



## Examining Pathways into Graduate School through Stewardship Theory

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## Abstract

The purpose of this research paper is to understand the trajectories of early-career graduate students and senior-level undergraduate students as they consider graduate school. To this end, we qualitatively examined a corpus of N=50 personal statements, taken from winners of the NSF Graduate Research Fellowship Program in one award cycle, to understand the trajectories that researchers take going into graduate school. Current graduate engineering enrollment numbers are declining with engineering doctoral attrition rates estimated to be about 24% and 36% for males and females, respectively. Students from traditionally underrepresented minority groups record doctoral attrition rates higher than 50%. This study employs the lens of Stewardship Theory, a theory commonly used to characterize the practices and activities of experts and PhD holders in generating, transforming, and conserving knowledge. Applied to our study, Stewardship Theory illuminates how particular undergraduate experiences, such as research experiences, teaching assistantships, tutoring, or outreach experiences, form the beginnings of an academic identity as a “steward of the discipline,” and prepare students for graduate school. Analysis of these fellowship awardees will help us identify and categorize experiences that encourage and prepare students to pursue graduate level studies, not that every student should or wants to pursue graduate school, but to help students begin to form academic identities. Our findings characterize the experiences that undergraduates and early-career graduate students have through this and use qualitative data to show how these experiences prepared students to envision their role as graduate students. As a result of these findings, the engineering education research and practice communities can better understand how students conceptualize graduate school, their career goals, and research-intensive careers to inform how these experiences are conducted. Our findings also hold implications for scholars studying the formation of the future professoriate, as the academic “pipeline” begins with students like the ones from which we collected data in this study.

## Introduction and Literature Review

In recent years, there has been a slight uptick in the focus on engineering graduate student education, particularly considering recent calls by the National Academies highlighting issues of well-being, lack of mentorship, and under preparation for today’s careers [1]. While this recent report showcases the issue, graduate attrition problems have been documented in literature for decades: In 2008, the Council for Graduate Schools reported one of the only quantitative studies to date tracking attrition and persistence, noting that graduate attrition in engineering is remarkably high: between 24%-36% for men and women in engineering, respectively [2]. More recently, in 2015, Sowell, Allum, and Okahana [3] reported data disaggregated for graduate engineering men and women of color, noting alarming statistics for most traditionally underrepresented groups, and that for African American engineering graduate students, the ten-year completion rates are only 48%.

Graduate education and attrition have been of interest in the research communities of higher education for decades [4]– [7], focusing typically on disciplines that note even higher levels of doctoral attrition, such as the humanities [8]. Scholars note that factors like effective

socialization[9]–[11], access to funding [12], [13], belongingness and development of community during difficult milestones [14], [15], time to completion[16], [17], and advisor relationships [18]–[20] are critical to student success and persistence. In engineering, though, there are several reasons why we must examine engineering graduate students separately from graduate students more broadly, or even graduate students in STEM. First, most engineering graduate students are funded, and most are funded for their research. Further, time to degree completion for engineering doctoral students is low—on average about 5 years—since engineering research is typically funded on grants or industry sponsorship that encourages results and publication. The culture of engineering departments, even though cultures vary between departments and institutions, is different than those of other science, technology, and math departments, which often have different structures for research groups, mentorship, and expectations of graduate students. Therefore, we posit that we must study engineering graduate students separately from students in other disciplines, though many of the themes may be the same.

Graduate level engineering education research promotes that graduate socialization into the expectations and norms of academic engineering are complex and overlap. Berdanier, Whitehair, Kirn, and Satterfield [21] recently studied how students discuss the overlaps between these factors, understanding that no one factor likely pushes a student to change significant career goals such as pursuing a PhD. They presented a new model for graduate attrition, called the GrAD model, to explore the dynamic nature of the decision to leave. Other scholars have delved into the importance of research group dynamics and role models to students forming academic engineering identities and developing competencies in graduate school. For example, Crede and Borrego [22] studied the role of research group size in the development and learning of graduate students, and Burt's [23] research on Black men in doctoral engineering programs points to the importance of belongingness and mentorship, particularly for minoritized populations.

Fewer researchers investigate the transitions between undergraduate and graduate programs, or how, why, and when undergraduates decide to pursue graduate school. While literature does demonstrate that undergraduate research experiences can be critical to exploring career paths that may involve graduate work or research, only a small fraction of undergraduate engineers consider pursuing graduate school, and especially the engineering PhD. The most salient piece of research to this conversation is Borrego's [24], [25] quantitative work exploring the reasons why undergraduates choose to go to graduate school. They found five themes emerged through their Exploratory Factor Analysis: Self-efficacy, Outcome expectations, Supports, Barriers, and Choice Actions, while also adding value to engineering education literature by exploring the differences between the goals of those pursuing Masters degrees and those intending to pursue a PhD.

In the present work, we aim to add to the conversation on the transition from undergraduate to graduate stages of education by examining personal statements written by engineering awardees of the National Science Foundation (NSF) Graduate Research Fellowship Program (GRFP) in one funding cycle. We examine these personal statements through the lens of Stewardship Theory, a framework that categorizes the activities conducted by PhD holders as stewards of their respective disciplines. We aim to understand how novice scholars are beginning to develop and communicate their academic and service work in a way that is valued by an academic community. By answering our overarching research question, “How do engineering undergraduates and early-career graduate students enact disciplinary

Stewardship?” we can begin to map the development of disciplinary Stewardship and socialization into the expectations and norms of academia. Understanding this population of students will also assist us in studying patterns of graduate school enrolment and attrition. Examination of the high achieving accomplished students in our data set will shed light on characteristics that are needed to be successful and persistent graduate student. By highlighting patterns and themes from these participants, we will form a clearer picture of what experiences prepare students to navigate through common factors that contribute to attrition.

### **Theoretical Framework: Stewardship Theory**

First proposed by Golde 2006 [26], Stewardship Theory proposes that PhD-holders across disciplines can characterize their impactful activities into three main categories: Conservation, Generation, and Transformation. The category of Conservation refers to defending, promoting, and conserving the core values and standards of a discipline. Generation refers to generating new disciplinary knowledge, typically in the form of research and publication activities. Transformation is the role of communicating or translating disciplinary knowledge to various stakeholders and communities, both those in the scholarly community and outside. Stewardship theory was formed in Higher Education but was first adapted to engineering by Cox’s research characterizing the knowledge, skills, and attributes of PhD-holders in academia and industry. As part of Cox’s larger work, Berdanier et al. [23] characterized behaviors of 40 PhD-holding engineers in academia and industry to operationalize Stewardship theory in the specific context of engineering. Table 1 below offers a shortened and abbreviated version of the codebook to demonstrate the kinds of activities that fall into each of the categories of Conservation, Generation, and Transformation. Of note: These representative activities are from the lens of PhD-holders in academia and industry; we fully expect to uncover what different representative activities may look like for beginning PhD students at the beginnings of their stewardship journey.

In this work, we seek to use Stewardship Theory as a lens to understand the activities that novice engineering scholars (senior level undergraduates and first- and second-year graduate students) communicate as valuable in their NSF GRFP. While these students are not PhD holders *yet*, we posit that Stewardship can provide valuable insight in the ways that these students are beginning to understand and conform to the implicit and invisible expectation to become a steward of their chosen engineering discipline.

Table 1: Stewardship Applied to Engineering PhD-Holders

Stewardship Tenet	Definition	Representative Activities
Conservation	PhD holders pass down the most critical and foundational disciplinary ideas and values to future generations to <i>conserve</i> the discipline	<ul style="list-style-type: none"> <li>• Subject-matter expertise</li> <li>• Technical leadership in academia or industry</li> <li>• Awareness of the field and the state-of-the-art</li> </ul>
Generation	PhD-holders are tasked with generating new disciplinary knowledge	<ul style="list-style-type: none"> <li>• Research activities</li> <li>• Publication and impact</li> <li>Teaching others to generate knowledge</li> </ul>
Transformation	PhD-holders translate their knowledge to stakeholders both inside and outside the disciplinary or academic communities	<ul style="list-style-type: none"> <li>• Teaching</li> <li>Verbal and written</li> <li>• communication skills</li> <li>Tailor communication to audiences, including nontechnical audiences</li> <li>• Outreach and Education</li> </ul>

## Methods

This research was conducted out of a larger study intended to study graduate engineering students' rhetorical academic engineering writing patterns, employing the National Science Foundation's Graduate Research Fellowship Program (GRFP) as a platform for studying a standard and relatively short, yet authentic, writing experience. The NSF GRFP is an annual competition in which graduate students in their senior year of undergraduate or their first or second years of graduate school compete to win three years of external funding. While a variety of data is used to evaluate applicants, such as GRE and GPA scores and letters of recommendation, the unique feature of the NSF GRFP is the requirement to write a two page research proposal and a three page statement of personal goals (hereby referred to as the "personal statement"). In the award cycle in which this study was conducted, students could apply once as an undergraduate student, and both their years in graduate school, an affordance that has since changed.

The prompts for the two essays do not necessarily align with Stewardship theory. For example, the prompt for the Personal Statement asks students to

*"Please outline your educational and professional development plans and career goals. How do you envision graduate school preparing you for a career that allows you to contribute to expanding scientific understanding as well as broadly benefit society? [...] Describe your personal, educational, and/or professional experiences that motivate your decision to pursue advanced study in science, technology, engineering, or mathematics (STEM). Include specific examples of any research and/or professional activities in which you have participated. Present a concise description of the activities, highlight the results, and discuss how these activities have prepared you to seek a graduate degree. Specify your role in the activity including the extent to*

*which you worked independently and/or as part of a team. Describe the contributions of your activity to advancing knowledge in STEM fields as well as the potential for broader societal impacts (See Solicitation, Section VI, for more information about Broader Impacts) [27]).*

While this prompt is broad, we use Stewardship Theory to bring to light the specific ways in which the participants address concepts of generation, conservation, and transformation to see how these early-career graduate students are beginning to act as members of their disciplinary communities. While NSF GRFP winners are a unique group that may not represent all students, we do argue that studying this population can point to some indicators of early preparation and socialization into the expectations and norms of graduate school. For this reason, studying this specific group can give insight into what experiences may foster the development of academic stewardship more broadly in the late-career undergraduate or early-career graduate engineering student population.

### *Recruitment and Participants*

After IRB approval, participants were recruited using publicly available data on NSF GRFP winners' names and institutions released in the award cycle of interest, available on the NSF FastLane website. In the award cycle of interest, 2000 GRFP awards were given across all disciplines, 510 of which were in engineering. Of these potential participants, email addresses were found using the internet and institutional directories for 330 participants. An email from the researcher requested participation in a survey of writing attitudes (as was the focus of the original, wider research project) and asked participants to upload the personal statement and research statement from their winning application package. After cleaning the data for incomplete survey responses and for those who did not upload both documents, a final total of N=50 participants were represented in the final data sets and corpuses of documents. The demographic distribution of the participants is indicated in the table below. Of the 50 participants, N= 10 were undergraduates at the time of winning the NSF GRFP, N=24 were first-year graduate students, and N=15 were second year graduate students.

Table 2: Demographic Information

<b>Racial/Ethnic Demographics</b>	<b>Number</b>	<b>Percentage</b>
White/Caucasian	39	78%
Asian/Pacific Islander	4	8%
Black/African American	2	4%
Hispanic/Latin American	3	6%
Multiple		
White/Asian	1	2%
White/Hispanic	1	2%
<b>First Language</b>	<b>Number</b>	<b>Percentage</b>
English	46	92%
Spanish	3	6%
Other	1	2%

These numbers are representative of the data reported for this GRFP award cycle that year, (54% women, and 21% belonging to an underrepresented group [27]. Engineering-specific data are not available. Nationally, in the same year, 23.5% and 28.1% of doctoral degrees were earned by women and non-White groups, respectively [28]. While we did not recruit based on any of these demographics, thirty-four participants (68%) had attended a research university for their undergraduate degree, and all were attending large research institutions with Carnegie classifications of R1 (highest research activity) or R2 (higher research activity) for graduate school. While the research proposals have been published in other work [29], the personal statements offer a deep insight into the reasons for which they are pursuing graduate research and are well-qualified for the NSF GRFP. These personal statements representing the 50 participants are the corpus that will be analyzed in the present study.

### *Data Analysis*

The 50 winning personal statements were de-identified with each one distinguished by a participant number. The coding schema was based on the three tenants of academic Stewardship: Conservation, Generation, and Transformation. All fifty transcripts were coded using NVIVO into the three categories. Any excerpt that dealt with how the participant experienced the learning process or how they charted their unique journey and acquired their level of knowledge was categorized as Conservation. Passages in which the participants describe research or comparable experiences that provided a platform to do something that had never been done before were coded as knowledge Generation. Discussions relating to how participants shared or sought to share their knowledge with others related to Transformation. Several quotes demonstrated two or even all three tenants of Stewardship, in which case they were coded underneath all applicable codes.

Deeper analysis was largely data driven. As the transcripts were coded, natural patterns and recurring sub themes emerged among the participants. These emergent themes heavily influenced the character assumed by the three predetermined codes. Each of the three tenants of Stewardship contained two underlying sub themes that provided rich context as to how Conservation, Generation, and Transformation manifest themselves among students who aspire to go to graduate school. The patterns resulting from transcripts eventually formed a handful of narratives that fit within our framework of Stewardship.

### *Limitations*

As with all research, there are limitations associated with this study. First, it is important to keep in mind that the participants wrote the personal statements to be evaluated by disciplinary experts for the purpose of winning the NSF GRFP. We did not have the opportunity to discuss any of the excerpts with the participants to gain more insight; however, we feel that even though some of the participants may “posture” and set their experiences in the best light for the audience and competition at hand, the way they discuss their motivations and experiences that have prepared them for graduate school and beyond is still valid, since it highlights the expectations of the academic engineering community. Similarly, we have no understanding of what resources applicants used as they wrote their statements, such that they may have been seeking to conform to the expectations of existing winning documents. However, the specific examples that each participant discussed showed that they had been engaging in these activities for years, not just for the purposes of winning the GRFP. We also posit that, regardless, the patterns that emerge show how students conceptualize what is valuable to the academic community. Last, our data set studies 50 documents, and—although

this is a large corpus for deep qualitative research—it cannot be intended to be generalizable. However, we do feel that the findings from this work add insight into the ways in which beginning graduate students are socialized as miniature stewards of their academic disciplines from early stages—even from undergraduate experiences, which has important implications in theory and practice for graduate programs in preventing attrition from graduate school.

## **Results**

Across the corpus of personal statements, being an engineer appeared to overlap with each participant's sense of professional identity so long as it represented the best opportunity for them to achieve their principle ambitions. Common motivations for a participants' choice to pursue their field of study included the desire to educate younger students and/or contribute to communities they are a part of or have personal experience with. In each case, participants spoke of engineering as the tool through which the actual goals of technological advancement, education, or societal impact could be attained. Nearly every participant began by establishing their personal connection with STEM subjects before elaborating on how their personal connection solidified into a passion that could only be fulfilled by education. Within each narrative, they outlined their hard work both in and out of the classroom, making sure to discuss how their commitment to their interests also led them to mentor and serve others using their knowledge. This pattern commonly employed by the participants remarkably reflects the three tenants of Stewardship Theory as if it were a template used to construct each personal statement. The guidelines provided for the GRFP orient applicants to demonstrate their aptitude for conserving, generating, and transforming knowledge. Stewardship Theory constitutes the implicit framework applicants are led to use in their bid to demonstrate their viability as graduate students.

### *Conservation*

Each participant demonstrated how they grew to become stewards of their discipline through their learning and studies. They distinguished themselves from their peers by highlighting their tenacity for learning and their involvement in various extracurricular activities. They excelled because they did not limit their involvement in their discipline to classroom assignments, but instead took ownership of their field of interest and took the initiative for their own learning. The way this was achieved varied among the participants but usually consisted of joining research groups, finding internships, or working for international organizations such as Engineers Without Borders.

A common practice among the participants was to open their personal statements by providing a backstory revealing how they became interested in engineering and the research they sought to become involved with. Participants typically ascribed the genesis of their career in STEM to curiosity, activism, lack of opportunity, or a combination of the three. Most participants offered relatively detailed exposition on prior research work and/or personal extracurricular studies. In this regard, knowledge Conservation and knowledge Generation are seen to work in a complementary manner. Students credited their interest in engineering to a specific childhood memory or experience. They then nurtured this interest as they progressed through high school and undergraduate coursework. Eventually, they grew to desire more than what their prescribed classwork was offering and sought to satiate their academic hunger by exploring extracurricular activities. These took the form of a research lab, an internship, aid work, or a study abroad program which imparted on them eye-opening knowledge or experiences that gave them a definitive sense of what they were specifically



passionate about pursuing at the graduate level. These extracurricular experiences played a pivotal role in transforming each student's curiosity and interest in engineering into a fully-fledged vision to which they anchored their long-term career goals. One participant illustrated this by opening their personal statement with one of the most striking introductions in the data pool.

*I will never forget my first night sleeping in a hammock, floating on Tonle Sap Lake in the heart of Cambodia. As my hammock swayed in the sundown breeze, I thought about the human feces floating past the Village Head's house that afternoon as we interviewed him about the villagers' practice of "open-water" defecation. I thought about my friend who missed the interview because he was doubled over vomiting off the side of our small boat, thanks to a pathogen-laden breakfast. I thought about how the lake is one of Cambodia's richest economic and ecological resources, as well as a waste stabilization pond for its tens of thousands of floating residents. I moved to Cambodia several months before that night, soon after completing my bachelor's degree in Plan II Honors (an interdisciplinary liberal arts program) and Latin American Studies at [University], with no contacts, no job, and no engineering education. In fact, I moved there with only a strong desire to work on a wastewater treatment project. (Participant 32)*

Spending time in other countries or in rural areas served to instill the desire to make an impact among those participants who cited such experiences. Participant 32 stands out as a prime example of a student who took an interest in an issue and sought to gain a first-hand experiential understanding of that issue. That understanding then developed into a personal career goal that engineering formed the pathway to achieve.

### *Generation*

A key link between these winning applicants was the proactive engagement in the Generation of new knowledge prior to enrollment in graduate school. Extracurricular experiences allowed participants to demonstrate not just their willingness to conserve their knowledge but also the ability to generate it. Participants went into detail describing their previous or ongoing research efforts and collaborations with faculty and experts from all over the world. From these experiences, they cited novel experimental procedures, significant findings, technological innovations, and academic papers they were responsible for or contributed to. Those that did not report prodigious research experiences rivalled their counterparts with their discussion of substantive and consequential contributions to nongovernmental organizations and societal development programs. Knowledge Conservation and Generation worked in tandem with one another as evidenced by the accounts given by the participants. The knowledge obtained from their previous coursework provided a foundation upon which they could push the limits of their understanding. Usually, interest in an area of engineering was associated with an issue or situation that current knowledge, tools, or implementations were unable to satisfy. Participants described having to stretch beyond what they had been taught in school in order to fully grasp what they were looking into. Only after taking in as much relevant information as they could, were they in a position to begin creating new knowledge and techniques used to solve the problem. The excerpt below captures this trend seen throughout the data set.

*In the spring of 2012, I got my first glimpse into the world of scientific research when I was tasked with designing and fabricating a solar calorimeter. This calorimeter would be used to calibrate an optical radiative flux measurement system and was vital to our ability to quantify the performance of solar reactors tested at the SERF. As an undergraduate with no previous research experience, to say that this was like drinking out of a fire hose would be putting it lightly. However, by struggling through my first exposure to scientific literature, performing numerous design iterations, and overcoming obstacles along the way, I acquired essential research skills that became the foundation for my continued love of research. I learned that what makes research difficult, but also what makes it exciting, is that there is never a single straightforward answer. Breakthroughs do not come simply, but by wrestling with the complexities of science we are able to push the limits of what was previously known. (Participant 56)*

Participants also looked ahead to what they planned to create or develop in the future in their bid to have a successful NSF GRFP. Prior experiences often inspired participants to develop and hone their long-term goals. Note that participants made sure to showcase their level of expertise regarding their prior or proposed areas of research. Participants who spent time working with humanitarian organizations tended to model their long-term objectives on whatever situation they had been immersed in and used this experience to assert their appropriateness for their proposed area of study.

*The object of my thesis is to develop a more cost effective defluoridation solution that East African defluoridation companies will be able to produce affordably with local resources - one that people will actually use. Arguably the most promising low-cost defluoridation adsorbent is bone char (BC), a HAP material derived from animal bone. However, like other fluoride adsorbents, the fluoride adsorption capacity of BC is below 5 mg/g, which is relatively low. In my literature review, I searched for economical ways that BC might be chemically altered at the molecular level as well as ways to increase its surface area in order to increase fluoride adsorption capacity. While in Kenya, we encountered the Nakuru Defluoridation Company (NDC), which produced BC as well as synthetic HAP pellets via a simple precipitation method. I realized that the properties of HAP pellets could be modified more easily due to the production process and started to focus my attention on the pellets. In March 2014, I had an epiphany. When precipitating HAP, fine sawdust could be added to the mixture. After the mixture is formed into pellets, charring them would burn the sawdust to create microscopic pores. This method has been used similarly to create a porous network in ceramic pots for filtering water by NGOs such as Potters for Peace. In effect, the adsorption capacity could increase significantly, due to the increase in pore space, while maintaining the low cost. In August, I travelled back to Nakuru, KE for three weeks to begin a collaboration with the NDC. I created the “enhanced” HAP pellets using their machinery, and its fluoride capacity is currently in testing. The NDC taught me their HAP production process so that I can generate small batches at [University] to test variations of the porous HAP pellets. I will use this process extensively in my proposed future research as well. (Participant 39)*

More broadly, the latter point stands as a critical characteristic uniting the participants. Every participant aimed to convince their readers that they belonged in their proposed area of study. Through their experiences and education, participants cultivated within themselves a sense of belonging to and ownership of their subject of interest. All 50 described specific research or projects they would engage in with the support of an NSF GRFP award. None of them indicated any doubt or uncertainty over their motivation or capability to perform in a graduate program. The knowledge garnered provided a platform upon which each could begin to contribute back to their area of interest. From these experiences, participants gained a sense of confidence in their ability to continue their research and education at the graduate level. For most, this was manifested in the desire to pass along their knowledge onto others.

### *Transformation*

The opportunities and experiences participants took formed a natural stage used to transform and share their knowledge with others. Nearly every participant reserved part of their statement for outlining how they mentored or planned to mentor other students. Even those who did not declare any ambitions to become educators highlighted their aptitude for tutoring other students. Furthermore, several described their experiences in co-mentoring relationships, such as when they worked in a multidisciplinary research lab and were responsible for teaching and learning from their fellow lab mates.

A strong correlation existed between the high ambitions of the aspiring students and a willingness to mentor similar students coming behind them. Nearly every participant demonstrated a passion and aptitude for their academic interest area that they sought to share with others. The mentorship of younger students, particularly those in K-12, was a recurring theme among the participants, who consistently desired to cultivate the same interest in engineering in younger students.

*Similarly, I have made a habit of mentoring high school students to encourage their interests, especially in STEM fields. For three years while attending MST I mentored Justyn, a local high school student I knew through my church's youth group, meeting one to two times per week to teach him guitar, the wave nature of sound and music, and to tutor him through geometry. While this was not through an official program, I believe the most effective means of encouraging STEM fields is through one-on-one mentoring, and I'm proud to say that Justyn is now studying criminal justice at a local college and we still keep in contact. I plan to continue mentoring middle and high school students while attending Notre Dame and have started to teach physics through skateboarding to two boys who are recent immigrants from Venezuela to encourage their budding interest in math and science. (Participant 13)*

The students that mentored and taught others did so in their own free time. Most participants spoke as if it was their responsibility to share engineering knowledge with others. Many participants treated their mastery over their subject as something to be shared with others for it to render the maximum benefit. Transforming knowledge to others stood out as the chief act of service participants felt they could confer to others to make a difference in their lives.

*I am confident that these boys will become great leaders, wherever their lives may take them. And I am grateful for the small but significant part I can play in touching their lives. I feel a sense of purpose and accomplishment as I work*

*with others - whether they be Cub Scouts, chicken farmers, engineering students, or Argentinians. My past experience is a firm foundation for my current PhD education, and the NSF GRFP Award will give me freedom to balance service, teaching, and research throughout grad school and beyond. I will use the experiences I gain as a graduate student, and later as a professor, to fulfill the commitment I made to myself many years ago while living among so many humble Argentinians: to make a difference in the lives of others. (Participant 10)*

Several participants described their dedication for mentorship in even more detail as they described their personal investment in specific social demographics. This was particularly salient among female applicants who often cited part of their motivation as arising from the desire to empower the next generation of female students to pursue engineering. 17 essays out of the 23 written by female participants explicitly mention the inspiration and education of female students as being of great importance to them.

*I supplemented my scientific coursework with classes in the women's studies department that would prepare me to address the underrepresentation of women in the fields of science, technology, engineering, and mathematics (STEM fields). It was in the "Gender, Science, and Technology" course taught by [Female Professor] that I decided that my passions for research, education, and expanding opportunities for young women in STEM fields would be fulfilled by a career as a university professor. (Participant 28)*

Many of these participants sought to help others overcome the same stereotypes and limitations that they themselves were subject to. For many participants, their journey in their engineering career was viewed as a platform upon which they could help others overcome their present circumstances. This mentality was especially evident among participants who indicated that deconstructing gender barriers endemic in engineering was central to their vision of how to impact others. Their own personal success was not the final goal of their efforts. Participant 9 recounts confronting gender norms while teaching secondary school students abroad, an experience that reinforced her commitment to broadening engineering to a wider female audience.

*Not only am I dedicated to and passionate about research, I am equally in love with teaching. That is one of the main reasons why I applied and became a Fulbright English Teaching Assistant in Nepal. I taught at a public lower secondary school and devoted my time and effort to my lessons and students, hoping to instill [sic] in them a joy for learning. One day when I was teaching my students how to write an essay about their dream job, I asked each of them what they wanted to be when they grew up. The boys dreamed of being doctors, engineers, politicians, farmers, and soldiers, while the girls exclusively responded with striving to be nurses, teachers, or mothers. Upon hearing all of their answers, I asked them, "What is my job?" "American teacher," they replied. "Here, yes, but in America, I am studying to be an engineer." They blinked back at me in momentary disbelief that I, a female, could be an engineer. I stopped speaking in English and opened up the class to a deeper conversation in Nepali about why they answered the way they did. This experience reinforced my belief that being a teacher is not just about imparting knowledge to students; it involves being a role model who inspires and*

*encourages them to challenge society's unseemly norms and consider themselves worthy of attaining understanding and fluency in whatever subject interests them.*

Mentorship of others was commonly performed in addition to their own coursework and research responsibilities. For all these applicants, it was evident that outreach and the education of others was central to their engineering identity and served to anchor their goals as they advanced through their programs.

## Discussion and Conclusion

The data and excerpts we show in this research provide a valuable lens to the activities that undergraduates and graduate students are exposed to which prepare them to become stewards of their disciplines. Lave and Wenger [30] might characterize some of these activities as “legitimate peripheral participation” in a community of practice, in which novices are introduced to the community or discipline little by little in increasingly important ways. We compile some of the main representative activities for the tenets of stewardship in Table 3.

Table 3: Representative Activities of Stewardship for Early-Career Researchers

Stewardship Tenet	Representative Activities
Conservation	<ul style="list-style-type: none"> <li>• Application of coursework to real-world problems</li> <li>• Leadership and participation in extracurricular engineering organizations</li> <li>• Pursuing and excelling in internships and co-ops</li> </ul>
Generation	<ul style="list-style-type: none"> <li>• Undergraduate research opportunities, including publication/presentations</li> <li>• Participating in ongoing collaborations, networking</li> <li>• Developing personal commitments for research discipline and impact</li> </ul>
Transformation	<ul style="list-style-type: none"> <li>• Volunteering and Mentorship</li> <li>• International experiences, such as teaching as a Fulbright fellow or through Engineers Without Borders</li> <li>• Sustained commitments to diversity, equity, and inclusion initiatives</li> </ul>

We expect that this research can add to the body of knowledge surrounding the factors that lead undergraduate students to pursue graduate school, and the body of knowledge investigating why graduate students leave. Understanding that perhaps not all incoming graduate students have not formed sincere commitments to research or to their future desired visions for impact, this research shows that perhaps graduate students should be encouraged to develop skills and participate in activities across all three tenets of stewardship in order to effectively socialize into their future roles as stewards of the discipline. While we do not

claim that our relatively small qualitative sample represents all students, we can take some recommendations from the NSF GRFP population that has been deemed as having high potential to contribute as a future academic engineer. Further, this work also has ramifications for broadening participation in academic engineering, because if graduate advisors or instructors and mentors of undergraduate students can foster the development of these tenets of stewardship, students may be more likely to pursue or thrive in graduate school. The table of ways that the three tenets manifest can also serve as ideas for mentorship and ways to encourage promising undergraduate students to begin to enculturate themselves in the expectations and norms of the academic community, such that graduate school may not be as big of a shock, thus reducing some of the more outrageous attrition rates particularly for traditionally underrepresented minority groups..

This work also relates to our research group's and other groups' past work in engineering graduate attrition, which has found that graduate students who have identities that are seemingly "at odds" with each other may tend to consider departing from their graduate programs. Kajfez' past work [31], [32] explored competing identities in teaching assistants as they balanced their roles in graduate school. Similarly, in our recent work [33], we found that students who are considering departing from graduate school often feel like they have sacrificed an identity that is core to them through their time in graduate school, and until they can reconcile or bring together those identities, they tend to strongly consider departure from graduate school, no matter how academically gifted. Participants in this study showed a distinctive lack of conflict between their core identity and their position as a graduate student in their chosen field. Follow up research would be useful to examine if graduate programs can cultivate the sense of academic stewardship seen in this data set within graduate students *after* they have begun their program but was not part of the original research design.

In conclusion, the corpus of 50 NSF GRFP winners' personal statements investigated in this research show a complex mosaic of experiences that led each participant to pursue graduate study. Stewardship Theory was used as a framework to examine each awardee and understand how they became caretakers of their chosen discipline. In each essay, participants began by demonstrating how they became consumers and guardians of the engineering knowledge imparted to them. They transitioned to showcasing how their personal motivation led them to start contributing back to their field of interest. Whether their primary motivation for graduate study originated from a desire to impact the living condition of others, to educate the next generation of STEM students, or to discover the next technological advancement, each participant also demonstrated how their knowledge and understanding of their field was shared with those around them. Their unique essays tended not to focus on how much they would personally benefit from graduate school or the NSF GRFP. Rather the focus of their petition was external and distinct from their immediate self-interest. The participants used their personal statements to illustrate how their knowledge would be used on the behalf of others or society. They treated the engineering profession, and the knowledge therein, as something they were entrusted with and felt comfortable assuming ownership of as they advanced towards their goals, showing their potential stewardship of the engineering discipline. Our findings have implications for graduate school education at the undergraduate and graduate level. As the health of engineering education continues to be monitored it is worth examining if programs are setting out to accomplish what the GRFP applicants are required to demonstrate, namely academic stewardship.

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