Perceived Advisor Support and Thesis Self-Efficacy: An Instrument Development

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Abstract

The path to degree completion for graduate students in engineering disciplines is fraught with challenges, but one factor that consistently shapes their persistence and success is their advising relationship. The way students perceive the support they receive from this relationship can influence their self-efficacy concerning the competences needed to finish their dissertation, thesis or applied project report. Understanding the relationship between the student's self-efficacy towards their culminating tasks and their perception of their advisor's support is essential, as from a motivational standpoint, it can serve as a closer proxy for degree completion.

This research paper presents the development and validation of the Advisor Support and Self-efficacy for Thesis completion (ASSET) survey, which measures two constructs: Thesis Self-efficacy and Advisor Support. The former measures graduate students' confidence to carry out activities to complete their final academic document, while the latter measures their perception of their advisor's support. Items for these constructs were adapted and generalized to be relevant to either doctoral or master's level students in engineering disciplines.

We collected survey responses from 170 engineering graduate students from a large public institution in the southwestern United States. Exploratory factor analysis yielded a single factor solution for the Thesis Self-efficacy construct, while Advisor Support yielded two factors, "Research support" and "Individualized support". Future work includes the dissemination of the ASSET survey to various graduate engineering programs, to further explore the predictive relationships between our constructs and help institutions create strategies for the success of both their graduate students and their faculty.

Introduction

Positive self-efficacy expectations, a person's beliefs in their abilities to achieve their goals, have been shown to be essential to academic persistence and professional success [1], [2]. As such, in efforts to stave off attrition from graduate programs, engineering graduate students' self-efficacy in the academic and research domains have received much attention from researchers [3], [4]. In recognizing that a students' self-efficacy is influenced by environmental factors outside of their control, the Social Cognitive Career Theory (SCCT) posits that a student's career and persistence intentions can be influenced by the supports or barriers that they perceive as they advance in their program [1], [5]. As the impact of the advisor-advisee relationship has been continuously shown to be instrumental to a student's success [6]–[8], it follows that it will directly influence the advisee's self-efficacy beliefs that can ultimately help them graduate successfully.

While significant work has examined the advisor-advisee relationship [6], [8]–[12], there is a gap in the literature concerning how specific types of support offered by the advisor can influence graduate students' self-efficacy towards their ability to successfully complete a thesis or dissertation in an engineering program. Investigating a student's self-efficacy towards the completion of their thesis or dissertation is crucial, as it could most closely proxy for degree

completion from a motivational perspective. Additionally, as engineering generally follows the "science model of advising", where advising relationships are characterized by close collaboration in research projects [6], [8], this relationship becomes a critical contextual to a student's success. Thus, the purpose of this study is to develop a survey instrument that can serve as a tool to relate engineering graduate students' thesis self-efficacy to their perception of their advisor's support. Drawing on previous work that explored the constructs of "Dissertation Self-efficacy" [13] and a student's perceptions of "Advisor Behavior" [8], the development of our instrument was guided by the research question: **What influence does the instrumental and psychosocial support that engineering graduate students perceive from their advisor have on their thesis self-efficacy? Using SCCT as our theoretical foundation, this work focuses on the development and validation of the *Advisor Support and Self-efficacy for Thesis completion (ASSET)* instrument with graduate students pursuing master's and doctoral degrees in engineering disciplines.**

Our resultant construct of *Thesis Self-efficacy* measures the confidence that a student has in their abilities to complete specific tasks that are key to the writing of their dissertation, thesis, or applied project report, while our *Advisor Support* construct measures a student's perception of the support they receive from their advisor in helping them progress to degree completion and preparing for a post-grad school position. Ultimately, the potential insights that our survey can provide might aid faculty advisors tailor their support in ways that will be impactful to the students' successful completion of their degree. In due course, such strategies could become a valuable asset in decreasing the attrition of engineering graduate students.

Context

The common structure of the engineering graduate school experience calls for an apprenticeship-style relationship between a student and a member of the faculty [14], [15]. This advisor-advisee relationship is one of the main ways in which a student is socialized into the academic profession as they learn the craft of research, networking in Academia, and other such skills from their faculty mentor [6], [16], [17]. It is, then, hard to overstate the importance of the advising relationship, which will have lasting effects on the student's current endeavors and future career [18], [19]. When it comes to the support they receive from their advisor, graduate students who feel supported are found to have a higher sense of belonging in their program, while their academic self-concept is also benefitted [20]. That same support has also been found to have a positive effect on the students' satisfaction with their experience in graduate school, further influencing their career choices [18], [21], and staving off attrition [22], [23].

A positive and successful advising relationship is paramount to the success of graduate students, especially to those who come from racial and ethnic underrepresented groups, as most go into graduate school having entered a space where they lack networks or personal connections that can share their cultural capital [24]–[27]. While these students consider factors such as funding, research interests, race, and personality when choosing an advisor [11], [28], it is difficult for them to assess how an individual's advising style might benefit them during these early conversations [29]. Additionally, the advisor's attitude and behavior towards non-academic challenges that may arise in the personal life of the student, such as family relationships and

challenges, can mitigate or exacerbate the impact that such circumstances can have on students' academic persistence [7].

Since the dissertation, thesis, or applied project report are the keystone of the graduate school endeavor, here too the advising relationship will undoubtedly play a major role in students' success. SCCT suggests that a person's ability to fulfill a task is based on their self-judgment of their capacity to complete it, which is influenced by the supports or barriers they find in their environment [1]. Consequently, during their advising relationship the students experience influential factors, such as verbal encouragement from their faculty supervisors, which can help them have greater confidence in regards to their abilities to conduct and report research [30]. Indeed, doctoral students who receive constructive feedback and regular encouragement from their advisor have been shown to have improved dissertation skills, which are essential to their final progress and completion of their degree [23]. The same has been found in relation to the students' beliefs on their own research-related abilities at both the masters and doctoral levels, where advisor support has been linked to the development of their research self-efficacy [4], [30]. However, while the work on research self-efficacy is informative, self-efficacy is not a global trait, but is rather linked to particular domains of performance [1], [31], [32], and thus a measure of a students' self-efficacy towards the writing of their dissertation, thesis, or applied project report can be considered a better motivational predictor to the completion of their degree [13].

Theoretical Framework

SCCT serves as a theoretical foundation that weaves together the *Thesis Self-Efficacy* and *Advisor Support* constructs present in this study. While the Social Cognitive Theory advanced by Bandura [31], [32] is at the heart of this framework, SCCT builds on it by taking into account the various contextual variables that can influence a person's career choice and development, including the end goal of activities related to vocational interest, as well as the support of the environment that surrounds them [1]. In short, the theory posits that career and academic goals, and an individual's actions to reach them, are influenced by self-efficacy beliefs, which are in turn influenced by the expectations of positive outcomes and received support.

SCCT has successfully been applied to study graduate students' motivations for persistence, and the factors that influence their success. Maher et al. (2020) used SCCT to understand the departure of students from graduate programs, where they found that factors that influence a student's self-efficacy, such as advisor support, have a direct impact on their decision to continue or leave their program. In a similar manner, research by Wilkins-Yel et al. (2022) highlighted the importance of advisor support for the persistence of women of color as they dealt with personal challenges during their STEM graduate studies. These findings are important in light of the results of a study by Fitzpatrick et al. [3], which used the SCCT framework to reaffirm that the self-efficacy beliefs of engineering graduate students significantly influences their persistence. In all, these results are a clear example of how self-efficacy influences a person's career trajectory while being influenced in turn by environmental and personal factors.

As we set out to develop our instrument, the SCCT framework bridges the influence of perceived advisor support and the student's self-efficacy beliefs on their abilities to complete their

dissertation, thesis, or applied project report. We explore the construct of *Advisor Support* as part of the contextual influences that impact students' self-efficacy beliefs, as measured by our *Thesis Self-Efficacy* construct. Following the precepts of SCCT, we can expect that graduate students' perceptions of the quality and content of their advisor's support will have an impact on their thesis self-efficacy, and ultimately their academic and professional success [5].

Methods

This study adapted and implemented constructs found in two survey instruments to explore our research question. The resultant survey was deployed through the QuestionPro online platform and was answered by a total of 175 graduate students at the doctoral and master's level. The data obtained was used to conduct an Exploratory Factor Analysis (EFA) on the instrument, which yielded one factor for the *Thesis Self-efficacy* construct, and two factors for the *Advisor Support* construct.

Survey Instrument Development

Our survey was developed by adapting two existing scales to our research question and context, namely the Dissertation Self-Efficacy Scale (DSES) [13] and the Advisor Behavior scale [8]. The DSES scale was adjusted to be relevant to either doctoral or masters' students in dissertation, thesis, or applied project tracks and, with 14 total items, was renamed *Thesis Self-efficacy*. The decision to generalize the items to doctoral or masters' students can help generalize our survey for use at MSIs, where a recent nationwide study showed that 89% of graduate degrees awarded at these institutions are master's degrees [34]. The Advisor Behavior [8] scale was adapted to reflect only those items related to the students' perception of their advisor's support in alignment with our SCCT lens, to explore how this dimension of the graduate student experience, over which they have no control, relates to their self-efficacy beliefs; with 18 total items, this construct was renamed *Advisor Support*.

Importantly, students filled out both the *Thesis Self-efficacy* and *Advisor Support* scales as part of the same survey, but these scales were presented in separate parts of the survey with their respective set of instructions. The original survey items, including instructions given to the participants, can be found in the Appendix. We gauged the face validity of the instrument with input from four engineering doctoral students, including one student whose first language is not English. The feedback received was centered on the clarity of the survey instructions, where the most significant improvement made at this stage was the change of scales for the first construct. Whereas *Thesis Self-efficacy* was initially designed to be answered on a 0-100 confidence scale following the DSES from which it was adapted [13], we ultimately adopted a 5-point scale for this construct, from "Completely confident" to "Not confident at all" [35]. This decision was based on student feedback that numbers such as "50" or "60" on a 0-100 point scale reminded them of a failing academic grade, rather than a moderate or neutral answer, and could interfere with their ability to accurately self-report their self-efficacy. *Advisor Support* did not require any changes in this respect because it was designed to be answered on a 5-point Likert agreement. No other changes were made to the *Thesis Self-efficacy* or *Advisor Support* scales as a result of assessing face validity.

Content validity was sought from researchers with expertise on self-efficacy measurements and graduate student advising. Two members of the engineering education faculty at a research-intensive institution accepted the invitation to provide their feedback on the constructs and were provided with the adapted survey instrument. These experts were provided with a review sheet to rate how suitable they believed each item was to the construct it was measuring. As reviewers, they also had the liberty to provide suggestions for the improvement of the survey instrument. The resulting feedback was centered on the improvement of the language used to describe tasks or behaviors, while making them generalizable to students in both PhD and masters programs. When all received feedback from both experts and students was addressed, the survey was deployed.

Participants

The participants in the study were actively enrolled engineering graduate students recruited from a public research-intensive institution in the Southwestern United States, which was chosen for convenience. Our recruitment efforts yielded a total of 175 participants, out of which 37 were doctoral students and 138 were master's students in various engineering disciplines. Out of these, 56 students were in different stages of writing a thesis or dissertation, while the remaining 119 students were working on applied project reports. 69 of our participants self-identified as female, with the remainder identifying as males. Finally, our participants came from varied disciplinary backgrounds, which included mechanical engineering, electrical engineering, civil engineering, industrial engineering, computer science, systems design, and engineering education among others.

Data Collection

Collaboration was sought with various engineering departments in the institution to reach the desired study population. Specifically, invitations to the survey were sent to engineering graduate students through mass e-mail communications from the graduate advising offices. Students who were interested in participating could access the online QuestionPro survey through a link shared in the invitation. As a further incentive, all participants who reached the end of the survey had the opportunity to enter a drawing for one of ten $20 gift cards. The survey was active for a period of about four weeks; participants had to reach the end of the survey to be used in our analysis. All data collection and recruitment for the study were done with previous IRB approval.

Data Analysis: Construct Validity and Reliability

EFA is an item-reduction technique that identifies the factor structure that explains the most variance in participant response pattern across the fewest number of common factors; each factor represents a single, unique dimension within the latent construct being measured [35]. We ran a separate EFA on each construct to determine how items loaded together onto factors and which items should be removed. For consistency, we followed the EFA process as outlined by McCoach et al. [35, p. 115-116]. Accordingly, our data met all key assumptions in preparation for the EFA for instrument development. With a total of 175 participants, we had about 12 participants per item for our *Thesis Self-efficacy* construct, and about 10 per item for our *Advisor Support* construct, meeting the recommended sample size requirements for EFA [35].

Three analytic tests were used to determine the number of factors to extract for each construct, namely Parallel Analysis, Kaiser's Criterion, and visual analysis of the generated Scree Plot. Following this, factors were then extracted using principal axis factoring; the oblique rotation technique with Promax was used as it allows for factors to be correlated, a common occurrence in social sciences. Items were retained of a factor if they had a factor loading ≥ 0.32 on one factor and a loading of < 0.32 on all other factors [36]. Reliability analysis included the calculation of Cronbach's alpha for each of the identified factors, the use of Inter-item Correlation Matrixes to verify that items fell within the correlation range of 0.30-0.80, and the verification of the inter-item variance (< 0.01) for the extracted factors [35]. These last steps were repeated as needed to obtain a high level of internal consistency for each of the factors extracted. The results of the analysis yielded one eponymous factor for the *Thesis Self-efficacy* construct, and two factors for the *Advisor Support* construct, namely *Work-life Balance* and *Career Development*. Finally, our survey answers did not contain missing data, and thus no remedial methods were used in this respect with the data obtained.

Results

Exploratory Factor Analysis: Thesis Self-efficacy

EFA was conducted on the 14 items used to measure *Thesis Self-efficacy* on the survey. With a Kaiser-Meyer-Olkin (KMO) sampling adequacy of .954, and the Bartlett's test of sphericity significant at the $p < .001$ level, our sample dataset was deemed to be appropriate for EFA [35]. When using analytic tests to determine the number of factors to extract, these tests did not reach a consensus, where the Kaiser's Criterion method and visual analysis of the generated Scree Plot suggested a two-factor construct, but the Parallel Analysis suggested a one-factor solution. We explored both a one-factor and two-factor solution, accordingly, but because the two-factor solution did not show a clear difference in their constructs related to *Thesis Self-efficacy*, the one-factor solution was favored. We then used principal axis factoring to extract the one factor, and the resulting factor loadings were examined and found to be above the minimum threshold magnitude of 0.32. For simplicity of analysis and reporting, we named the factor after the construct, i.e., *Thesis Self-efficacy.*

Following this, Cronbach's alpha was calculated and demonstrated a high level of internal consistency reliability ($\alpha = .956$). In addition, all correlations between the 14 items were within the acceptable range of 0.3-0.8, and the Inter-Item variance was .006. Table 1 presents the result of the EFA for the *Thesis Self-efficacy* factor, namely, each item and its factor loading; it shows that all 14 items first used in the survey remained as part of the construct.

Table 1 Final Factor solution for Thesis Self-efficacy construct

Items	Factor
	Thesis Self-Efficacy
1. Select a suitable research topic for study	0.766
2. Formulate a research question(s) or problem statement(s) for study	0.766
3. Select an appropriate research design for a study	0.838

Items	Factor
	Thesis Self-Efficacy
4. Describe the purpose and importance of a study	0.805
5. Collect data or field notes for a study	0.755
6. Review and synthesize the scholarly literature in your area of study to write a Literature Review	0.754
7. Select the appropriate quantitative or qualitative analysis methodology to address a research question	0.839
8. Clearly explain the methods you used to address a research question	0.815
9. Run or apply the appropriate quantitative or qualitative analysis to address a research question	0.799
10. Interpret the results obtained from a quantitative or qualitative analysis	0.850
11. Discuss your interpretation of a quantitative or qualitative analysis	0.792
12. Clearly present the results obtained in a study	0.815
13. Work with your graduate advisor(s) for needed help and support	0.745
14. Approach other researchers in your topic area for assistance	0.632

Exploratory Factor Analysis: Advisor Support

When conducting the EFA for the *Advisor Support* construct we included all 18 items presented to the students. With a KMO sampling adequacy of .929, and a Bartletts test of sphericity significant at the $p < .001$ level, our sample was shown to be suitable for EFA. As with the *Thesis Self-efficacy* construct, the analytic tests used to determine the number of factors to extract did not yield a clear consensus. However, a two-factor solution was favored, as the resulting factors represented separate constructs related to different and distinct aspects of the advising relationship between a faculty member and a graduate student. These two factors were extracted using principal axis factoring and an oblique rotation approach with Promax. An inspection of the factor loadings found that the survey items "Is attentive and responsive to my needs" and "Teaches me skills needed in my field" cross-loaded with values above the 0.32 threshold across both factors; these items were removed from further analysis. Upon repeating the extraction process, all the resulting factor loadings were found to be above the minimum threshold magnitude of 0.32, with no further cross-loading issues.

The reliability analysis for Factor 1 of the *Advisor Support* construct showed a high level of internal consistency, with a Cronbach's alpha of .938, and an Inter-Item variance of .002. An exploration of the Inter-Item Correlation Matrix showed all 6 items had correlation values within the acceptable range of 0.3-0.8, so no items were removed from the factor. On the other hand, when evaluating the internal consistency of Factor 2, the generated Inter-Item Correlation Matrix showed that the item "Cares about me as a whole person, not just as a scholar", was closely correlated (> 0.8) to other items within the factor. Upon closer consideration, it was found that this item addressed concepts present in other items and, as such, the decision was made to remove it. No further issues were found in the Inter-Item Correlation Matrix. The resulting final construct for Factor 2 had a total of 9 items and a high level of internal consistency, with a Cronbach's alpha of .941 and an Inter-Item variance of .005.

Table 2 presents the final factor loadings for the *Advisor Support* construct. We name the first factor *Research Support,* a construct that covers the perceived assistance from a faculty advisor in matters regarding research and degree progress. The second factor we named *Individualized Support*, with items that show the perceived level of care, rapport, and individualized counsel received by the students as their advisor helps them develop into future professionals.

Table 2 Final Factors for Advisor Support Construct

	Factor	
Items	Research Support	Individualized Support
1. Gives me regular feedback on my research	**0.885**	
2. Is available when I need help with my research	**0.934**	
3. Gives me constructive feedback on my progress toward degree completion	**0.779**	
4. Is available when I need to talk about my progress in my program	**0.820**	
5. Teaches me the details of good research practice	**0.638**	
6. Provides information about ongoing relevant research	**0.769**	
7. Takes an interest in my well-being and life-work balance		**0.539**
9. Provides emotional support when I need it		**0.658**
11. Has my best interests at heart		**0.544**
12. Would support me in any career path I might choose		**0.588**
13. Helps me secure funding for my graduate studies		**0.693**
14. Teaches me to write grant and contract proposals		**0.983**
15. Helps me develop professional relationships with others in the field		**0.798**
16. Assists me in writing presentations or publications		**0.792**
18. Advocates for me with others when necessary		**0.753**

Discussion

This study made use of EFA methodologies to develop and validate the *ASSET* survey instrument. The first EFA explored the *Thesis Self-efficacy* construct, where further analysis yielded a single factor for the proposed items. Though the survey items were adapted to better serve our target audience, where our participants were not only in a thesis or dissertation path but also included students who were writing an applied project report, this result is consistent with the one-factor solution found in the validation of the DSES [13] on which the *Thesis Self-efficacy* scale was based. As the concept of self-efficacy is not a global one, but specific to a performance domain [1], [31], our analysis confirms the items present in the construct are measuring different aspects of the writing of an academic document to report work performed in a rigorous scientific environment. Thus, the one factor solution describing the students *Thesis Self-efficacy* is consistent with the underlining theory of self-efficacy [31], [37] as it looks at tasks that belong to the specific domain of writing a thesis, dissertation, or project report .

When exploring the construct of *Advisor Support*, the analysis yielded two factors, marking a departure from the work by Zhao et al. [8], whose results yielded an *Advisor Behavior* construct comprised of three different factors. However, the scope of this work was not to serve as a confirmatory exploration of past results, but as an adaptation of the constructs to better serve our

target audience of engineering graduate students. Our *Research Support* construct suggests that engineering graduate students perceive the support they receive from their advisor in areas related to their research work as separate from other types of support, in accordance with previous findings on research and writing support [38]; because researchers have found that graduate students often bring intrinsic research motivations to their pursuit of a graduate degree, they might perceive a direct contextual support in this area as distinctly important [1], [39]. Thus, our *Research Support* is representative of how students perceive their advisor's behavior towards their research work as an essential area of support [14]. Our second factor for *Advisor Support* includes items related to students' perceived support from their advisor in the areas of professional skill development, financial security, and work-life balance, as well as their sense of connection to their advisor; we called this factor *Individualized Support*. Both of the factors that comprise the *Advisor Support* construct represent different perceived areas of the advising relationship that have been previously identified by other researchers when working with graduate students, where research writing-related support is found to be different from personal support [8], [9], [14], [38], further validating our EFA findings.

Limitations and Future Work

While the survey was disseminated at a large institution with various engineering programs, the sample considered in this study varies greatly by program and discipline. Thus, future work will see to the dissemination of our final instrument to engineering graduate programs at various institutions to obtain a larger, and more balanced, sample that will allow us to further explore the predictive relationship between our constructs more fully. In addition, a more balanced sample will allow us to perform tests of invariance to determine whether the constructs are consistent across groups (i.e., applied project students, thesis students, dissertation students, etc.) The use of additional demographic data will add context to our future work, which can help institutions create strategies for the success of both their graduate students and their faculty via the development of structured advising practices and policies. Where past research has shown that traditionally minoritized students tend to search for advising relationships with shared racial, ethnic or gender identities [29], [40], [41], our future work will look at how these relationships can also influence their *Thesis Self-efficacy*. Moreover, identifying survey participants as first-generation or continuing-generation students could add more nuance to our model, as it has been proven in the past that the students' expectations of graduate school can be influenced by this factor [42].

Conclusion

This initial dissemination and validation of the ASSET survey instrument demonstrated the viability of the adapted scales in the context of the engineering graduate student community. Our exploratory factor analysis on this dissemination showed two main findings. First, items related to graduate students' confidence in their capacity to carry out activities related to completing their thesis loaded as a single factor. Second, items related to graduate students' perceived support from their advisor loaded onto two factors: the first factor comprised items related to the advisor's support of their research work, which we termed "research support," while the second factor comprised items related to the advisor's personalized help with developing business and professional skills specific to the student's field, which we termed

“individualized support.” We believe that the future dissemination of our instrument may prove helpful in providing a quantifiable predictive relationship between the types of support students receive from their advisor and their beliefs about their abilities to write the document that will grant them their degree goal. In this manner, we also expect that these relationships may be further informed by the context and background of the students, leading to practical suggestions for developing productive advising relationships between graduate students and their advisors.

References

[1] R. W. Lent, "Social Cognitive Career Theory," in *Career development and counseling: Putting theory and research to work*, S. D. Brown and R. W. Lent, Eds., 2nd ed.John Wiley & Sons, Inc, 2013, p. 32.

[2] R. W. Lent, S. D. Brown, and K. C. Larkin, "Relation of Self-Efficacy Expectations to Academic Achievement and Persistence," *Journal of Counseling Psycology*, vol. 31, no. 3, pp. 356–362, 1984, doi: 10.1037/0022-0167.38.1.30.

[3] M. E. Fitzpatrick, S. G. Burrows, and J. A. Yonker, "An Exploratory Study of Engineering Graduate Student Persistence: Self-Efficacy and Contextual Influences," *Journal of Career Development*, p. 089484532211237, Sep. 2022, doi: 10.1177/08948453221123789.

[4] R. Livinţi, G. Gunnesch-Luca, and D. Iliescu, "Research self-efficacy: A meta-analysis," *Educational Psychologist*, vol. 56, no. 3, pp. 215–242, Jul. 2021, doi: 10.1080/00461520.2021.1886103.

[5] H.-B. Sheu, R. W. Lent, M. J. Miller, L. T. Penn, M. E. Cusick, and N. N. Truong, "Sources of self-efficacy and outcome expectations in science, technology, engineering, and mathematics domains: A meta-analysis," *Journal of Vocational Behavior*, vol. 109, pp. 118–136, Dec. 2018, doi: 10.1016/j.jvb.2018.10.003.

[6] L. Lunsford, "Doctoral Advising or Mentoring? Effects on Student Outcomes," *Mentoring & Tutoring: Partnership in Learning*, vol. 20, no. 2, pp. 251–270, May 2012, doi: 10.1080/13611267.2012.678974.

[7] K. G. Wilkins-Yel *et al.*, "Understanding the impact of personal challenges and advisor support on stem persistence among graduate women of color.," *Journal of Diversity in Higher Education*, vol. 15, no. 1, pp. 97–110, Feb. 2022, doi: 10.1037/dhe0000236.

[8] C. Zhao, C. M. Golde, and A. C. McCormick, "More than a signature: how advisor choice and advisor behaviour affect doctoral student satisfaction," *Journal of Further and Higher Education*, vol. 31, no. 3, pp. 263–281, Aug. 2007, doi: 10.1080/03098770701424983.

[9] J. L. Bloom, A. E. Propst Cuevas, J. W. Hall, and C. V. Evans, "Graduate Students' Perceptions of Outstanding Graduate Advisor Characteristics," *NACADA Journal*, vol. 27, no. 2, pp. 28–35, Sep. 2007, doi: 10.12930/0271-9517-27.2.28.

[10] B. Burt, A. McKen, J. Burkhart, J. Hormell, and A. Knight, "Racial Microaggressions within the Advisor-advisee Relationship: Implications for Engineering Research, Policy, and Practice," in *2016 ASEE Annual Conference & Exposition Proceedings*, New Orleans, Louisiana: ASEE Conferences, Jun. 2016, p. 26029. doi: 10.18260/p.26029.

[11] S. Joy, X. Fen Liang, D. Bilimoria, and S. Perry, "Doctoral Advisor-Advisee Pairing in STEM Fields: Selection Criteria and Impact of Faculty, Student and Departmental Factors," *IJDS*, vol. 10, pp. 343–363, 2015, doi: 10.28945/2302.

[12] E. Mosyjowski, S. Daly, D. Peters, S. Skerlos, and A. Baker, "The Ph.D. Advising Relationship: Needs of Returning and Direct-Pathway Students," in *2014 ASEE Annual Conference & Exposition Proceedings*, Indianapolis, Indiana: ASEE Conferences, Jun. 2014, p. 24.1238.1-24.1238.13. doi: 10.18260/1-2--23171.

[13] J. J. Varney, "The role of dissertation self-efficacy in increasing dissertation completion: sources, effects and viability of a new self-efficacy construct," *College Student Journal*, vol. 44, no. 4, pp. 932–947, Dec. 2010.

[14] Committee on Effective Mentoring in STEMM, Board on Higher Education and Workforce, Policy and Global Affairs, and National Academies of Sciences, Engineering,

and Medicine, *The Science of Effective Mentorship in STEMM*. Washington, D.C.: National Academies Press, 2019, p. 25568. doi: 10.17226/25568.
[15] M. A. Maher, J. A. Gilmore, and D. F. Feldon, "Cognitive Apprenticeship and the Supervision of Science and Engineering Research Assistants," *Journal of Research Practice*, vol. 9, no. 2, 2013, doi: 10.1080/13611267.2012.678974.
[16] C. T. Amelink and C. D. Edwards, "Exploring the Socialization Experiences of Underrepresented Engineering Graduate Students," *J Women Minor Scien Eng*, vol. 26, no. 4, pp. 357–379, 2020, doi: 10.1615/JWomenMinorScienEng.2020032606.
[17] J. C. Weidman and L. DeAngelo, *Socialization in Higher Education and the Early Career: Theory, Research and Application*. 2020. Accessed: Sep. 03, 2021. [Online]. Available: https://doi.org/10.1007/978-3-030-33350-8
[18] C. T. Amelink and M. S. Artiles, "Minority Student Experiences in Engineering Graduate Programs: Socialization and Impact on Career Trajectories," presented at the 2021 ASEE Virtual Annual Conference Content Access, 2021, p. 10. [Online]. Available: https://peer.asee.org/37511
[19] E. Hocker, E. Zerbe, and C. G. P. Berdanier, "Characterizing Doctoral Engineering Student Socialization: Narratives of Mental Health, Decisions to Persist, and Consideration of Career Trajectories," in *2019 IEEE Frontiers in Education Conference (FIE)*, Covington, KY, USA: IEEE, Oct. 2019. doi: 10.1109/FIE43999.2019.9028438.
[20] N. Curtin, A. J. Stewart, and J. M. Ostrove, "Fostering Academic Self-Concept: Advisor Support and Sense of Belonging Among International and Domestic Graduate Students," *American Educational Research Journal*, vol. 50, no. 1, pp. 108–137, Feb. 2013, doi: 10.3102/0002831212446662.
[21] G. Dericks, E. Thompson, M. Roberts, and F. Phua, "Determinants of PhD student satisfaction: the roles of supervisor, department, and peer qualities," *Assessment & Evaluation in Higher Education*, vol. 44, no. 7, pp. 1053–1068, Oct. 2019, doi: 10.1080/02602938.2019.1570484.
[22] D. Litalien and F. Guay, "Dropout intentions in PhD studies: A comprehensive model based on interpersonal relationships and motivational resources," *Contemporary Educational Psychology*, vol. 41, pp. 218–231, Apr. 2015, doi: 10.1016/j.cedpsych.2015.03.004.
[23] S. M. Marshall, B. Klocko, and J. Davidson, "Dissertation Completion: Higher Education's Invisible Problem," *JERAP*, vol. 7, no. 1, Jun. 2017, doi: 10.5590/JERAP.2017.07.1.06.
[24] B. A. Burt, K. L. Williams, and W. A. Smith, "Into the Storm: Ecological and Sociological Impediments to Black Males' Persistence in Engineering Graduate Programs," *American Educational Research Journal*, vol. 55, no. 5, pp. 965–1006, Oct. 2018, doi: 10.3102/0002831218763587.
[25] S. K. Gardner, "The Challenges of First-Generation Doctoral Students," *New Directions for Higher Education*, vol. 2013, no. 163, pp. 43–54, Sep. 2013, doi: 10.1002/he.20064.
[26] H. L. Perkins *et al.*, "An Intersectional Approach to Exploring Engineering Graduate Students' Identities and Academic Relationships," *International Journal of Gender, Science and Technology*, vol. 11, no. 3, pp. 440–465, 2020.
[27] E. Ramirez, "'No One Taught Me the Steps': Latinos' Experiences Applying to Graduate School," *Journal of Latinos and Education*, vol. 10, no. 3, pp. 204–222, Jul. 2011, doi: 10.1080/15348431.2011.581105.
[28] E. A. Mosyjowski, S. R. Daly, and D. L. Peters, "Drivers of research topic selection for engineering doctoral students," *IJEE*, vol. 33, no. 4, pp. 1283–1296, 2017.

[29] S. Santa-Ramirez, “Sink or swim: The mentoring experiences of Latinx PhD students with faculty of color.,” *Journal of Diversity in Higher Education*, vol. 15, no. 1, pp. 124–134, Feb. 2022, doi: 10.1037/dhe0000335.
[30] N. C. Overall, K. L. Deane, and E. R. Peterson, “Promoting doctoral students’ research self-efficacy: combining academic guidance with autonomy support,” *Higher Education Research & Development*, vol. 30, no. 6, pp. 791–805, Dec. 2011, doi: 10.1080/07294360.2010.535508.
[31] A. Bandura, “Self-efficacy: Toward a Unifying Theory of Behavioral Change,” *Psychological Review*, vol. 84, p. 25, 1977.
[32] A. Bandura, “The Evolution of Social Cognitive Theory,” in *Great Minds in Management: The Process of Theory Development*, Oxford: Oxford University Press, 2005, pp. 9–35.
[33] M. A. Maher, A. M. Wofford, J. Roksa, and D. F. Feldon, “Exploring Early Exits: Doctoral Attrition in the Biomedical Sciences,” *Journal of College Student Retention: Research, Theory & Practice*, vol. 22, no. 2, pp. 205–226, Aug. 2020, doi: 10.1177/1521025117736871.
[34] NCES, “Digest of Education Statistics: 2019,” *National Center for Education Statistics*, Jun. 2021. https://nces.ed.gov/programs/digest/d20/tables/dt20_312.40.asp
[35] D. B. McCoach, R. K. Gable, and J. P. Madura, *Instrument Development in the Affective Domain*. New York, NY: Springer New York, 2013. doi: 10.1007/978-1-4614-7135-6.
[36] “Principal Components and Factor Analysis,” in *Using multivariate statistics*, 6th ed.Boston: Pearson Education, 2013, pp. 612–680.
[37] A. Bandura, “GUIDE FOR CONSTRUCTING SELF-EFFICACY SCALES,” in *Self-Efficacy Beliefs of Adolescents*, F. Pajares, Ed., Greenwich, CT: Information Age Publishing, 2006, p. 32.
[38] L. McAlpine, M. Castello, and K. Pyhaltö, “What influences PhD graduate trajectories during the degree: a research-based policy agenda,” *High Educ*, vol. 80, no. 6, pp. 1011–1043, Dec. 2020, doi: 10.1007/s10734-019-00448-7.
[39] J. London *et al.*, “Motivations for Pursuing an Engineering PhD and Perceptions of its Added Value: A U.S.-based Study,” *IJDS*, vol. 9, pp. 205–227, 2014, doi: 10.28945/2050.
[40] S. Blake-Beard, M. L. Bayne, F. J. Crosby, and C. B. Muller, “Matching by Race and Gender in Mentoring Relationships: Keeping our Eyes on the Prize,” *Journal of Social Issues*, vol. 67, no. 3, pp. 622–643, Sep. 2011, doi: 10.1111/j.1540-4560.2011.01717.x.
[41] D. L. McCoy, R. Winkle-Wagner, and C. L. Luedke, “Colorblind mentoring? Exploring white faculty mentoring of students of color.,” *Journal of Diversity in Higher Education*, vol. 8, no. 4, pp. 225–242, 2015, doi: 10.1037/a0038676.
[42] A. M. Wofford, K. A. Griffin, and J. Roksa, “Unequal expectations: First-generation and continuing-generation students’ anticipated relationships with doctoral advisors in STEM,” *High Educ*, vol. 82, no. 5, pp. 1013–1029, Nov. 2021, doi: 10.1007/s10734-021-00713-8.

Appendix

Survey Items

The items in the Thesis Self-efficacy scale are shown in Table I as they were presented to the students. When students filled out the survey, they would first answer these items before moving on to the next scale. The instructions exhorted the students to rate their level of confidence regarding the task presented by each item.

Table I Survey Items for the Thesis Self-efficacy Construct

Instructions: Please rate how confident you are in your ability to successfully accomplish the following tasks in relation to your thesis, dissertation, or applied project.[a]
1. Select a suitable research topic for study.
2. Formulate a research question(s) or problem statement(s) for study.
3. Select an appropriate research design for a study.
4. Describe the purpose and importance of a study.
5. Collect data or field notes for a study.
6. Review and synthesize the scholarly literature in your area of study to write a Literature Review.
7. Select the appropriate quantitative or qualitative analysis methodology to address a research question(s).
8. Clearly explain the methods you used to address a research question.
9. Run or apply the appropriate quantitative or qualitative analysis to address a research question.
10. Interpret the results obtained from a quantitative or qualitative analysis (whichever you apply in relation to a research question).
11. Discuss your interpretation of a quantitative or qualitative analysis (whichever you apply in relation to a research question).
12. Clearly present the results obtained in a study.
13. Work with your graduate advisor(s) for needed help and support.
14. Approach other researchers in your topic area for assistance.

[a] 5: Completely confident; 4: Somewhat confident; 3: Moderately confident; 2: Slightly confident ;1: Not confident at all.

Following these items, the students were then presented with the Advisor Support scale as shown on Table II. In this case, the instructions asked the students to rate their agreement with the statements presented.

Table II Survey Items for the Advisor Support Construct

Instructions: For each of the following statements, rate your advisor's behavior towards you.[a]
1. Gives me regular feedback on my research.
2. Is available when I need help with my research.
3. Gives me constructive feedback on my progress toward degree completion.
4. Is available when I need to talk about my progress in my program.
5. Teaches me the details of good research practice.
6. Provides information about ongoing relevant research.
7. Takes an interest in my well-being and life-work balance.

Instructions: For each of the following statements, rate your advisor's behavior towards you.[a]
8. Cares about me as a whole person, not just as a scholar.
9. Provides emotional support when I need it.
10. Is attentive and responsive to my needs.
11. Has my best interests at heart.
12. Would support me in any career path I might choose.
13. Helps me secure funding for my graduate studies.
14. Teaches me to write grant and contract proposals.
15. Helps me develop professional relationships with others in the field.
16. Assists me in writing presentations or publications.
17. Teaches me skills needed in my field.
18. Advocates for me with others when necessary.

[a] 5: Strongly agree; 4: Somewhat agree; 3: Neither agree nor disagree; 2: Somewhat disagree ;1: Strongly disagree.