issue Brief 2
October 2020

RUTGERS EDUCATION AND EMPLOYMENT RESEARCH CENTER

ISSUE BRIEF 2 | OCTOBER 2020

TPSE Math
Transforming Post-Secondary Education in Mathematics

Transforming Post-Secondary Education in Mathematics (TPSE Math) aims to effect co structive change in math education at U.S. community colleges, 4-year colleges and research universities by working closely with faculty leaders, university administrations, membership associations, and disciplinary societies. TPSE Math identifies innovative practices w ere they exist, advocates for innovation where they do not, and works with and through partners to implement and scale effective practices in the pursuit of mathematically rich and relevant education for all students, whatever their chosen field of study. TPSE Math is funded by a grant from the Carnegie Corporation of New York.

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## INTRODUCTION

Transforming Post-Secondary Education in Mathematics (TPSE Math), a project funded by the Carnegie Corporation, the Alfred P. Sloan Foundation and the National Science Foundation, is dedicated to enhancing math education in two- and four-year colleges to prepare students with the *"mathematical knowledge and skills necessary for productive engagement in society and in the workplace"* (https://www.tpsemath.org/). In 2019, TPSE contracted with the Rutgers' Education and Employment Research Center (EERC) to study career readiness programs for math students and to identify and study promising practices in math departments across the country.

EERC, housed within the School of Management and Labor Relations, engages in multi-site, multi-method qualitative and quantitative evaluation, and conducts research to inform curricula and programs at the intersection of education and workforce development. With input from members of TPSE's Mathematics Advisory Group (MAG), EERC developed and administered an online survey to faculty, department chairs and senior administrators at 143 public and private two- and four-year colleges across the nation as well as five non-profit organizations (survey respondents N=219). The survey asked questions about career preparation, career pathways, advising, research and internship opportunities, alumni networks, interdisciplinary collaborations, and partnerships with employers.

In addition, the EERC team conducted 26 in-depth phone interviews with faculty, staff, and students at seve colleges[1] identified through the su vey as having innovative programs. We also viewed a TPSE webinar with a presentation from the Dana Center at the University of Texas – Austin. The webinar and interviews provided a more detailed cross-institutional perspective on career readiness activities and programs.

This brief on curriculum is one of six briefs and an executive summary prepared by EERC that discusses the findings and recommendations that emerged from this qualitative research study.[2]

[1]Babson College; Villanova University; Brigham Young University - Idaho; Harvey Mudd College; University of Nebraska – Lincoln; University of Arizona; and the University of Wisconsin.
[2]All the briefs in this series are available from the EERC website at:
https://smlr.rutgers.edu/content/transforming-post-secondary-education-mathematics-research

## WELCOMING STUDENTS AND CREATING COMMUNITY

At the University of Texas -Austin, faculty have created a number of "rituals" (see Box) to welcome students and create a community of learning. Their rituals, and the actions of faculty at other colleges, to reach out to students have helped students overcome initial fears about doing the work and feeling they belong in math – especially in calculus. Faculty at the University of Arizona send weekly emails to students notifying them of department news, research opportunities, internships/externships, and conferences. Not only do the emails expand students' awareness of the multiple possibilities in math but also signal an invitation into the math community. Such on-ramping activities have helped to attract a more diverse group of students and increase the numbers of math majors and minors.

### WELCOMING STUDENTS

In a recent TPSE webinar, a University of Texas-Austin faculty member and PhD student who co-teach Calculus discussed how they create a community of students in which there is mutual support and learning rather than competition. Their activities begin prior to the semester when they send out an electronic survey to all students. The survey asks students about themselves, where they are from and even who their high school math teacher was. The survey gives the teaching staff more personal information ab ut the student and helps faculty during the firs class to reach out to them – calling each by name, letting some know they know their high school math teacher. They then ask students to introduce themselves to one another. These "*rituals*" breaks down the traditional barriers that exist in a classroom.

The teaching team also welcomes the students into the social world of mathematics introducing them to their *"math genealogy."* They talk about the long history of mathematicians of which the students are now a part – linking them to the past through the teacher and positioning them as the next generation of mathematicians. Such discussions have helped students to enter into the world of mathematics - to feel that they belong and have a place in math and STEM. Students are then told that the class they are in is intentionally set up to be harder than other sections and they will struggle but they should not attribute their difficulties to heir own skills and abilities. Finally, they tell students that they expect to see them at office hours du ng the semester and they keep track of who attends these hours and send notes to those who do not come.

## INCORPORATING CAREER READINESS INTO CURRICULUM AND COURSE CONTENT

Embedding career readiness content into math curriculum and courses helps students understand the many ways math can be applied in real-world situations. (For more on this see the EERC brief: *Preparing Math Majors for Careers: Practices and Policies for Career Readiness*). It helps students navigate difficult career decisio and better prepares them for careers in mathematics by educating them about the options and opportunities available to them. In fact, 78 percent of respondents to the TPSE-M survey indicated that integrating information to prepare students for careers with mathematics content is one of the most widely used ways math departments teach students about career readiness. Integration was second only to faculty advising (88 percent) as a preferred method of disseminating career-focused information to students.

A respondent from Villanova University spoke of how confusing educational paths can be to students:

> *We have a mathematics major and minor, and an applied stats minor for undergrad students. But the [career] tracks are not so clear. They have to spend time exploring their career options. There can be indecision, and indecision borderlines on confusion sometimes. It can be anxiety provoking. And that is the last place we want our students to be.*

Students may not be aware of all the career options available to them as a mathematics major:

> *Employers tell us they want students that possess the skills that math students have. But they're [the students are] not applying. So, that makes me know we need to expose them to more of these pathways. So, it's a very real problem. Employers have the need; students have the skills. We need to do a better job helping them make the match.*

A respondent at Villanova said, *"there's not any one thing that's sort of the magic bullet, but there are many things departments can do to help students."*

Departments seemed to vary widely with regard to what they consider to be career-readiness activities and to what degree they are included in curricula. Examples of the range of career-readiness activities cited include: required or elective career-oriented courses fully focused on educating students about and preparing them for mathematics careers; career-focused modules integrated into mathematics courses; classroom visits by employers, alumni, upperclassmen, or internship coordinators; and simple resume-building exercises offered in classe or career centers. In addition, the integration of real-world problems into curricula and a focus on modeling are newer strategies math departments are using to prepare students for future careers. (For more on this see the EERC brief: *Preparing Math Majors for Careers: Practices and Policies for Career Readiness*). Several respondents also mentioned encouraging students to participate in on-campus math clubs and societies as well as national math events and competitions.The following sections examine these activities and strategies more closely.

## CREATING A MATHEMATICS COMMUNITY

Villanova University created a cohort model for their mathematics majors, requiring incoming freshmen students to take a 1-credit "Mathematics Communities" course. Department staff fel creating a cohort model would help students develop a sense of community, work together to solve problems in and out of the classroom, and develop teamwork and relationship-building skills that would help them in future careers.

One student described the class as *"so nice because I can see people around school and say, 'how did you solve this problem?'*

Another student highlighted the role of group work in creating that sense of familiarity:

***With this class now we know each other and [can say], you know, 'hey that person is in my other class' and stuff. And with only 25 of us in the class, we work in groups, and the groups change, so you get to know everyone.***

Another credited the class with making faculty seem more approachable:

***Being in this smaller class with just the math majors, I feel like we have gotten to know the professors very well, and now I know I can go to them if I need help with figuring out what classes to take or what is best for me to take before I graduate.***

## CAREER-ORIENTED DEGREE PROGRAMS

Over the past few years, the math departments at a number of colleges where EERC conducted interviews have restructured their degree offerings to increase career readiness opportunities. For example, the University of Nebraska, Lincoln's (UN-L) mathematics department restructured its major to include a variety of tracks, and to make its traditional math major more focused on career pathways. Students can specialize in standard mathematics, which now combines the mathematics degree with research or another area of interest such as finance or physics. Alternately, math majors can choose from several other tracks: Discrete Mathematics and Cryptography, which focuses on those subfield through coursework in computer science; Education, for those planning to pursue endorsement and certification to teach mathematics; Mathematical Biology, which offers coursework concerning biology and the mathematics of biological science; Mathematical Finance, where coursework centers on actuarial science and finance; Mathematics of Physical Phenomena, where coursework focuses on the physical world; or Statistics, where coursework centers on statistical analyses. The department is also in the process of adding a data science track.

It is especially worth a note that the UN-L mathematics department was able to expand the mathematics tracks it offered without adding new courses or faculty. It accomplished this by engaging existing faculty in discussions about strategies to refocus and develop new course content that could better align students with a career pathway.

Babson College is another good example of how programs can be structured to better align students with a career path without requiring extensive resources. Babson has no traditional math major, but rather offers a business analytics concentration within its Business Management degree. Students select course options that reflect their interests and career goals, including courses in big data methods, R programming, quantitative methods, math of sports, linear algebra, computational and math finance, etc. The elective courses, one faculty respondent explained, are aimed at supplying students with *"skills they need in the job market."* Thus, at Babson, teaching calculus is segmented, meaning it is taught in individual courses so students can better appreciate its uses in real-world contexts. As a faculty respondent stated,

> *We teach it [calculus] in the time and in the context of when they will need it. So students will see it and use it when it's needed. For instance, we teach the integrals needed for actuarial science, then use them directly in applications to insurance. Students learn well that way. They learn the concept, and they immediately use it.*

Elective courses generally include guest speakers from industry who talk to students about what certain jobs encompass. For example, the math of sports course includes guest speakers from baseball; one of whom is an alumni college sports analyst.

## CAREER-FOCUSED COURSES

Mathematics majors are frequently unaware of the range of career options available to them. In response, and in contrast to colleges with specific career-related math de rees, some colleges have developed career-focused courses to expose students to various career, research, and internship opportunities. (For more on this see the EERC brief: *Preparing Math Majors for Careers: Practices and Polices for Career Readiness*).

At Villanova, mathematics department faculty worked with the institution's internship coordinator to develop a required course for all incoming freshmen (see *Creating a Mathematics Community inset*). The department created a cohort model around the course; all incoming freshmen take the course together, which creates an opportunity for them to get to know one another. Because the department is relatively small (approximately 30 incoming freshman students each year), this is feasible.

Villinova's one-credit required course, called Mathematics Communities, was developed from a professional development template widely used at the college and modified to include mathematics-specific material. The course is designed for 10 contact hours over a semester. A subcommittee of five mathematics faculty created the course modules. In each module, a faculty member teaches a session—discussing their own research, working on real-world problems, and leading groupwork. Aside from the incoming rotation of faculty members, the class also includes upperclassmen panels, internship panels, and guest speakers such as employers and alumni. The course is designed to do three things: create a community (cohort model) of math students, create awareness of internship and career options and opportunities, and introduce students to real-world math problems. A respondent at Villanova, who described the course as providing *"career prep for life,"* went on to say that career education helps students *"to make the best decisions they can for their lives."*

The Villanova class is meant to help students see the various career pathways available to them and give them a chance to explore them:

> *The idea is to begin the career education discussion. Embedded [in the course] is the resume and cover letter and stuff, but also the array of career paths that exist for math majors. . . . These roles, careers, that math majors can do, exist in so many different industries, from financial to tech to others.*

Students echoed this, saying that their conceptions of what they could do with their degree had expanded throughout the course. One student respondent wanted to be a sports analyst upon enrollment, but he said the course had introduced him to many other careers he was also interested in:

> *This course has changed my mind a little bit. I'm not feeling so limited in just this one career. If I saw a job title or internship that was something else that I have recently become interested in, I would apply for it. I wouldn't wait for just the one career. And the specific job title of sports analyst, it's very competitive for internships and jobs. So I think now having more interests, it will benefit me a lot.*

The course includes a panel of *"very active"* upperclassmen who have started job searches, have completed research opportunities, and have started or finished internships. Students can ask them *"about the opportunities they had and how they got them and what they wear, etc."* One interviewee said, *"the information is coming from actual students, which is fantastic."*

The class also includes guests who discuss research opportunities. One student said:

> *We have speakers—mostly university speakers—talk about careers, they are professors in lots of things, operational research, modeling, stats, etc. To give you a taste of different things; things that I [have] never heard of or don't know how to do. [That] gets us thinking about what we can do with math.*

Another student said being exposed to so many things she can do with her math degree has helped her become more confident in her ori inal choice:

> *I'm going to keep with stats, but now I'm reassured that is what I want to do. It's been helpful that other fields of study come in because now I know "I don't want to do that!" "Or that!" And there are lots more careers available than I originally thought. The whole field seems more open to me. It's been really good.*

At Harvey Mudd College, students are required to take a variety of courses that integrate real-word problems thereby expanding their real-world, career-ready skills. Upon graduating, students will have taken two to three courses in programming, statistics, or engineering. A faculty respondent at the school said, *"they then have the toolset to talk to employers about problems that have applications in the real world because they have seen them in their classes."*

Math students at Harvey Mudd are also required to complete a colloquium before graduating. Industry representatives participate in the colloquium course as guest speakers. One faculty respondent said the course *"deliberately connect[s] students to skills and resources."* This faculty respondent suggested that departments reach out to their campus career center for help with setting up industry speakers or setting up giving presentations about job preparation skills and resources.

A faculty respondent at Brigham Young University, Idaho, (BYU-I) discussed how offering electives that focus o specific career skills such as data science, R statistical analysis, programming, statistical consulting, and other topics allow students to choose the skills they want to learn. He said, *"it's not the math degree, it's the other classes that weren't required that get them hired."*

## CAREER-ORIENTED ACTIVITIES

Several math departments encourage students to join math clubs/groups/societies on campus. Many faculty also interact with these groups, inviting them into their classes to present real-world problems for students to solve, hosting guest speakers from their ranks, or requiring students to attend one or more events hosted by them. Others encourage students to participate in national math competitions. At BYU-I, entry fees for national competitions are sometimes paid for by the department so students can participate at no costs to them.

Mathematics students in the above cited one semester course at Villanova, called Mathematical Communities, were required to attend three on- or off-campus events incorporating speakers or activities that relate to a career in mathematics. Events featuring researchers, alumni, visiting professors, and industry representatives were included as options. A Villanova student discussed going to a talk about research opportunities at the university. He said the talk *"was helpful because even though I don't want to do research right now, I didn't know it was a thing in math; I always thought research was more science."*

Incorporating real-world problems and involving students with math modeling are other ways departments are preparing students for careers and giving them real-world *"hard skills"* they can transport to the job market. (For more on this see the EERC brief: Preparing Math Majors for Careers: *Practices and Polices for Career Readiness*). At Harvey Mudd, students take an undergraduate presentations course where they find real-world problems an present on them. They are encouraged to review the news for current events that are math-related and complete a presentation. One faculty respondent suggested the same exercise could be done as an assignment: *"There are ways to do it and make it work for every department culture I think,"* he said.

BYU-I students are encouraged to participate in the Data Science Society, which works on real-world problems. There is no fee for students to participate, and no grades are given; participation simply allows students the opportunity to develop real-world skills and gives them something to put on a resume. BYU-I also requires all data science majors to complete a 300-hour internship and a senior project. Mathematical Sciences majors at BYU-I get the choice of internship or senior project. BYU-I faculty encourage students who want to go into industry to complete an internship while those who are planning on graduate school are encouraged to complete a senior project. Faculty feel these requirements prepare their students for the job market because they ensure students graduate with work experience and the beginnings of a portfolio they can present to potential employers.

Finally, national math events are a good way to get students involved in solving real-world math problems and participating in team-building exercises. (For more on this see the EERC brief: *Preparing Math Majors for Careers: Practices and Polices for Career Readiness*). In 2019, Villanova sponsored DataFest Philadelphia for the second consecutive year. DataFest Philadelphia is part of the national American Statistical Association DataFest, a *"48-hour case competition where teams of two to five students receive a rich, complex dataset from a large company and analyze it for insights."* The event allows students to *"take data analysis beyond the constraints of a typical classroom setting"* by enabling students to *"work with real-world data as a team—uniting students in statistics, computer science, engineering, mathematics, social science and other fields for an intense weekend of data wrangling and analysis."* Students come from various institutions to compete. Other universities and departments can sponsor a DataFest or similar event in their area. A faculty respondent from Harvey Mudd College suggests that departments should try modeling or other math competitions because they serve as a *"kind of mini [math] clinic."* He called it a *"fairly low cost"* way to get students involved in career readiness skills because it's something that can be done without making the kind of formal, institutional-level changes often required to redesign curriculum or add new courses.

## CHALLENGES

EERC's interviews with faculty and staff, and the r sponses to the TPSE-M survey, suggest that colleges across the country fall along a continuum in their capacity to provide career readiness and career pathway opportunities to their students. While each department's vision about the role of math departments in this area surely shapes its effo ts, colleges and math departments also vary considerably in their size, structure, culture, and resources. Colleges with a comparatively large number of faculty members have an advantage when it comes to preparing their students for careers in math. For instance, Villanova has a big math department, which makes it easier for the department to set up multiple committees dedicated to creating and deploying resources for students. A faculty committee exists for Co-MaStER (Community of Mathematicians and Statisticians Exploring Research)—an organization designed to give students a *"one-stop shop"* for undergraduate research opportunities (see *Villanova's Co-MaStER inset*). Committee members collect research opportunities from faculty and post them to the Co-MaStER website. Another committee exists specifically o modify the required Mathematics Communities course, and yet another ongoing committee serves that class as participating faculty—those who teach the various modules of the course. Smaller departments could not sustain that level of demand on faculty.

BYU-I is unique in that it does not require its faculty members to publish, and there is no ranking system. The structure allows for open and ongoing collaboration among faculty. Still, as with other departments and colleges, faculty buy-in is a critical factor in modifying or changing traditional math courses and programs. For example, BYU-I added an entirely new degree program, data science, to its mathematics department. A faculty respondent observed that data science is a *"discipline that falls in the void"* between other types of degrees. However, there still was pushback from some faculty in the department as to what should be included in a data science degree. Ultimately, the math department included a business course and a communications course, so the focus was not all on *"hard skills."*

Similarly, while it was ultimately successful, the math department at the University of Nebraska, Lincoln, weathered a long and iterative process that involved many faculty discussions when it reviewed its course offerings and restructured its mathematics degree.

Change comes much more easily at colleges where there is an institutional culture that embraces career readiness and strives to embed career skills in courses. This appears to be the case at Villanova, Harvey Mudd, and Babson, where the math departments were able implement significant changes in a relatively sho t period of time. However, these and other colleges indicated that they also face some real challenges.

## REAL-WORLD DATA AND PROBLEMS MODELING

With the apparent exception of some faculty teaching actuarial sciences and statistics, EERC found the use of real-world problems and modeling exercises to be limited. (For more on this see the EERC brief: *Preparing Math Majors for Careers: Practices and Polices for Career Readiness*). In part this may be the result of faculty being *"trained as pure mathematicians"* with *"limited real-world experience."* Given the culture around research and tenure at many colleges, faculty may also be more focused on teaching and research within the academy than seeking out industry connections.

Identifying real-world problems and integrating them into classes can be challenging for faculty, and according to one interviewee, using real data and modeling can be *"messy."* In addition, not all faculty are ready to have applied math added to their program's curriculum. For instance, at BYU-I, some were unhappy with the department's modification of calculus to a *"calculus for data scientists"* course, feeling that the modification imp ied *"regular"* calculus was not useful enough.

## OPPORTUNITIES FOR STUDENT RESEARCH

As discussed above, involving students in research, including projects conducted by industry employers, can help students build their skills and prepare for employment or graduate school. Students, however, are often unaware of research opportunities on campus or within their locale.

## VILLANOVA'S CO-MASTER

Making students aware of available research opportunities is similar in many ways to ensuring their awareness of internships or career pathways. Research opportunities can lead to career opportunities, but students are often unaware of them. One faculty respondent said, *"we know that people in the industry are looking for students that know how to communicate and have the skills . . . and research is part of that."*

At Villanova, faculty realized students were largely unaware of the myriad of research opportunities available to them, but they had no central way to "advertise" these opportunities to students. Therefore, several faculty members created Co-MaStER: Community of Mathematicians and Statisticians Exploring Research. The Co-MaStER webpage on Villanova's website organizes research by semester of availability and provides a brief overview of the type of research a student would be doing.

One faculty respondent noted that although faculty always conducted research with students, it was not a widely known opportunity. As a result, it inadvertently became an *"invitation-only"* situation. Co-MaStER empowers all students to access information about these opportunities, making them *"available for everyone. Any math major can do it."*

Student respondents said they like the opportunity to do research, but some said they were not aware of how many research opportunities were available to them.

Villanova faculty addressed this lack of information by creating a math research webpage on the college's website (see Villanova's Co-MaStER inset). This is a fairly easy strategy to increase the number of students who begin research projects while still undergraduates. One faculty respondent pointed out, "This should be a collective responsibility—it is everyone's responsibility—how we talk to our students and when about how to do this work." The same respondent also noted that students need to think about career development as a process: "Career development is iterative. The more they learn the more they have to start over. If they start late, there is a lot of opportunity they lose out on."

## RECOMMENDATIONS

Challenges to incorporating career skills in mathematics courses can be mitigated several ways:

**Consider the size of your department.** Department size can impact the amount of resources available to implement changes. If the department is large, there may be more faculty willing to contribute time, committee involvement, and curricular input. However, in a large department, other changes—such as creating a cohort model—may be difficult because of the number of students enrolled. If a department is small, there may be fewer faculty members available to implement changes, but small changes—such as incorporating a real-world math project into a course or inviting guest speakers to classrooms—may be possible.

**Consider the structure of your department.** Some departments can make big changes because faculty are not structured in a hierarchical manner, which encourages collaboration. Other departments do not have publishing requirements for faculty, which frees up faculty time. Some departments offer incentives for faculty to make industry connections or bring in real-world problems for students to solve. Considering the resources available in your department can help inform what types of curricular changes your department should tackle.

**Prepare students to start thinking about their career early on.** Regardless of the type of career-oriented integration your department makes, it should encourage students to think about their career path early in their academic career. All the successful career-readiness activities outlined here were implemented to incoming students or offered throughout their education.

**Recognize that many students are not well-informed about the range of careers available to them as mathematics majors.** Staff or faculty at all the universities involved in this brief indicated that most students at their institutions were unaware of the full range of career options available to them.

Departmental changes were viewed as more successful when students were given multiple ways to explore their career options. The more options available (or by having one or more required), the more students' awareness seemed to increase.

**Faculty development.** Many faculty respondents to the TPSE-M survey indicated that they were interested in participating in professional development workshops or other opportunities to 1) expand their knowledge of career pathways for math majors; and 2) learn to identify and use real-world problems in their classes. But they also indicated that professional development activities require departmental support—allocation of time, for example, and recognition that such activities were viewed as critical for the well-being of their departments' programs.

## CONCLUSION

A misconception among some math department staff and faculty is that inte rating career readiness and career pathway content takes a tremendous amount of faculty time and departmental resources. The results of the TPSE-M survey and data collected from EERC's interviews demonstrate the existence of multiple strategies departments and faculty can employ to add or enhance career readiness content without using extensive resources. Rather than a major commitment of time and financial suppo t, these strategies require a shift of focus, some creativity, and a commitment to help students prepare for the future. While a systemic and integrated program is ideal, EERC's analysis suggests that minor changes can have a big impact.

Each of the six briefs prepared by EERC showcases different strate ies that have proven successful and that, with a minimum of resources, can be replicated and scaled to fit diverse institutions, e.g., offering elective care exploration/preparation courses, adding assignments that involve real-world problems, integrating course content on different career pathways, using online modules, inviting guest speakers, engaging with local employers, identifying research opportunities, offering internships, and engaging alumni in departmental activities. In addition, at colleges where there is an established career center, it important that the math department and individual faculty make use of its resources including center staff's connections with industry employers. Active department-center collaborations can also reduce duplication of efforts, especially around the development of industry partners, leverage expertise, and facilitate student referrals.

Some of the strategies identified in ERRC's briefs  are more resource dependent, including departmental curriculum reviews and restructuring or adding new degree programs (e.g., applied mathematics, data science). Given the dynamics of the Covid19 pandemic, including decreased college funding, shifts in student enrollment, and changes in how students perceive majors and career pathways, it is important for each college to fully assess which career readiness strategies are most relevant and feasible. However, regardless of how it is done, incorporating career knowledge and skills into higher education pathways is key to preparing students for careers in mathematics.

## ACKNOWLEDGEMENTS

We could not have produced these reports without the help of Arlen Hastings and Beth Brainard at TPSE, the TPSE Board, and the many faculty members who answered our survey and agreed to participate in an interview. Thank you also to the chairs, senior administrators, center staff and students who a  reed to participate in an interview. Thank you all for giving us your time and sharing your experiences with us. We also want to thank all those who worked with us on a research plan. A special thanks to Thomas Barr from the American Mathematical Association who helped us to develop the survey and interview template and provided helpful feedback to these drafts.

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