

Student-centered Strategies for Promoting Inclusive, Supportive, Diverse Environments in Graduate STEM Education

Dr. Colleen Elizabeth Bronner, University of California, Davis

Colleen Bronner is faculty member in the Department of Civil and Environmental Engineering at University of California, Davis. She has a Ph.D. in Civil, Structural and Environmental Engineering from the University at Buffalo, where she also earned a B.S. in Environmental Engineering, and a M.S. degree in Civil and Environmental Engineering from the University of California, Berkeley. Her current research interests include inclusion of underrepresented groups in engineering, effectiveness of active learning strategies, and engineering in PK-12 education.

Alin Wakefield, University of California, Davis

Alin Wakefield serves as the Research and Graduate Studies Development Coordinator in the College of Engineering at UC Davis.

Dr. Jean S. VanderGheynst, University of Massachusetts, Dartmouth

Jean VanderGheynst is Dean of the College of Engineering and Professor of Bioengineering at the University of Massachusetts, Dartmouth, and Adjunct Professor of Biological and Agricultural Engineering at the University of California, Davis. Prior to joining UMass Dartmouth, she was Executive Associate Dean for Research and Graduate Studies in the College of Engineering and Professor of Biological and Agricultural Engineering at University of California, Davis.

Dr. VanderGheynst's research focuses on next generation biofuels and bioproducts and agricultural biotechnology. Current projects examine the management of microbial communities in applications including water treatment, food and energy production, and soil treatment for the control of pests and pathogens. Dr. VanderGheynst received her BS degree from Syracuse University in Chemical Engineering in 1991 and PhD degree in Agricultural and Biological Engineering from Cornell University in 1997.

Kara Moloney Ph.D., University of California, Davis

Student-centered strategies for promoting, supportive, diverse environments in graduate education

Colleen E. Bronner, Alin Wakefield, Kara Maloney
University of California, Davis

Jean VanderGheynst
University of Massachusetts, Dartmouth

Introduction

Current STEM graduate education is not meeting the needs of all students. In the *2018 Graduate STEM Education for the 21st Century* report, educational leaders call for transformation of the current STEM graduate education to a system that is 1) student-centered, 2) provides diverse, equitable, and inclusive environments; 3) supports graduate student mental health; 4) provides core competencies; and 5) allows for career exploration. These transformations are particularly important for students from underrepresented groups and/or underserved communities.

The Preparing Engineering Graduate Students for the 21st Century (PEGS21) program at the University of California, Davis (UC Davis) is a National Science Foundation (NSF) Scholarships in Science, Technology, Engineering and Mathematics (S-STEM) program targeting graduate student applicants who are academically talented, low-income and/or first generation. This NSF grant will fund five cohorts over its length; the first cohort started in the 2016-2017 academic year. Through a cohort-building seminar, multi-pronged mentoring activities, and a stipend to ease the transition into graduate school, this student-centered program supports attempts to address, in part, all transformation areas needed in STEM graduate education. A critical component of the program, and the focus of this paper, is professional development workshops and seminars in which PEGS21 scholars participate in their first year.

The objectives of this paper are to: 1) connect PEGS21 Program activities to the transformation areas; 2) identify professional development workshops that are valuable for the target graduate student population; 3) explore how these workshops intersect with the five common challenges to graduate school retention for students from underrepresented groups; and 4) share lessons learned with universities considering similar programs. After an overview of the PEGS program, the qualitative analysis tools used and their results are presented. The paper concludes with a discussion of results and future plans to improve the PEGS21 program and its assessment methods.

PEGS21 Program

The PEGS21 program at UC Davis seeks to examine the transition from undergraduate to graduate study in engineering, extending the research of Gardner (2007), Gardner and Holley (2011) and Tate et al. (2014) who identified five following challenges to graduate degree attainment in first-generation students.

- 1) *Breaking the Chain*: Low-income, academically-talented, first-generation (LIATFG) graduate students may have to overcome obstacles to enter and persist in graduate study and their parents are frequently unable to help them navigate their educational pathway.
- 2) *Knowing the Rules or Ambiguity*: LIATFG graduate students may be unclear about the expectations of graduate study. They may perceive that their peers know the “rules of the game” while they do not know what is expected or how to navigate the system.
- 3) *Living in Two Worlds*: Families of LIATFG students are often supportive of college, but may be less understanding of the value of graduate education. LIATFG students may not feel they fully belong to either their family/culture, or within academia.
- 4) *Seeking Support*: LIATFG students can have difficulty building the necessary support systems (whether they be social, academic and/or financial) to persist to degree completion.
- 5) *Balancing Act*: The pace and intensity of graduate study frequently catches LIATFG students off guard. Particularly in the first and second year of graduate study, students are challenged by issues of time and balancing not only of their academic pursuits, but also their family relationships and responsibilities.

Program Overview

The PEGS21 program eases the transition for a cohort of about 15 first-year graduate students each year through a variety of interventions designed to foster supportive relationships, enhance professional skills, and reduce financial barriers to help students address the challenges described above (Table 1).

Table 1: Components of the PEGS21 Program

<i>Interventions</i>	<i>Frequency</i>	<i>Posited Challenge Addressing</i>	<i>Description</i>
Cohort Seminar	Weekly in first year	Knowing the Rules; Living in Two Worlds	Seminar topics designed to create sense of belonging (e.g., imposter syndrome), develop professional skills (e.g., time management), and provide support (e.g., advisor-mentee relationships)
GradPathways Workshops	two per quarter (six total)	Knowing the Rules; Seeking Support	Workshops open to all university graduate students to develop professional and personal skills (described in detail later)
One-on-one mentoring	At least once per quarter	Seeking Support;	All participants meet with the same PEGS21 advisor for quarterly check-ins
Peer mentoring	At least two times per quarter	Seeking Support; Living in Two Worlds	Participants from prior cohorts volunteer and are assigned as mentors to first-year PEGS21 participants
Stipend	Awarded in three installments during first year	Balancing Act	Each participant is awarded a \$10,000 stipend in their first year; their home department also agrees to provide the participant a 25% research or teaching assistant position and full tuition support
Financial support for professional development activities	Varies	Balancing act	Each participant is allocated funding to attend a conference during their graduate study; each student is also allocated funding to attend an entrepreneurial workshop for science and engineering participants

Participants

The program began in fall 2016 and starts a new cohort each academic year. Table 2 provides select demographic and academic information about each of the first three cohorts.

Table 2: PEGS21 Participants 2016 to 2019

	Cohort 1	Cohort 2	Cohort 3	TOTAL
Gender				
Female	6	5	7	18
Male	4	9	4	17
Other	-	-	-	-
Race/Ethnicity				
White	4	-	4	8
Black	1	1	-	2
Asian/Asian-American	2	1	5	8
American Indian, Alaska Native	-	1	-	1
Pacific Islander	-	-	-	-
Hispanic	3	11	2	16
First Generation*	1	7	5	13
Program				
Biological Systems	1	2	-	3
Biomedical	1	-	2	3
Chemical	-	-	2	2
Civil/Environmental	5	5	1	11
Computer Science	-	-	2	2
Electrical/Computer	2	1	1	4
Energy Systems	-	3	-	3
Materials Science	1	1	1	3
Mechanical	-	2	2	3
Transportation	-	-	-	-
Degree Program				
Doctoral	3	6	5	14
Master's	7	8	6	21
TOTAL SCHOLARS	10	14	11	35

*First generation defined as neither parent earning a bachelor's degree

The majority of students are first-time graduate students and new to UC Davis. Six of the doctoral participants earned a M.S. before participation, but only two from a top-tier research institution. Ten students earned their bachelors at UC Davis.

Methods

This paper focuses on the written reflective assignments collected in the first two years of the PEGS21 program.

Qualitative analysis of written reflections

Studying language provides insights into what a speaker might be thinking, and to discover the ways that language represents and constitutes realities (Johnston, 2004). Specifically, study of language-in-use provides insight into language-users' self-perception (Rymes, 1995). For this study, it was posited that the language participants used in their reflections would provide insights into their first-year graduate experience, particularly their self-efficacy, a term used to describe one's sense of competence in being able to achieve (Bandura, 1977; Bandura, Caprara, Barbaranelli, Gerbino, & Pastorelli, 2003). While self-esteem is general, self-efficacy is situational and contextual (Linnenbrink & Pintrick, 2003). Perception of self-efficacy influences self-regulation and management (Bandura et al., 2003), and influences behavior accordingly. Therefore, it was posited that reflections would demonstrate how participant self-efficacy was affecting their behaviors in graduate school.

Intervention: Grad Pathways Assignment

UC Davis GradPathways is a nationally recognized program that provides graduate students and postdoctoral scholars with professional development opportunities. The program aims to develop strengths and skills within eight "core competencies" including success and socialization; presentation skills; leadership and management; career management; writing and publishing; teaching and mentoring; professionalism and ethics; and wellness and life balance. PEGS21 scholars participate in at least two (2) professional development GradPathways workshops each quarter. Participants are then asked to reflect on the value of each workshop on their learning. PEGS21 participants self-select the workshops they attended.

For each of the graduate pathways workshops attended, participants complete a post-workshop reflection assignment on why they selected the workshop topic and what they learned from the workshop. Reflections are submitted electronically for review and comment based on a complete and thorough exposition of the writer's point of view.

Analysis of Reflections

The analysis of the written reflections was inductive, interpretive, and iterative (c.f. Denzin & Lincoln, 2005; Hsieh & Shannon, 2005; Strauss & Corbin, 1998;). The members of the research team read and coded written reflections independently. While the team shared the general goal of gaining insight into participants' perspectives about the learning opportunities offered by the GradPathways workshops, we engaged in the coding process differently. Two members of the research team used the challenges to graduate degree research (hereafter referred to as Barriers) as an informal, *a priori* coding framework, while the other team member engaged in an open-coding process (Strauss & Corbin, 1998).

The initial analysis revealed that participants' written reflections yielded little explicit discussion of the Barriers, which were attributed to the related but not identical goals of GradPathways and PEGS21. The research team then identified three inductive categories "derived from data during data analysis" (Hsieh & Shannon, 2005, p. 1286), with which to further analyze the data: 1)

participants’ reasons for selecting workshops; 2) self-reported learning; and 3) evidence of participants’ capacity to transfer knowledge.

The research team then conducted a summative content analysis (Hsieh & Shannon, 2005) to focus on the language-in-use. A summative content analysis involves counting and comparisons, usually of keywords or content, followed by the interpretation of the underlying context. The research team used an open-source concordance program to 1) identify the most commonly recurring one- and two-word phrases; 2) locate all instances of words related to the coding categories (as shown in Table 3 below); and 3) examine each Key Word in Context (KWIC). Locating the most frequently occurring one- and two-word phrases is useful for establishing an overall, big-picture of the data. While an important first step, however, calculating word frequencies alone provides little use for analyses of participants’ reasons for selecting workshops. By focusing on both the key words, and their surroundings, the analysis provides insights into participants’ expectations, plans, and goals.

Table 3: Categories of analysis and associated keywords

<i>Inductive Category</i>	<i>Keywords</i>
Reason for selecting the workshop	<ul style="list-style-type: none"> ▪ workshop + because ▪ select* ▪ goal*
Self-reported learning	<ul style="list-style-type: none"> ▪ learn* ▪ help* + me ▪ skill + me
Capacity to transfer/apply knowledge	<ul style="list-style-type: none"> ▪ I + can ▪ I + will ▪ I + plan

Results

Connection to barriers

As Table 4 demonstrates, participants’ responses consistently included references which aligned to two of the Barriers to persistence: Knowing the Rules and Seeking Support.

Table 4: Count and percentages of indirect references to the “Barriers” framework, by response

	Breaking the Chain	%	Knowing the Rules	%	Living in Two Worlds	%	Seeking Support	%	Balancing Act	%	Workforce Readiness	%
Fall 2016 (n=23)	3	13%	9	39%	0	0%	10	43%	1	4%	0	0%
Winter 2017 (n=26)	1	4%	9	35%	2	8%	5	19%	2	8%	7	27%
Spring 2017 (n=27)	0	0%	6	23%	1	4%	10	38%	1	4%	8	31%

Participant motivation

Analyses of the written reflections revealed that participants selected workshops for three primary reasons: 1) to seek information (knowledge / skill); 2) to further develop a pre-existing knowledge / skill; and 3) to support their personal growth. Examples of participants' reasons for selecting workshops are provided in the lists below. Table 5 provides examples of reasons students gave for attending specific workshops.

Table 5: Example participant motivations for attending specific workshops

<p><i>Seek information / Acquire New Skills</i></p> <ul style="list-style-type: none"> • I decided to attend this workshop because I wanted to hear more about how the university handles this subject. • I attended the workshop because I had been having a bit of a tough time selecting a lab to settle in and I was wondering if maybe I wasn't being proactive ... • I selected this topic because it sounded like I could benefit from it and because it worked with my schedule... • I attended the workshop ... in order to step out of my comfort zone a little bit. • I selected this seminar to attend because it aligns with my goals of finding a job in industry immediately after I acquire my Master's degree. • The reason that I wanted to attend this workshop was the fact that I wanted to get a better understanding of the process that goes into grant writing. • I decided to attend the ... workshop because I wanted to make sure that I was spending my money correctly for my current situation. • I decided to attend the graduate writer's retreat ... since I am required to write a proposal for one of my courses. • I chose to attend [this] workshop because it promised tips on writing proposals, and it delivered. • I chose to attend the [workshop] because I foresee myself writing grants in the future and want to get a head start. • The one thing that always stuck out to me was how do I go about picking a mentor and what do I want in a mentor
<p><i>Develop Skills</i></p> <ul style="list-style-type: none"> • After giving two presentations, I noticed I was nervous standing on stage in front of a large group...I wanted to learn skills to make me more comfortable presenting to a large group of people, especially when those groups include people who are well known in my field. • I attended because I wanted to learn a bit more about the do's and don'ts of writing ... • I selected this topic while I was in the middle of writing up a report for an assignment ... • Wanted to improve my effectiveness as a leader • I did not expect grant writing to be easy; however, it is a lot more involved and difficult than I was necessarily prepared for when given the assignment [reason for choosing workshop on grant writing] • I plan to continue being a TA for STEM classes and I want to advance my ability to reach all students
<p><i>Support for Personal Growth</i></p> <ul style="list-style-type: none"> • Important topic due to importance of teamwork in professional and academic world • Would like to teach some day • I remember a while back when I came to understand that faculty and professionals had to constantly apply for grants as well and wondering what that process involved • I wanted to take this workshop because applying for grants will be in my graduate school future. Grant writing is scary and overwhelming and I'm worried that when I need to start applications I wouldn't know what to do or where to begin • I chose this workshop because engaging with my research mentor is something I can picture myself having trouble with in the future...because I tend to be an independent worker and I can picture myself trying to conduct research for my thesis with minimal contact with my adviser

Participants' self-reported learning workforce skills: Participant responses fall along a spectrum from technical (i.e., writing) to cultural/relational (i.e., learning the rules about mentorship). Skills that appeared multiple times and the type of workshop attended are summarized in Table 6.

Table 6: Participant reported workforce development skills from workshop attendance

Topic of workshop attended	Skills multiple participants reported learning	Related challenges multiple participants infer in reflections
Oral communication & presentation	Oral communication; self-efficacy	Knowing the Rules
Teaching	Leadership; teamwork	<i>Limited connection to challenges</i>
Persistence/"True Grit"	Self-efficacy; communication	Seeking Support; Knowing the Rules
Grant writing	Written communication skills	Knowing the Rules
Time management	Time management	Balancing Act; Knowing the Rules
Mentoring	Proactive networking;	Seeking Support; Knowing the Rules

An example of participants feeling that the workshops helped them “know the rules” commonly occurred in grant writing workshops. Participants expressed increased knowledge of how important it is to follow proposal instructions on topics from content to formatting. Representative examples include “I thought it was quite intriguing how many aspects of grant writing we assume are trivial but can have grand consequences or rewards depending on how they are executed,” “important to follow the guidelines and read instructions carefully, and be aware of the audience,” and “grant proposals need months of work and must be started months ahead of time.”

Time management workshops was the most common workshop that related to participants balancing activities. Participants indicated that having tools and a new mental model for approaching time management helped reduce stress. For example, a student mentioned planning their time over 24 hours each day “makes our tasks and work seem less daunting, as it allows us to appreciate how much time we actually have to get things done. We can be less stressed and enjoy both the down time and the production time of each day.” Another participant noted how she could adapt her current time management approach: “I absolutely love making lists and find great satisfaction in crossing off completed tasks. Every day I come up with a list of items that need to get done, however I do not schedule time slots for each task. It's very easy for me to get consumed by a task and not move on to the other tasks. To solve this issue, the instructor recommended prioritizing the tasks and using a 24hr schedule.”

Participants' capacity to transfer knowledge: Participant responses ranged from recitation of content without reflection on how to use to specific articulation of how participants intended to apply what they learned during a workshop to their academic, professional, and/or personal futures. The following excerpts capture examples in the latter category. In some cases, student reflections indicated that part of the transfer of knowledge included an increased sense of belonging in graduate school.

- Plan to employ the "fake it until you become it" strategy next time I feel nervous or awkward before a presentation
- I plan to attend more seminars on teaching and learn more about classroom interactions and being an effective instruction

- The area where I can most improve is communication. I tend to be very shy and this has prevented me from asking questions
- I learned that I would like to improve my communication and being proactive with tasks and anticipating problems
- However, the experience of feeling uncomfortable and like an outsider in this group made a huge impact on me. It was a small window into what culture shock feels like for many of the visiting scholars and international students at our university. I consider myself very tolerant and accepting of others, and would never intentionally make someone feel isolated for uncomfortable; however, this workshop helped me realize that I may be doing this unintentionally, and made me aware of ways I can avoid doing this in the future (e.g. actually accompanying someone to their destination instead of just rambling off directions)
- Prior to this workshop, I always started my day with my easiest task to ease myself into my day. As the instructor pointed out, as the day progresses one becomes more tired and less likely to overcome our most challenging task.
- The last takeaway was to schedule in our breaks. She reminded us that we are not robots and need breaks. By scheduling breaks, we give ourselves the opportunity to reset before resuming our work.
- It was good to assess myself and acknowledge areas that I would like to improve and think about myself as a mentor might...it was good to help me identify the people and think about the mentorship role they could play and how I could be their mentee.
- It was comforting knowing that other people - including successful people - feel a similar self-doubt that I sometimes feel about myself
- The workshop surpassed my expectations and reminded me that I too have resilience
- I had always been under the impression that the most successful people were geniuses, however a research study showed that grit is the key to success and a high IQ is not the dominating factor
- After learning that I need grit to be successful, I began to wonder how do I get "grittier"
- The workshop was extremely helpful, and reminded me that I am meant to be in grad school and already possess grit

Discussion

Although results indicated modifications were needed to both the assignments and assessment framework, they provided useful insights on participant needs and perceptions in their first year of graduate school, including the value of workshops focused on professional, academic, and personal development.

Connection to Barriers

Their selection of GradPathways workshops indicate PEGS21 participants are attempting to overcome the barriers. However, due to the limited self-reflection in some reflections, it was difficult to always know which barrier. It was clear that even if two participants attended the same workshop, it may address different barriers for each dependent on their previous experiences and knowledge. Some ways the barriers and workshops appeared to align are described below.

- 1) *Breaking the Chain*: This barrier was referenced infrequently by participants. It is posited that this barrier is more relevant as barrier to graduate school and less of a concern after entering graduate school – unlike the other four barriers.
- 2) *Knowing the Rules or Ambiguity*: This barrier seemed to drive workshop selection either solely or in conjunction with seeking support for the majority of participants.
- 3) *Living in Two Worlds*: While this barrier was infrequently referenced, a few participants did seek workshops where they would be able to find others who were similarly feeling like they were living in two worlds. It is posited that this barrier may be addressed more by participants from highly underrepresented groups (e.g., African American women), however the sample size is too small to be significant.
- 4) *Seeking Support*: Participants selected workshops that allowed them to seek support in academic, financial, and social areas of their graduate experiences.
- 5) *Balancing Act*: A portion of workshop participants attended workshops focused on time and/or financial management, which could be related to addressing the balancing act. However, additional information would be needed.

Modifications to approach

The reflections revealed differing levels of self-awareness among participants. To target participant self-awareness, in winter 2019 the GradPathways assignment was adapted to include a pre-workshop activity (Figure 1); its impact on reflections will be assessed in summer 2019.

Before you attend your selected GradPathways workshop, please respond briefly to the following.

1. Please state the workshop topic.
2. What do you already know about this topic?
3. What do you hope to learn by attending?
4. What challenges do you anticipate applying the topic to your life?

Submit your short answers to these questions before you attend the workshop

Figure 1: Pre-workshop assignment

Future work

After the program concludes and there is a larger sample size. Additional plans include comparing differences between different groups of students: doctoral vs. masters students, first-generation vs. students who have had at least one parent earn a bachelor's degree, difference between students in different majors, and potential different demographic groups. The results will be used to make recommendations for a sustainable program for addressing graduate student professional, academic, and personal development opportunities and meeting the needs addressed in the National Academy of Engineers' *2018 Graduate STEM Education for the 21st Century* report.

Conclusion

Analysis of participant reflections of GradPathways professional development workshops revealed motivations for students selecting workshops, participant perceptions of workforce skills acquired, and the capacity for participant to transfer knowledge acquired into their academic, professional, or personal future. To adequately assess the impact of the workshops on addressing the five challenges the student assignment and the assessment framework require modification to focus on participant motivation for attending workshops, perception of workforce skills acquired, how they transferred knowledge acquired, how it affected student's sense of belonging, and connections to the challenges of knowing the rules, seeking support and balancing activities.

References

- Bandura A., Caprara, G.V., Barbaranelli, C., Gerbino, M. & Pastorelli, C. (2003) Role of Affective Self-Regulatory Efficacy in Diverse Spheres of Psychosocial Functioning. *Child Development*, <https://doi.org/10.1111/1467-8624.00567>
- Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191-215. <http://dx.doi.org/10.1037/0033-295X.84.2.191>
- Denzin, N.K. & Lincoln, Y.S. (2005). The Sage Handbook of Qualitative Research, Sage Publications, Los Angeles.
- Gardner, S. K. (2007). "I heard it through the Grapevine": Doctoral student socialization in chemistry and history. *Higher Education*, 54, 723-740.
- Gardner, S. K., & Holley, K.A. (2011). "Those invisible barriers are real"; The progression of first-generation students through doctoral education. *Equity & Excellence in Education*, 44(1), 77-92.
- Hsieh, H. & Shannon, S.E. (2005). "Three Approaches to Qualitative Content Analysis," *Qualitative Health Research*, <https://doi.org/10.1177/1049732305276687>
- Johnston, P.H. (2004). Choice words: How our language affects children's learning. Stenhouse Publishers, 2004, ISBN: 9781571103895, 106
- Linnenbrink, E.A. & Pintrick, P.R. (2003) "The role of self-efficacy beliefs in student engagement and learning in the classroom," *Journal of Reading and Writing Quarterly*. 19(2), 119-137, <https://doi.org/10.1080/10573560308223>
- National Academies of Sciences, Engineering, and Medicine. 2018. Graduate STEM Education for the 21st Century. Washington, DC: The National Academies Press. <https://doi.org/10.17226/25038>.
- Strauss, A. & Corbin, J. (1998) Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory, 2nd edition, Sage Publications, Los Angeles, ISBN: 0803959397

Tate, K.A., Fouad, N.A., Reid Marks, L Young, G., Guzman, E., & Williams, E.G. (2014) Journal of Career Assessment. 23(3), 1-15