Report on the Applied Mathematics Graduate Interdisciplinary Program (AM GIDP)
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Rationale for Writing this Unsolicited Report:

As my tenure as the chair of the Applied Mathematics GIDP concludes in January 2024, I find it pertinent to provide an overview of our program's initial tasks, accomplishments, and challenges.

This report is aimed at benefiting not only the students, affiliates, members, and alumni of the program but also the broader community interested in the field of contemporary applied mathematics. By sharing insights and experiences, I aim to foster discourse and collaboration while acknowledging the progress made during my tenure.

Furthermore, this report is addressed to the leadership at the University of Arizona. It serves as a reminder of the critical role played by educational initiatives in advancing research pursuits. This report also stems from my belief in the value of transparent communication and accountability. While the notion of compiling a report might have been suggested eventually, I find it fitting to offer this account proactively.

In the following sections, I will delve into the endeavors, accomplishments, and challenges encountered within the AM GIDP, shedding light on its evolution and aspirations for the future.

Transforming Applied Mathematics in the 21st Century: A Journey of Innovation and Progress

The landscape of Applied Mathematics has evolved so much over the past (almost) five decades since the inception of the AM GIDP in Tucson. The dynamic interplay between mathematics and various scientific domains, encompassing physical, life, and engineering sciences, has led to an unprecedented surge in applications. Emerging fields like modern control theory, information theory, computer science, and notably (as most recent) Artificial Intelligence (AI) have harnessed the power of mathematics, reshaping the realm of possibilities. De facto many of these disciplines, which are relatively new (on the scale set by the history of mathematics) were on demand at least as much as the classical fields of applied mathematics, such as ODEs, PDEs and stochastic processes. Despite the growing demand for these contemporary applications, the traditional curriculum of applied mathematics had yet to fully align with this new reality.

With the privilege of taking the reins as the AM GIDP chair in 2019, I embarked on a mission to reshape the program's curriculum, infusing it with modern relevance and vitality. The transformation sought to bridge the gap between the program's de facto practices and the de jure

expectations of the ever-evolving applied mathematics landscape. The journey was not undertaken alone; the support and collaboration of numerous colleagues and of our program coordinators Stacey LaBorde and Keri Oligmueller, played a pivotal role in navigating this transformative path.

During the span of four and a half years, our collective efforts yielded significant outcomes, crystallizing the program's response to the new era of applied mathematics:

1) A New Core Curriculum for a New Era: We undertook a comprehensive overhaul of the core curriculum, revamping six core courses to align with the contemporary standards of applied mathematics. This rejuvenated curriculum now encompasses the diverse spectrum of applications and methodologies that characterize modern mathematics. The contributions of key program members such as Shankar Venkataramani (Math 584) and Misha Stepanov (Math 589), along with involvement of Laura Miller (Math 581), Chris Henderson (Math 584), and Leonid Kunaynsky (Math 589), were pivotal in successfully transitioning to the new core classes. The establishment of a postdoctoral position, filled by program alumnus Colin Clark, played a critical role in this success. Colin initiated and implemented interactive recitation sessions bridging different core courses and also spearheaded an integration workshop for incoming students in August.
2) Streamlined Qualification Process: We introduced a more straightforward qualification process that aligns with the successful completion of the core courses. This qualification procedure is now overseen by three committees, each led by the respective instructors of Math 581, Math 584, or Math 589. This change not only simplifies and streamlines the student pathway but also guarantees a unified educational journey. Notably, this transition has enabled students to make more effective use of their first summer in the program by engaging early in internships or other opportunities to explore their future in research.
3) Broadening Horizons in Recruitment: Our recruitment strategy is undergoing a metamorphosis, extending its reach to a broader pool of prospective students, in particular students with undergraduate training in other mathematics reach disciplines, such as physics, engineering and computer science. By embracing a diverse range of talents and backgrounds, we aimed to foster a richer intellectual environment.
4) Forging Strong Collaborations: Collaborations with National Laboratories (NLs) and Industrial Laboratories (ILs), interested in building a pipeline of applied mathematicians to work on the problems of national and regional significance, were nurtured through initiatives like the annual LANL Days, Raytheon day and annual recruitment visits from multiple NLs and ILs. These partnerships fostered real-world relevance and exposure for our students. We are quite close to becoming a dedicated PhD program in Applied Mathematics for many of our NL and IL partners.
5) Cultivating a Thriving Student Community: By enhancing and establishing various social activities, from brown bag seminars to weekly hikes and an annual Grand Canyon trip, we created an environment that transcends the classroom and fosters feelings of accomplishments, belonging and camaraderie among the students.
6) Pioneering AI for Sciences: Recognizing the emergent role of Artificial Intelligence (AI) in scientific inquiry, we established ourselves as leaders in "AI for Sciences" on campus and nationally. Our involvement in AI-related initiatives further solidifies our program's leadership in this pivotal domain. In the past four years, we have lead numerous AI-related

collaborative proposals involving multiple universities for funding from NSF, DOD, DOE and private foundations. Our commitment to securing grants in this vital field remains unwavering as we strive to bring funding opportunities in this emerging sub-field of applied mathematics to the UArizona.

More information about the program, its students, professors, core courses, seminar and colloquia series, workshops and social activities can be found at the following websites:
https://appliedmath.arizona.edu/
https://appliedmath.arizona.edu/students/current-students
https://appliedmath.arizona.edu/people/faculty
https://appliedmath.arizona.edu/students/core-courses
https://appliedmath.arizona.edu/events/full-calendar
https://appliedmath.arizona.edu/program-info/newsletter

Looking ahead, we are collaborating with the Department of Mathematics to introduce a new MSc program in Applied Mathematics, anticipated for the fall of 2024. This program will integrate AM GIDP core courses, representing a significant milestone in our mission to shape the future of applied mathematics education.

Table 1. Applied Math student involvement in research 2015-2023

Program in Applied Math -- Graduate Student support data history 2015-2023									
Funding Source	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
TA's with Math	15	16	17	19	17	17	17	18	16.5
RA's									
Coll of Sci (Math, EEB, GEO, LPL, MCB)	6	13	9	7	9	15	16	15	10.5
Opt Sci	3	3	3	1	2	2	1	1	0
Engineering (AME, SIE, MSE)	1	1	2	1	2	2	2	5	4.5
Physiology	1	0	2	2	1	1	0	0	0
Training Grants Fellowships (NSF, NIH)	2	3	2	2	2	4	4	4	5.5
External Fellowships (NSF-NDSEG, NIH, DOD, DOE, LANL, Sandia)	2	2	2	3	3	4	9	9	10
Institutional Fellowships (Univ. Fellow, Tabor, Chertkov)	7	7	4	5	12	11	8	8	11
Other instutitional support (ARCS, Uaccess, SpaceGrant)	1	1	1	3	3	2	1	1	3
Outside employmnt (Raytheon, Airbus, Rincon, Crit Path)	6	4	5	5	3	3	5	3	4
Total TA'ships	15	16	17	19	17	17	17	18	16.5
Total RAs+Trg grants+Ext Fllshps+Ints Fllshps+Employed	29	34	30	29	37	44	46	46	48.5
Total # of students:	44	50	47	48	54	61	63	64	65

Table 2. Applied Math Student Funding Details 2023-24

Applied Mathematics Student Funding Details : Year 2023-24							
Funding Source	**Ext Fllshp**	**Inst Fllshp**	**Trng Gr**	**RA's**	**TA's**	**Ext Empl**	**Total**
RA's w/College of Engineering							
ECE				1.5			1.5
AME				1.5	1		2.5
SIE				0.5			0.5
RA's w/College of Science							
Astronomy				1			1
Computer Science				1			1
EEB				0.5			0.5
Geoscience				1			1
Math				6			6
Planetary Science				1			1
NIH training grant			2				2
NSF-RTG training grant			3.5				3.5
NSF GRFP	3						3
NDSEG	1						1
National Labs							
Sandia	1.5						1.5
LANL	3						3
Other							
Space Grant		0.5					0.5
ARCS	0.5						0.5
Fulbright	1						1
Leave of Absence							3
Institutional funds							
GC-GIDP Fellowship (.50)		1.5					1.5
GC Chertkov Fellowshps (.50)		5					5
TA ships w/Math (.50)					16.5		16.5
GC- Tuition only		4					4
External employment							0
Other						1	1
Airbus						1	1
Raytheon						1	1
Rincon Research						1	1
Totals:	10	11	5.5	14	17.5	4	65

Table 3. Applied Math Student Summer internships 2019-Present

Applied Math Student Summer internships 2019-Present		
National Labs (DOE)	**Government Agency**	**Industry**
Los Alamos National Lab (4 students)	Air Force Research Laboratory	Critical Path Institute, Tucson, AZ
Lawrence Livermore National Lab	National Institute of Mental Health (NIMH)	Zuze Institute of Berlin (ZIB)
Sandia National Lab (6 students)	Food & Drug Administration	Ancestry.com
Argonne National Lab		Genesis Research
Lawrence Berkeley National Lab		Biosphere II, Oracle, AZ
Nevada National Security Site		Transcend Engineering, LLC
		Wells Fargo
		Sovereign Wealth Fund of the UAE
		Arete Associates, Tucson, AZ
		Lightsense Technology

Table 4. Applied Math PhD Graduates 2013-2023 Employment

Applied Math PhD Graduates 2013-2023 Employment			
National Labs	**Government Agencies**	**Industry & Non-Profits**	**Academia**
Los Alamos National Lab	Department of Energy	Amazon	Boston University
Sandia National Lab	Food & Drug Administration	American Express	Courant Institute
Pacific Northwest National Lab	US Naval Academy	Applied Biomath	Gonzaga
Lawrence Livermore National Lab	Department of Defense	Bank of America	Harvard
Nevada National Security Site	Air Force Research Laboratory	Ford Motor Company	Purdue
	NASA Jet Propulsion Lab	Goldman Sachs	Oregon State University
		Google	Michigan State University
		Legal Zoom	Universita di Padova
		Math Works	UT Austin
		May Mobility	Wake Forest University
		Medtronic	Johns Hopkins
		Raytheon	Nordita Institute
		Rincon Research	
		Wells Fargo	
		You Tube	
		Critical Path Institute	
		MITRE	
		Moffitt Cancer Center	

Program Progress in Numbers: Insights and Achievements

Numbers are a powerful reflection of program dynamics, encapsulating the journey from 2015 to the present. The tables below provide an insightful overview of our students' engagement in education and research.

Table #1 (Student Engagement Trends) outlines the evolving landscape of student engagement and support from 2015 to the present. The number of Teaching Assistants (TAs) supported by the Mathematics department has remained relatively steady, ranging from 15 in 2015 to 16 in 2023. The count of Research Assistants (RAs) saw an increase in 2020, reaching 20, and has since

maintained this level. Notably, our program has benefited from two prominent training grants, led by T. Secomb (via NIH on “Computational and mathematical modeling of biomedical system”) and K. Lin (via NSF on “Applied Mathematics and Statistics for Data-Driven Discovery”), funded by NIH and NSF, respectively. These grants cater to a diverse array of graduate students across campus, with the number of Applied Math students supported increasing from 2 in 2015 to 6 in 2023.

An impressive upsurge is observed in the realm of external and internal fellowships, as well as co-employment partnerships with National and Industrial Laboratories (NLs and ILs). The count of external fellowships, including prestigious awards like the NSF-NDSEG fellowship, surged from 2 in 2015 to 10 in 2023. Institutional fellowships, reflecting institutional recognition, have shown positive growth, numbering 7 in 2015, 12 in 2019, and 10 in 2023. Notably, several of our students have found co-employment opportunities within NLs such as LANL and SNL, as well as ILs including Raytheon, Rincon Research, and Airbus.

Table #2: Student Research Distribution

Table #2 showcases the distribution of student research projects across various colleges and departments within UArizona in 2023. The largest contingent of Research Assistants (RAs), 10 in total, are affiliated with the Department of Mathematics. Furthermore, our program's reach extends to other departments within the College of Science, with 5 students contributing to Astronomy, Ecology and Evolutionary Biology (EEB), Geoscience, Computer Science, and Planetary Science. Notably, our program's influence also spans the College of Engineering (CoE), with 5 students actively collaborating with the Departments of Electrical and Computer Engineering (ECE), Aerospace and Mechanical Engineering (AME), and Systems and Industrial Engineering (SIE).

Table #3: Applied Math Student Summer internships 2019-Present

Table #3 showcases our achievements in facilitating students to capitalize on early opportunities with national and industrial laboratories. By streamlining the qualification process, we've empowered students to spend their first summer in the program immersed in internships. We ardently champion and endorse these internships as launching pads for research involvement. Impressively, many of these preliminary summer internships mature into enduring research partnerships. The newly secured IGE/NSF grant will reinforce our triadic collaboration framework, enabling eager students to pursue their PhD under the joint mentorship of a national or industrial lab expert and a university professor.

Table #4: Applied Math PhD Graduates 2013-2023 Employment

Table #4 lists the universities, national labs, and companies that have employed our graduates from 2013 to 2023. Over the past decade, the array of career opportunities available to our applied mathematics students has greatly expanded. A significant majority of our graduates pursue careers related to research and education in applied mathematics. Intriguingly, the employment destinations show a nearly equal three-way distribution among academia, national laboratories, and industry.

Additional Noteworthy Numbers and Events

In addition to the dynamics mentioned above, our program has actively participated in various NSF educational grants. We became a part of the NSF grant, led by D. Glickenstein focusing on “Enhancing pathways to a PhD in the Mathematical Sciences”. Most recently, our program proposal, titled "Innovation in Graduate Education: Integrating Data Science into the Applied Mathematics PhD: Generalized Skills for Non-Academic Careers," has been recommended for NSF funding.

Significantly, the program has successfully secured four partnership hirings over the past three years, cementing collaborations with Material Science and Engineering (M. Latypov, hired in 2020), Sociology & School of Information (Ch. Gomez, hired in 2022), Mathematics (P. Shipman, hired in 2023), and upcoming plans with Computer Science in 2024.

Amid the evident challenges posed by COVID-19, a series of intriguing adaptations has reshaped our research and operations. Notably, our community swiftly responded by inaugurating a seminar dedicated to constructing mathematical models for the pandemic. This initiative bore fruit in the form of multiple publications and externally funded projects, supported by organizations such as NSF and UArizona's AEGIS consortium. Embracing the virtual realm, we integrated Zoom into both our research and education initiatives. This transition has enabled us to record and subsequently share all seminars, colloquia, and other public activities of the program online. Additionally, Zoom has seamlessly integrated into the fabric of our courses, facilitating remote participation and recording to enhance the overall learning experience.

Our commitment to knowledge dissemination is evidenced by the transformation of Math 581 course notes into a book, which is currently under review for publication by SIAM.

Furthermore, the Department of Mathematics’ diversity committee has reported substantial improvements in our diversity figures over the past four years. This is reflected in our AM program student distribution (of 63 PhD students currently enrolled in AM GIDP, 22% are women and 18% are underrepresented minorities). We take great pride in these strides towards a more inclusive and diverse academic environment.

Reflecting on Lessons Learned and Areas for Improvement:

As we continue to shape the future of our Applied Mathematics Graduate Interdisciplinary Program (AM GIDP), it's essential to acknowledge the valuable insights gained from our experiences thus far. These lessons guide us in refining our program and ensuring that our students receive the best possible educational journey. Here are some key takeaways:

1) Prioritizing Mental Health Support: Looking back, we recognize the importance of prioritizing the mental health and well-being of our students. The demands of scientific research, particularly in mathematics, can be challenging, and it's crucial to provide a supportive environment that fosters open discussions and collaboration. Early detection,

proactive measures, and pleasant collaborations among students have proven effective in nurturing their mental well-being.

2) Balancing Research and Employment: An essential aspect of our program is preparing students for careers beyond academia, including national and industrial laboratories. While we remain committed to this approach, we acknowledge the need for ongoing efforts to align these opportunities with students' studies. Continued collaboration between students, lab staff, and university professors is essential to achieving this balance successfully.
3) Adapting Admissions Screening: We aim to diversify our student body by admitting candidates with various mathematical backgrounds and aspirations. In pursuit of this goal, we are learning how to enhance our admissions screening process. By alerting candidates to the importance of math skills before interviews and assessing their foundational knowledge, we improve their chances of success during the program and beyond.
4) Enhancing Seminar Engagement: Our seminars, including the applied mathematics colloquium, are vital platforms for intellectual exchange. To encourage broader participation, we plan to collaborate with many sister departments and programs on campus. Innovative approaches, such as joint events and presentations covering both classic and emerging topics, will enrich the learning experience and foster a sense of community.
5) Recognizing the Master's Option: We've observed a growing interest among our students in pursuing a Master's degree, particularly for roles in industrial and national laboratories. This trend signals a shift in the landscape of applied mathematics, prompting us to collaborate with the Department of Mathematics in launching a new master's program in applied mathematics. This initiative aligns with our commitment to providing relevant and diverse career pathways for our students.

By reflecting on these lessons and areas for improvement, we are dedicated to refining our program's offerings and ensuring that every student's journey through AM GIDP is enriched, empowering, and aligned with their aspirations.

Navigating the Path Ahead: Advancing the Applied Mathematics PhD Program

With a rich history on the forefront of research and education, our program is poised to embrace the ever-evolving landscape of contemporary research in Applied Mathematics. Guided by recent advancements and transformations, e.g. in AI for Sciences, we have a clear trajectory for progress. Our vision encompasses the following strategic directions:

1) **Enhancing Core Courses:** Striking a balance between breadth and depth, we aim to continue the process of our core courses refinement. Graduates who have completed these courses should be well-equipped not only for successful research but also possess a comprehensive understanding of application landscapes and opportunities, including the latest developments.

2) **Developing Advanced Courses:** Building on the evolution of our core courses, our focus turns to designing advanced offerings that delve into emerging frontiers of contemporary applied mathematics. Collaborative efforts with program members and affiliated departments will fuel the creation of these novel courses.
    a. We are committed to fostering innovation among our program members and affiliated faculty from the Department of Mathematics. Their development of new special topic courses, such as "Monte Carlo" (Lin and Kennedy, last time offered in 2022 spring), "Graph and Network Models" (Chertkov, 2022 fall), "Information Theory" (Wehr, 2022 fall), "Nature of Computations" (Rychlik, 2020 spring), "Stochastic Control and Learning" (Chertkov, 2023 fall), and "Optimal transport and its applications" (Henderson, 2023 fall), highlights our drive to offer timely and essential content. Pending approval from the Mathematics Department Graduate committee, select Math 577 courses will eventually become part of our official curriculum, co-listed between Mathematics and Applied Mathematics.
    b. Our program affiliates beyond the Department of Mathematics, particularly those hired in partnerships with other campus departments, play a pivotal role in enriching our curriculum. Offering of "Physics Informed Neural Networks" by M. Latypov (Department of Materials Science and Engineering, CoE) in the fall of 2022 serves as an example of such collaborative course development.
    c. Identifying niches within applied mathematics that are in high demand by graduate students across UArizona but are not comprehensively covered presents a promising avenue. Areas like "Fluid Mechanics", "Theoretical and Applied Optimization", and "Reinforcement Learning" epitomize the types of subjects we should actively explore and subsequently develop courses to address.
3) **Elevating Collaboration through IGE:** Having recently secured the Innovation in Graduate Education (IGE) NSF proposal, we are poised to elevate our partnership with National and Industrial Labs to the next level. Our IGE project seeks to integrate data science and AI, nurturing graduates for non-academic careers through a triadic collaboration model involving students, laboratory experts, and university professors. This innovative approach will foster cross-disciplinary skills and serve as a model for other programs in applied mathematics nation-wide and internationally.
4) **AI Engagement and Beyond:** Building upon our program's successful efforts in AI for sciences, we will actively collaborate with stakeholders to develop competitive proposals in this dynamic field. By forging partnerships across campus, we aim to position Tucson as a hub for conferences, workshops, and studies where AI serves to advance sciences.