Challenges facing STEM graduate students

Scientific knowledge and expertise will play pivotal roles in addressing pressing, global challenges such as climate change, the spread of infectious disease, and the ever rising demand for natural resources. Moreover, national investments in scientific research and education are crucial for innovation and economic growth. Graduate education in STEM fields is thus essential for training the next generation of scientists whose efforts will both help to solve pressing global problems and lead to future prosperity. However, despite long-term investments in graduate training and the production of highly skilled scientists, graduate students in STEM disciplines face an increasingly difficult career landscape, which limits their ability to apply their expertise both within and beyond the academy[1,2].

We wish to address the following issues in graduate education. First, while the scope and scale of basic research have expanded globally, the number of permanent academic positions in the US has not grown to accommodate the supply of newly trained scientists and engineers[1]. Second, while STEM graduate programs confer the high levels of technical expertise needed for non-academic jobs, they do not emphasize extra-disciplinary skills that are valuable in today's economy, or expose students to career options beyond academia. Finally, the great extent to which scientific knowledge must be brought to bear to solve global problems is unfortunately matched by equally profound misunderstandings of science by policy makers and the broader public, impeding progress towards solving national challenges.

Therefore, our solution is to broaden current graduate training in the sciences in order to simultaneously expand career options for STEM graduates and allow them to productively interface with sectors of society outside the academy, both private and public, through the External Graduate Assistant (EGA) program. An EGAship is an internship for a graduate student at a non-academic organization (government, NGO, private firm, etc.) to be completed during the academic year in place of a more traditional teaching assistantship (TA). The NSF will incentivize the creation of EGAships, thereby allowing academic and non-academic organizations to better prepare future scientists for diverse career opportunities and to address fundamental challenges that lie at the intersection of many sectors of society.

The Existing Graduate Training Landscape

Although myriad programs facilitate interactions between STEM students and non-academic organizations to complement academic training, these programs largely target undergraduate and post-doctoral demographics[3]. Undergraduates develop practical skills complementary to their classes through full- or part-time internships. At the post-doctoral level, there are training opportunities such as EPA and Sea Grant fellowships and MBA programs for STEM graduates. At the STEM graduate level, programs such as the NSF GK-12 incentivize graduate students to work in K-12 schools, while programs like the Knauss Marine Policy Fellowships and DOE CSGF program support full-time off campus training opportunities. However, synergistic approaches that combine part-time extra-academic opportunities with concurrent graduate study are largely absent in STEM graduate training programs. This lack of

broad-scale institutional structure for such approaches presents a unique opportunity to establish an EGA program. In this program, STEM graduate students will collaborate with non-academic organizations (hereafter, Partner Organizations [POs]), both public and private, to address societal challenges from multiple professional perspectives while expanding and cultivating extra-disciplinary skills.

The structural similarity between EGAships and TAships sets the stage for the EGA program's practical adoption into graduate curricula. In a TAship, graduate students perform needed work on a part-time basis for their parent university while simultaneously gaining teaching experience. The TAship thus prepares a graduate student for the pedagogical components of an academic career. In an EGAship of comparable time commitment and compensation, the graduate student will contribute her STEM expertise to a PO while gaining extra-academic experience, thus preparing the student for a broader career landscape and strengthening bonds between academia and POs for future collaborations.

Implementing the External Graduate Assistant Program

The EGA Program unites needs of STEM graduate students with needs of POs, providing beneficial outcomes for all involved parties (Figure 1). Specifically, a graduate student will collaborate with a PO to apply STEM knowledge to a shared, research-oriented goal. Like a TAship, an EGA recipient will simultaneously continue her existing graduate program while continuing to receive stipend support. For example, an EGA could work with a senator's office to examine the implications of climate change legislation, or could partner with a community development NGO to share the latest research on urban farming with the public. Similarly, an EGA could collaborate with a clean energy startup to translate promising research into cutting-edge technologies. Opportunities need not be limited to local institutions; in some cases, technology allows for remote EGA collaborations.

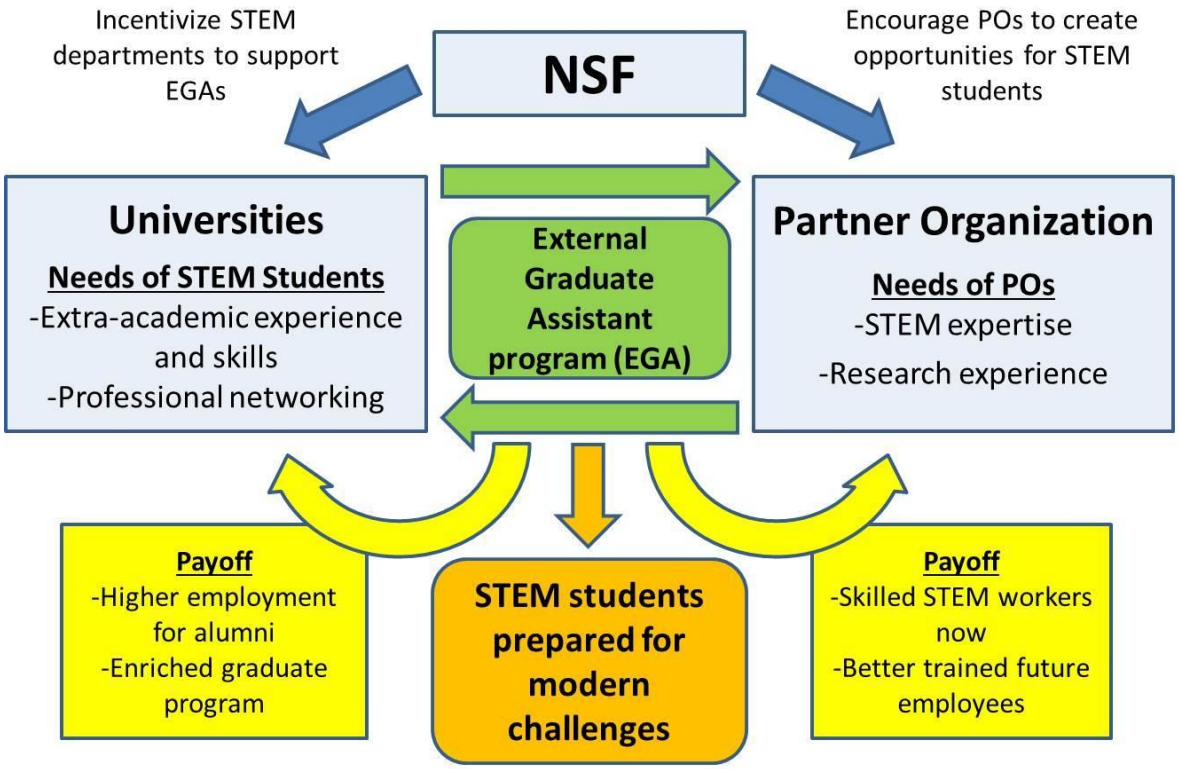

Figure 1: Conceptual diagram of the goals of the External Graduate Assistant program.

NSF will play a crucial role in the EGA program by incentivizing participation and facilitating connections between academic institutions and POs. In order to stimulate participation in EGAships, NSF will launch and maintain a website called the *Partner Organization Database* (POD). NSF will hold yearly calls for POs to participate in the EGA program and list suitable POs in the database. Students will learn about potential EGAship projects through the POD. When a student identifies a suitable EGAship, a simple form will be available on the website to interface with a designated contact person at each PO. Additionally, the website will contain contact information for EGA Program alumni both to build a professional alumni network and enable NSF to track program outcomes. The POD is essential to facilitate connections between universities and non-academic organizations as well as lower the barrier to beginning an EGAship.

NSF will award EGAships to individual students on an application basis. Interested graduate students will approach prospective POs through the POD and collaborate to write a short description of a proposed project. This document, along with a letter of support from the student's advisor and a supervisor at the PO, will constitute the EGA application. A panel of reviewers will rank applications based on the extent to which the proposed project will (1) allow the graduate student to acquire new, useful skills, and (2) create meaningful networks between students, universities and POs.

Completion of an EGAship will satisfy one TAship requirement for the student. To encourage graduate programs to accept EGA credit in place of TA credit, NSF will provide

financial incentive to the student's institution equivalent to the replacement cost of one TAship at that university. Such financial incentives will be feasible and broadly applicable because of their relatively low costs. In comparison to the NSF-GRFP, which fully funds a single student over 12 academic quarters, the EGA program could flexibly fund numerous individual EGAships on a quarterly/semesterly basis.

Changing Graduate Education

Although the outcomes of an EGAship will be specific to each individual experience, we recognize several general outcomes for students who participate. Beyond gaining experience in applying disciplinary skills in non-academic settings, extra-disciplinary outcomes of EGAships include an increased ability to manage projects; to partner, collaborate, and engage with individuals from diverse backgrounds; to communicate scientific goals to non-scientists; and to execute projects that cross traditional academic disciplines, among others. POs will benefit from working with STEM-trained EGAs and scouting highly competent future employees, whereas universities will have more marketable graduates and enriched, diversified graduate programs. Ultimately, both POs and universities will benefit from the closer collaborations and partnerships facilitated by EGAships and the increased visibility of STEM graduates to potential employers and the broader public.

The EGA program will transform graduate education through a two-tiered approach: (1) NSF incentivizes universities and POs to facilitate the EGA as an acceptable alternative to the TA, resulting in institutional support for STEM training beyond the academy; (2) Student-initiated participation in the EGA program and a growing network of EGA alumni will encourage STEM students to seek broader extra-academic training and expose them to novel career and collaborative opportunities. These two approaches will generate a STEM graduate education culture that is cognizant of the individual career challenges STEM students face while preparing these graduates to work among many sectors of society. More broadly, STEM-based solutions are required for many global challenges, but there is a deficit of relevant preparation in traditional graduate school curricula for implementing efficient solutions beyond the academy. The EGA will engender a culture of extra-disciplinary training in STEM graduate education and strengthen academic and non-academic partnerships in order to solve tomorrow's challenges.

References

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