120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #5759

Designing a Survey Instrument for a National Study of Direct-pathway and Returning Engineering Graduate Students

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Abstract

Though a majority of engineering PhD students begin their doctoral career shortly after completing an undergraduate degree, what we call direct-pathway students, a significant minority of students are "returners," students who pursue a PhD after working outside of academia for five or more years. In the first phase of a three year NSF-funded study to characterize the population of returning engineering PhD students, we developed a nationally-distributed survey to compare experiences and perspectives of returners and direct-pathway students. The survey development was grounded in Eccles' Expectancy Value Theory (EVT), as well as literature on returning students and a pilot study. The survey included questions about students' motivation for returning, their previous work and school experience, their future career plans, the challenges of graduate school, and their strategies for adapting to these challenges. This paper presents the development of the survey, in which we highlight best practices from the literature that informed the development and refinement process. We show iterations of the survey and data from the advisory board and our cognitive interviews that informed the final version of the instrument.

I. Introduction

We define *returners* as students who spend at least five years working as practitioners between completing their undergraduate degree and enrolling in a graduate program. In engineering and other STEM PhD programs, graduation age data suggests that a majority of doctoral students are *direct-pathway students*, students who enroll in a graduate degree almost directly after completing their undergraduate work[1]. Though returners are a minority of engineering doctoral students, their unique background and experiences make them an important group to study for a number of reasons:

1. Returners represent new pathways to engineering graduate education. Highly trained engineers are critical to continued competitiveness in our global economy but there are currently too few students enrolling in engineering graduate programs[2]. The National Science Foundation has called for additional pathways to and through engineering programs, and returners represent one such pathway[3].
2. Returners bring a different perspective to their graduate work as well as their post-graduate endeavors than their direct-pathway peers. They have experiences in a variety of contexts, which often includes previous work in academia, industry, military, or government in addition to their graduate work, which may influence their research and research outcomes[18]. Research and theory describe the connection of ideas from across various contexts as an important source of innovation[4].
3. Returners contribute to the diversity of the university community. Diversity has been linked to a variety of positive outcomes including: increased innovation, enhanced problem-solving capacity, and broader perspectives[5,6,7,8,9].
4. Returners previous work experiences provide the opportunity for more immediate practical applications of their graduate research. Because returners are likely to reenter the work force in a higher position than those without previous experience and also bring

this understanding of work as a practitioner to their graduate work, the potential increases for the applications of their research to be more immediate and direct[10].

Because returner status is not a tracked demographic, there are few data about the size and composition of this group, aside from data on the average age at graduation, which suggest most graduate students in STEM fields begin their graduate work at a relatively young age[1]. Local university data suggest returners are indeed a minority of engineering graduate students. Consistent with this lack of demographic data, to date very little research exists about the experiences, motivations, and perspectives of returners, particularly in engineering. In order to be able to support the success of returners and ensure graduate programs become a more accommodating and appealing option for current engineering practitioners who wish to seek additional education, we must first gain a greater understanding of returners' values, motivation, costs, and experiences related to their graduate studies. This greater understanding is critical to ensure universities are able to best utilize returners' perspectives, knowledge, and skills.

Our research is aimed at addressing this need for a greater understanding of returners' graduate school experiences and perspectives. This paper demonstrates a rigorous approach to the survey development of what we call the Graduate Student Experience and Motivations Survey (GSEMS). We discuss how theory and research grounded survey development, the multiple phases of pilot testing, and provide example of iteration on the instrument. This rigorous approach to survey development helps to ensure that the survey is coherent, comprehensive, and valid in the constructs necessary to answering our research questions.

II. Background

Very little research exists on graduate-level returners, particularly within the field of engineering. However, there is research on adult students at both the undergraduate and graduate levels and on the experiences of other underrepresented groups that provides a useful starting point for our study. These studies indicate that there are multiple differences between direct-pathway and returning students; returning students are often more goal-oriented[11, 12], more motivated and mature, have stronger teamwork skills[13], and generally display a high work ethic[12]. Returning students also face unique challenges, including: a different work style than many of their peers[14], a lack of mentoring and information about applying to and enrolling in graduate programs[12], less recent practice with advanced mathematics[12], a reduced chance of receiving fellowships and research and teaching assistantships[15], and have additional demands on their time for family responsibilities such as child care or care for aging parents[15]. In engineering programs specifically, research suggests that returners may perceive these programs as less welcoming and have reported experiencing feelings that they do not fit with the rest of the graduate population[14]. Conrad, Haworth, and Miller[16] found that the teaching approaches used within a graduate program significantly affected students' satisfaction with the experience and could influence their decision to stay enrolled in the program. These findings are consistent with the principles of the field of andragogy, or adult education, which is grounded in the idea that the education of adult students can and should look different than education for younger students, due to adults' different preferences and motivations for learning[17].

Because returners have different educational needs than direct-pathway students and yet such little research exists on returners, we began to collect data, starting with a pilot project in which we interviewed ten returners. The participants included six men and four women. They had a

variety of different types of work experience in industry, government, and educational settings, were in various stages of their graduate career, and covered an age range from 26 to 45. Many of the participants expressed experiencing academic challenges in their return to graduate school including forgetting information they had learned in their undergraduate education, difficulty finding study partners, and courses that covered material they already knew through their jobs prior to graduate study. These returners also described struggles due to their many responsibilities outside of their academic work, including family, community involvement, and their personal health. Participants also cited the financial costs of lost income while out of the workforce and difficulty finding funding. Many of participants also indicated they had challenges related to adjusting from a work environment to a university environment, including the different expectations, norms, and status of students[18, 10]. This pilot work formed some of the foundation in the development of an instrument for a larger study.

The Graduate Student Experiences and Motivations Survey is the first of three phases within a larger 3-year, multiple phase study of returners. The study phases include 1) characterizing this population as compared to direct-pathway students and developing a better understanding of their experiences and motivations through a national survey, 2) understanding how both returners' and direct-pathway students' previous work interacts with their graduate research through in-depth interviews and focus groups, and 3) documenting stakeholder views from industry, academia, and government and university institutional policies that relate to returning students' experiences and decisions to return. We aim to use our study findings to inform efforts to better recruit graduate returners, support these students during their academic career, and better utilize their unique talents and perspectives.

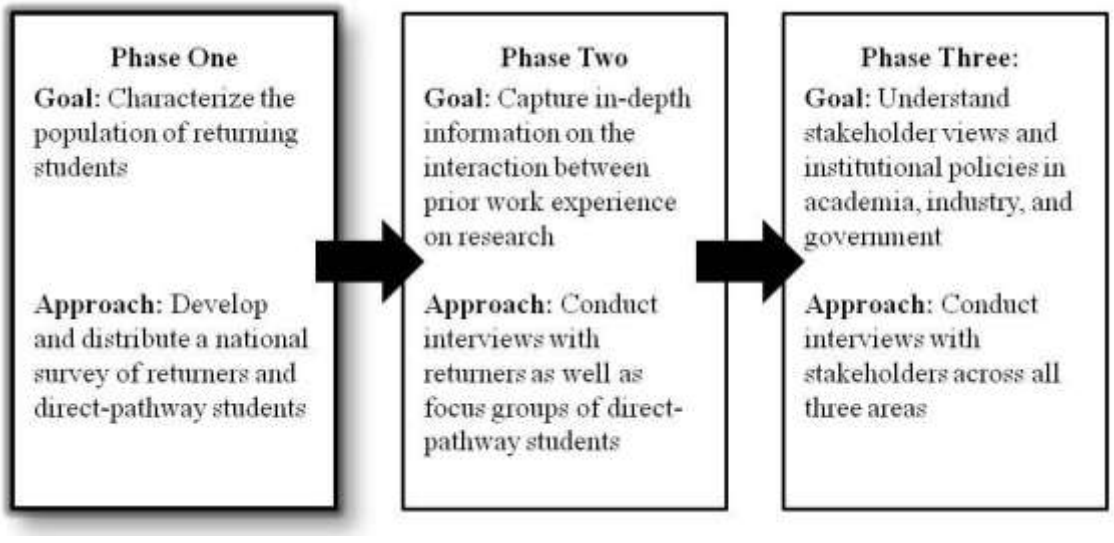

Figure 1: Study Phases

Figure 1 represents all three phases of the study and the approaches used in each. Though this paper focuses exclusively on the current (first) phase, it is our goal that our efforts across the three phases will culminate in a better understanding and support of returning students.

III. Research Goals

The Graduate Student Experience and Motivations survey aims to identify common themes in the perceptions and graduate school experiences of a diverse population of returning graduate students and how their perspectives and experiences compare to those of direct-pathway graduate students. This survey aims to improve our understanding of why both groups of students choose to pursue a PhD, what their experiences during the course of completing the degree are like, and what they plan to do upon graduating. Specifically our work is guided by the following questions for both returners and direct-pathway students:

- How do students' perceptions of graduate school compare?
- What influences students' confidence in their ability to succeed in their PhD?
- What motivates students to enroll in an engineering PhD program?
- What aspects of earning a PhD do students most value?
- What costs do students experience during graduate school?
- What strategies do students use to reduce these costs?
- What do students plan to do after completing a PhD?

IV. Survey Development Process

The final version of the survey distributed to participants was the result of months of development and revision. The survey was carefully designed to address our research objectives in a clear and comprehensive manner. Development of the survey was an iterative process that involved input from a variety of researchers, advisors, students, and stakeholders. The survey is grounded in Eccles' Expectancy Value Theory[19] and based in part on a cost framework that emerged from our pilot project.

A. Expectancy Value Theory

Eccles'[19] Expectancy Value Theory (EVT) is a framework that explains how and why people make choices based on the expected results of those choices, the costs required to make the choice, and their own interests and values. EVT suggests that behavior is a result of one's belief in their ability to achieve a goal and the value he or she places on achieving that goal. Eccles[19] identifies four types of values:

- Interest value: the individual's anticipated enjoyment of engaging in the activity
- Attainment value: the individual's perception of how the activity contributes to the conception of who he or she is fundamentally
- Utility value: the individual's perception of the advantages that result from engaging in the task for future goals or rewards
- Cost: the individual's perception of the sacrifices required, including effort, time, and psychological impact

We used this theory to scope out the types of questions we would in our survey to understand students motivations to enroll and persist in graduate school. Examples can be seen in Table 4.

B. Preliminary Research

In our pilot work, three initial interviews were analyzed using an inductive framework, allowing us to identify emergent themes. The three interviews were each analyzed separately, with several themes identified for each individual case, and then they were analyzed as a group to identify cross-case themes. These themes were then grouped based on the various aspects of the returners' identities. In analyzing the data for themes, we saw that participants were concerned with the challenges and sacrifices that would be involved in obtaining their graduate degree[18, 10]. Given this focus on the value of the degree and the cost of obtaining it, it became evident that EVT would be well suited for further investigations of the decision to return and persist. Thus in our follow-up analysis of interviews with ten returners, we used the EVT.

This analysis showed that the strongest value driving the decision to return was utility value, as opposed to attainment and interest values[20, 10], and also that the cost of the degree (both financial and non-monetary) was significant in the decision process. An inductive approach was used to investigate both the types of utility seen by the participants and the types of costs[20, 10]. It was found that there were three main components of utility value for the participants: to transition from their current career path into an academic career path, to change the focus of their industrial career into a new specialty area, and to advance further along their current career path[20]. In the analysis of cost, it was seen that the costs experienced by participants could be grouped into four categories: intellectual costs, financial costs, balance costs, and cultural/environmental costs[10]. The participants also developed cost reduction and mitigation strategies, which could likewise be grouped into these four categories. A few examples of the types of costs and cost reduction strategies are shown in Table 1.

Table 1: Cost, and cost reduction and mitigation strategies

Category	**Cost**	**Cost Reduction and Mitigation Strategies**
Intellectual	• Need to re-learn material • Difficulties working with or finding study groups/partners	• Finding good resources for re-learning material • Actively seeking out study groups
Financial	• Cost to pay tuition • Lost wages while in school	• Finding fellowships and scholarships • Reductions in personal expenses
Balance	• Less time for family • Less time for community involvement	• Preparing family for the experience • Maintaining some reduced involvement in the community
Cultural/Environmental	• Feeling of being "demoted" • Learning a new culture at the university	• Establishing a support system • Establishing common ground with other students

These frameworks provided structure for our survey: the survey examined students' recalled confidence in their ability to successfully complete a PhD prior to enrolling as well as during the course of their PhD program and what contributes to this confidence. It also included sections on students perceived values of pursuing a PhD, as well as the anticipated and actual costs/concerns and the strategies they use to help reduce the impact of these costs.

C. Survey Development

The development of our survey included numerous phases of review and iteration. First, members of our research team individually drafted questions based on the EVT as well as a review of the literature on adult, returning, and engineering students, their personal interactions with returning and direct-pathway students, and their own perceptions and experiences. Several members of the research team compiled the individual questions into one document organized by topic that became the first draft of the survey. This enabled us to identify gaps in the survey and to compare and combine similar questions. Our team met periodically to discuss and revise the survey during this stage, evaluating it for clarity, comprehensiveness, and relevance to our objectives. The diversity of our team, which included the graduate chair of one of the engineering departments who worked with many direct-pathway and returning graduate students, a former "returner" who worked in industry prior to completing her PhD, a faculty member in engineering education, and a student affairs professional within the College of Engineering, provided a range of expertise as related to research on the returning and direct-pathway student populations.

The literature on survey design guided our development of the instrument; we were very deliberate in considering order, word selection, and the purpose of each question. Best practices in survey design include pre-defining the information desired and avoiding peripheral questions, and writing precise, clear, relatively short items using natural language[37, 38]. We also carefully considered rating scales, using fully anchored scales that have descriptive words tied to each number or level of the scale, typically using a five-point scale for most questions (literature suggests no more than six or seven levels to ensure there is an actual difference between adjacent points)[37,38]. For some question types, such as those for ethnicity and future plans, we chose checklists to allow for multiple responses, but for most questions we included a response scale for each category[37].

Built on the best practice described the in the previous paragraph, and after multiple rounds of revisions, we asked our advisory board to review a draft of the survey. The advisory board consisted of three members, one representing a government perspective, one representing an industry perspective, and one representing an academic perspective. Our advisory board member in academia is and also works at a university with a high returner population. We asked our advisory board to draw on their professional expertise to provide survey feedback including:

- Are the various questions (and question options) about the decision-making process, values, costs, and cost-reducing strategies comprehensive based on your knowledge about graduate student experiences?
- Do you see any questions that seem unnecessary?
- What questions are ambiguous or unclear? Do you have any suggested improvements for these?
- What do you think about the length of the survey?

- Do you have any concerns about the survey design?

Our advisory board did not find significant problems with the survey and made several suggestions for improvement. We revised our survey to reflect this feedback. See Table 2 for examples:

Table 2: Examples of advisory board feedback

Original Version	Suggestion	Revised Version
Strategies used to reduce concerns did not include a mention of the advisor	Add question about advisor to this section	Added question about advisor as a source of support
"Please estimate the average time you spend on each activity below during an average work day (Monday through Friday)"	Measure these based on work week total, rather than by day	"Please estimate the average time you currently spend on each work-related activity below during an average work week (Monday through Friday, including evenings)"
Funding sources did not include option of employer funding for degree	The military and some businesses cover the cost of a graduate degree	Included employer as a source of funding

After revising our survey based on our advisors' feedback, we piloted it with current graduate students. We emailed approximately 40 current PhD students in chemistry and physics whose contact information was publically available on the university website and offered them the opportunity to participate in our pilot. Of those 40, six students elected to participate in this round of survey piloting. Three pilot participants were direct-pathway students and three were students who had returned to pursue a PhD after spending some time in the workforce. This allowed us to gain the perspective of students in a STEM discipline without including any potential participants in our pilot. Each pilot session lasted approximately 1.5 hours and participants were compensated $30 for their time.

We utilized a think-aloud cognitive interviewing technique to ensure the survey captured these students' experiences as well as to check for relevant components of measurement error identified by Collins[21], which include:

1) *comprehension problems*, resulting from vocabulary, unclear task, and/or sentence structure

2) *validity problems*, resulting from multiple interpretations of a question or interpretations inconsistent with intent

3) *processing difficulties*, resulting from difficulty retrieving the information to answer a question

The think-aloud method of cognitive interviewing requires participants to read each question aloud and verbally describe their thought process as they answer each question. A facilitator briefly introduced the study, explaining the nature of the study and the think-aloud cognitive interview testing procedure. The facilitator allowed the students to talk through each question, prompting them when necessary to obtain answers to the following questions:

- What do you think the question means?
- What you are thinking about when you consider an answer?
- Does the question reflect your experience?
- How easy is it to answer the question?
- Why did you select the choice you did?
- Why you did not select the other choices?

Participant feedback was carefully noted by the researcher and then complied for all participants and organized by topic. This allowed our research team to compare feedback and easily recognize common difficulties or suggestions. Feedback from the pilot participants included suggestions about the survey flow, format, and content. Specifically, students suggested additions to the options provided for various questions, so that these choices reflected their experience. Several students also made suggestions that several of the longer question blocks be separated into shorter, more manageable blocks or separate pages. Participants also identified several questions that they felt were not clearly worded and suggested alternate wordings. This feedback proved to be valuable information that aided us in reducing potential measurement errors stemming from comprehension, validity, and processing difficulties. The following is an example of how the survey was revised based on feedback from the pilot:

Table 3: Pilot feedback

Original Version	Feedback	Revised Version
"Please indicate how important each of the following factors are related to the value of earning your PhD"	Question is confusing, make it clear that this question is asking about how important the various possible benefits of a PhD are to you	"Please indicate how important each of the following factors are as benefits in earning your PhD"
Original Scale: "Very unconcerning," "Somewhat unconcerning," "Neither concerning nor unconcerning," "Somewhat concerning," "Very concerning"	Scale is confusing: "Neither concerning nor unconcerning" is same as "Very unconcerning"	Final scale: "Not at all challenging," "A little challenging," Somewhat challenging," "Challenging," "Very challenging"
One question about influence of advisor	An advisor can have a huge (positive or negative) impact on confidence, feeling supported, success, and retention.	Added a section on advisor relationship, effectiveness

After editing the survey based on feedback from the pilot, our team reviewed the survey to propose any final changes. Only several minor suggestions were made and after adapting the survey to reflect these suggestions, consensus was reached on the final form of the survey.

V. Summary of Final Survey Content

Expectancy Value Theory and the cost and cost reduction categories that emerged from our pilot project provided the framework for our survey, which focuses on the values returning and direct-pathway students assign to a PhD program and the costs associated with enrolling and persisting in the program. The survey includes questions about students' motivations for returning, their previous work and school experience, their future career plans, the costs of graduate school, and their strategies for adapting to these costs.

In addition to EVT and our pilot work, our survey content is based on our consultations with faculty members and current and previous PhD students as well as the literature on engineering students, graduate education, and adult learners. While we relied heavily on previous research in our survey design, due to the limited research on engineering returners, some of the questions were informed by the experiences of our team, our expert advisors, and the experiences of students in our pilot studies. The table below includes our survey sections, sample questions, and the literature that informs the questions within that section.

Table 4: Final survey sections and sample questions

Section Topic	**Sample Questions**	**Citations**
Demographic Information	• What is your gender? • What is your current age? • What is your citizenship status? • What is your relationship status? • How many children do you have?	N/A
Academic Background Information	• What year did you complete your undergraduate degree? • Have you completed a Master's degree? If so, when? • What was your undergraduate major? • What was your undergraduate Grade Point Average? • How did you score on the GRE?	Schilling, 2008[14]; Clark, 1984[22]
Current Academic Information	• What did you start your current PhD program? • Please indicate which of the following milestones have you completed in relation to your PhD research • Please estimate the average time you spend on class, homework, research, and other academic duties • What are your sources of funding?	N/A
Pre-PhD Activities/Career	• How long did you work in industry after undergrad? • To what extent was your undergraduate major relevant to your work experience prior to pursuing your PhD? • What best describes your most recent position prior to pursuing your PhD? • How would you rate your satisfaction with your career immediately prior to pursuing your PhD? • How long before making the decision to pursue a PhD had you received a promotion at your most recent position?	Peters & Daly, 2011[18]; Schilling, 2008[14]

Expectancy of Success in Graduate School	• Prior to beginning your PhD, how confident were you in your ability to successfully complete your degree?
	• How confident are you in your ability to successfully complete your degree?
	• Please indicate how each of the following as influenced your belief in your ability to succeed:
	  ○ Interaction with my graduate advisor
	  ○ Interaction with my peers
	  ○ Interaction with faculty
	  ○ Research progress
	  ○ Belief in my ability to complete the work
	  ○ Others' expressed belief in my ability
		Eccles, 2009[28]; Anderson & Swazey, 1998[23]; Bandura, 1977[29]

Decision to attend graduate school	• Who did you consult with about your decision to pursue a PhD? How supportive were they?
	• What factors were important to you in your decision to return?
	• How well do you feel the application process enabled you to showcase your personal strengths and experiences?
	• What sources of information did you use when selecting a graduate program?
	• What information was important to you when selecting a PhD program?
	  ○ Financial aid information
	  ○ Academic requirements
	  ○ Information about specific professors
	  ○ Information about the culture/makeup of the graduate student population
	  ○ Admissions requirements
	  ○ Surrounding community
		Anderson and Swazey, 1998[23], Stoecker, 1991[24], Peters & Daly, 2011[18]; Padula & Miller, 1999[25]; Mills & McCright, 1993[26]; Countryman, 2006[27]

Values of the PhD	Please indicate how important each of the following factors are related to the value of earning your PhD: Interest • Doing exciting research • Learning new things • Exploring interesting topics in greater depth • An opportunity to further explore my passions • Gaining teaching experience Attainment • Fulfilling my goal of obtaining a PhD in engineering • Benefitting others with my work • Achieving high goals I set for myself • The status of a PhD • Realizing my identity as a researcher and scholar Utility • The ability to advance in my career • Changing focus in my career • Having the credential of a PhD that enables me to obtain certain positions and opportunities • The prospect of a higher salary	Eccles, 2009[28]; Peters & Daly, 2011[18]; Mills & McCright, 1993[26], Padula & Miller, 1999[25]
Costs of the PhD	Please indicate the extent each of the items listed below has been a concern in your graduate experience: Financial • Price of tuition • Price of insurance • Change in financial security • Foregone salary • Loan debt upon completion Balance • Less time for family interactions, including children and/or a spouse • Less time for hobbies and personal interests • Regret about being unable to devote time to certain activities	Eccles, 2009[28]; Peters & Daly, 2011[18]; Schreyer Institute for Teaching Excellence, 2007[30]; Anderson & Swazey, 1998[23]; Aycock, 2003[31]; Padula & Miller, 1999[25]

	• Less time to take care of myself Intellectual • Needing to re-learn material for some classes • Difficulty finding study groups • Not feeling as smart as my peers • Spending time on topics I already knew about from past experience • Learning software programs necessary for my work Cultural /Environmental • Adjusting to a new environment/university culture • A change in professional status • Maturity of peers • Less structured chain of command • Relationship with faculty members	
Cost Reducers	Please indicate if you used any of the following cost-reducing strategies. If the answer is yes, please indicate how helpful the strategy was. Financial • Fellowships/scholarships • Graduate research assistantship • Household income • Student loans • Reductions in expenses • In-state tuition • Employer financially supporting degree Balance • Emotional support from family members • Help with household responsibilities • Getting advice on work/life balance • Maintaining my hobbies • Taking a lighter course load • Setting boundaries on my time • Doing academic work only on campus Intellectual • Attending professor's office hours • Working with my peers on schoolwork • Using online resources and other books • Joining academic organizations • Talking through material with my advisor Cultural /Environmental • Establishing a support network within my program • Having mentors talk about their experiences • A community of fellow PhD students with similar backgrounds • My advisor's understanding of my needs • My personal outlook on change	Eccles, 2009[28]; Aycock, 2003[31]; Padula & Miller, 1999[25]; Peters & Daly, 2011[18]

Advisor Relationship	• Please rate how effectively you feel your primary advisor meets your individual needs in each: o Management style o Feedback on research o Personal supportiveness	Main, 2012[32]; Khiewnavawongsa & Schmidt, 2009[33]
Post-PhD Plans	• What do you plan to do upon receiving your PhD? • How would you assess your change in each of the following since beginning your PhD program? o Enthusiasm for my field o Technical Skills o Knowledge in my field o Confidence in my abilities	Peters & Daly, 2011[18]

The final survey was electronically distributed via the Qualtrics survey software. It was comprised of thirteen sections, taking participants approximately 30 minutes to complete. Participants were compensated $20 for their time.

VIII. Conclusion

The development of Graduate Student Experiences and Motivations Survey demonstrates a systematic approach to survey development, grounded in literature about survey development, and guided by best practices for establishing survey validity and reliability. Common methods of determining validity in order to ensure a study is credible include:

1. Triangulation: use multiple, different sources to inform the development of study themes or categories[34]
2. Disconfirming evidence: search for negative evidence that is inconsistent with themes[34]
3. Researcher reflexivity: researchers disclose personal biases, perspectives[34]
4. Collaboration: working closely with participants throughout a study to ensure their perspective is represented[34,35]
5. Peer debriefing: Review of the data and process by a peer familiar with the research method or topic[34]
6. Use measures that have already been tested in other contexts[35]
7. Conduct cognitive interviews[35, 21]
8. Audiotape interviews during survey pre-testing[35]

Nearly all these validity measures are evident in the development of our survey, with the notable exception of using or comparing against different, existing measures of a phenomenon, as no such measures exist. We also made the decision to take detailed notes, rather than audiotape pre-test interviews to ensure our participants' comfort. To establish reliability, we plan to measure split-halves reliability, in which the survey sample is randomly divided in two and the results are compared[35]. Rigor in survey development is also demonstrated by documenting the development process; an example of this thorough documentation of survey development can be found in another study on engineering decision making by Eris et al.[36], "Development of the Persistence in Engineering (PIE) Survey Instrument." The methods employed help to ensure the Graduate Student Experiences and Motivations Survey is a credible survey that can make a significant contribution to our understanding of the perspectives and experiences of direct-pathway and returning engineering graduate students.

Data collection closed in February, after several rounds of national recruitment. Analysis of the data is currently in progress. Results of the analysis of the Graduate Student Experiences and Motivations Survey as well as data collection and analysis outcomes of the subsequent phases of our study will be topics of future publications.

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