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From Conventional Wisdom to Evidence-Based Practice: Validation of Programmatic Design Decisions in Engineering Doctoral Education

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Session XXXX

From Conventional Wisdom to Evidence-Based Practice: Validation of Programmatic Design Decisions in Engineering Doctoral Education

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Abstract

Engineering educators rely heavily on experience and "conventional wisdom" in making key programmatic design decisions. This appears to be particularly true of doctoral education, which has received less research attention than undergraduate education among the engineering education community, as well as the broader STEM education community. Thus, there is a need for greater attention to developing evidence-based practice to support these decisions. This paper presents some of the preliminary results from an ongoing NSF-funded study (Award No. 220503), focused on understanding the longitudinal development of researcher identity in engineering doctoral students. The study employs user experience (UX) research methods including journey mapping, focus groups, surveys, and interviews to identify the most influential factors to identity formation over time for both online and on-campus doctoral students within one engineering department at a large state university. The current paper focuses on the longitudinal results from the journey maps of an online cohort of students. Data from the 10 participants are analyzed using a multi-step coding process involving three researchers, and key themes are extracted. Findings provide evidence-based support for many common design elements of doctoral programs, such as the "front loading" of coursework to develop research interest and capabilities, and the importance of initiating research collaboration with the dissertation chair early in the student's program. However, the findings also reveal some factors that may be unique to online doctoral education, such as the increased complexity of the matriculation process (in particular due to challenges related to communication with on-campus parties) and a strong preference for solo vs. group work in course assignments. Future research includes the incorporation of findings from the on-campus cohort of students, as well as the longer-term incorporation of students from other majors and universities.

Introduction

Identity is posited to be a key determinant of persistence and success in both educational and career contexts[1,2,3]. While engineering identity has received significant research attention at the undergraduate level, graduate levels of engineering education have attracted much less research to date[4,5,6,7]. Graduate education in general, and doctoral education in particular, are distinct from undergraduate education as students matriculate with a professional identity (typically one already aligned with a field of engineering) and a key focus is on the development of independent research capabilities (formation of a research identity)[5,8,9]. Although research on engineering identity at the graduate level is currently growing, several critical gaps remain to be filled. This includes characterizing the research identity formation process over time in doctoral engineering students, and identifying factors that facilitate and hinder effective formation of this identity. Further, the research identity formation process in doctoral students does not appear to have been extensively studied in any STEM discipline.

This paper reports partial and preliminary results from an ongoing study funded by the National Science Foundation (Award No. 2205033), which aims to apply user experience (UX) methods to longitudinally study research identity development in engineering doctoral students and identify key factors that influence this development. UX methods include multiple techniques that study human experiences in a particular context for the purposes of capturing their authentic needs and identifying opportunities to improve those experiences. UX methods allow us to empathize with real users (in our case, doctoral students) and stay grounded in lived experiences rather than generally accepted assumptions about people[10]. In addition to building the fundamental knowledge base regarding research identity formation in doctoral engineering students, the research findings can be used to develop evidence-based practice for engineering doctoral program design. The remainder of the paper presents the methodology, results, and summary/conclusion.

Methodology

A longitudinal, multimethod approach was adopted to collect data on research identity development and its influencing factors from students enrolled in a doctoral engineering program at a large state university in the US. Surveys, journey mapping, and focus groups were adopted for the first round of data collection, whereas interviews substituted for focus groups in subsequent rounds. Multiple qualitative and quantitative analysis methods were applied to the data within a phenomenological analysis framework. This paper focuses only on the round 1 and round 2 journey map data collected for the cohort of 10 online (distance) students; however, the department under study includes both on-campus and online (distance) doctoral students, and results for on-campus students will be reported in future research. These data were collected in 2022 (round 1) and 2023 (round 2). All 10 students provided journey mapping data for round 1, whereas four provided data for round 2, indicating substantial attrition between rounds, which will be discussed more in the results and summary/conclusions. Additional partial and preliminary results can be found in other work[11,12,13].

As part of round 1, participants were provided with a brief introduction to journey mapping, including the use of an example persona (a hypothetical engineering doctoral student) to illustrate the journey

mapping process. Following this brief training session, participants were provided with a copy of the Microsoft PowerPoint-based journey mapping template. In the template, participants were asked to indicate activities they believed were significant in some way to the development of their research identity. This included the semester the activity occurred, a description of the activity, their affective response to the activity (response options: "Very Negative", "Negative", "Somewhat Negative," "Neither Positive nor Negative", "Somewhat Positive," "Positive, "Very Positive"), and a description of how they believed the activity impacted their research identity development. The data was returned to one member of the research team via email. Following data collection, the journey maps were scrubbed of any potentially identifying information and then coded.

In the coding process, a code list generated based on a separate pilot study in 2021 was utilized as a starting point for assigning codes to the activities. However, this initial code list was expanded and refined during the coding process[11]. Three coders independently assigned codes and then met to discuss any disagreements; all initial disagreements were successfully resolved during discussions. Following the coding, a list of subcodes was developed to allow additional detail to be captured beyond the primary codes. The same process was used with three independent coders followed by discussion to resolve disagreements. Table 1 displays the list of codes and subcodes.

Code Acronym & Name	Subcode Acronyms & Names		
OP: Overall program	OP0: No subcode OP1: Acceptance OP2: Matriculation (bureaucratic & academic issues before first class)	OP3: Fellowship requirements OP4: Bureaucratic and administrative issues after first class OP5: New – Starting the Program OP6: Cohort	OP7: Workload OP8: TA/RA/GTPA
PA: Projects and Assignments	PA0: No subcode PA1: Individual Assignments	PA2: Group Assignments PA3: Textbook Issues	
S: Scholarship (Publications)	S0: No subcode S1: Submission of paper for conferences S2: Submission of paper for journals	S3: Acceptance of paper for conference S4: Acceptance of paper for journal S5: Bachelor Thesis S6: Master Thesis	S7: Dissertation
R: Research	R0: No subcode R1: Guided Research (working with mentor as research guide)	R2: Unguided research (independent research student does alone) R3: Idea generation outside of program guidance	R4: Feeling like a Researcher R5: Class Interaction
C: Courses	CO0: No subcode CO1: Discussions in class CO2: Course topics CO3: Books CO4: New Course	CO5: Course Organization CO6: Student Performance CO7: Classroom Interaction CO8: Online Course Technology CO9: Instructor Interaction	CO10: Connection to Program
A: Advising	A0: No subcode A1: Staff Advisors	A2: Academic Advisors A3: Research Advisors	
M: Mentorship	M0: No subcode M1: Faculty	M2: Peers M3: University Academic Support	
EF: External Factors	EF0: No subcode EF1: External programs	EF2: Covid EF3: Internships / Work	EF4: Housing / Moving in
UN: Undetermined	No subcodes		

Table 1. Codes and Subcodes

A number of graphical methods were used to display and evaluate trends in the data. In particular, the paper next discusses results related to longitudinal patterns in the directionality of the responses, and patterns related to code/subcode frequency and directionality. We also discussed whether the observed patterns were or were not "expected."

Results

Findings by Directionality

In this first analysis, the affective impact participants assigned to their comments regarding activities was examined according to three broad directionality categories: **Positive (P)**, which comprised Very Positive, Positive, and Somewhat Positive; **Neutral**, which comprised Neither Positive nor Negative, and **Negative (N)**, which comprised Very Negative, Negative, and Somewhat Negative. The frequency of these three categories was then examined over time, using a bar chart, as shown in Figure 1. The distribution of comment directionality over time (by participant semester) displayed some patterns that were expected and others that were not. As can be seen, the first pattern noted is that Positive (P) comments dominated Negative (N) and Neutral comments. While this pattern is not expected per se, it is a reassuring one as the dominance of Negative (N) or Neutral comments might indicate significant problems with program design with respect to research identity development. The second pattern is that the overall number of comments – as most clearly reflected by observing the trend for Positive (P) comments – declines over time. This finding is expected as the majority of participants were within their first five semesters at the time of the round 2 data collection. The third pattern is that, in contrast to Positive (P) comments, Negative (N) and Neutral comments do not display a marked decline and instead remain relatively constant over time; this may be due to the smaller overall number of such comments compared with Positive (P) comments. However, it is worthy to investigate whether the same trend continues as the data set grows in subsequent research rounds.

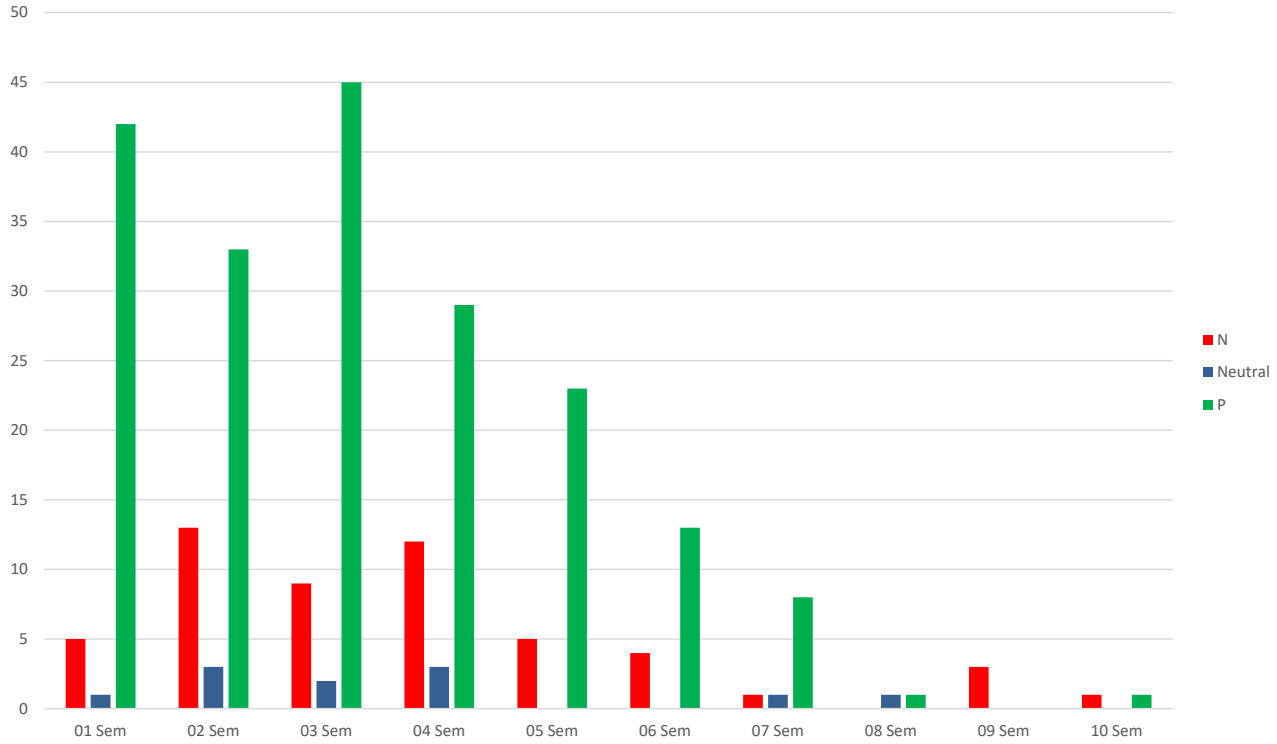

Figure 1. Distribution of Positive (P), Negative (N), and Neutral Comments by Participant Semester

Findings by Code and Subcode

As previously indicated, the next set of analyses focused on understanding the response patterns by code and subcode. For this part of the analysis, in addition to examining the frequency of responses, the participant affective responses were numerically scaled to provide a measure of relative importance, such that: Very Positive (VP) = +3; Positive (P) = +2; Somewhat Positive (SP) = +1; Neutral (Neu) = 0; Somewhat Negative = -1; Negative = -2; and Very Negative = -3.

Figure 2 displays a stacked line chart of the aggregate scaled responses to the major activity codes by participant (each line represents a different participant in the analysis). The total value of each response code (y-axis) was determined as the sum product of the number of times a given activity code was associated with a particular affective response category (assigned by the participant) and the scaling of that affective response category described above. For example, for the participant with the highest value of response code for the courses (CO) activity code, there were 25 Very Positive (x3), 22 Positive (x2), 16 Somewhat Positive (x1), 4 Neutral (x0), 1 Somewhat Negative (x(-1)). 3 Negative (x(-2)), and 1 Very Negative (x(-3)) responses, resulting in a total value of the response code of 125.

A number of conclusions can be drawn from the data. First, despite differences in the magnitude of the peaks and troughs experienced, the overall response patterns look remarkably similar across participants, which is encouraging, particularly from the possibility to ultimately identify archetypal personas from the journey maps. In general, the respondents display the largest peaks for Courses (CO), and smaller peaks for Mentoring (M) and Research (R). These findings should also be interpreted in light of the fact that, as discussed above, most participants were within their first five

semesters at the time of the data collection. Thus, the importance of Courses (CO) is largely in line with conventional wisdom for doctoral program design, which supports the front loading of any courses early in the program, and the incorporation of early Research (R) activities in courses, such as writing literature review papers, as a way to promote the development of research skills and thought processes (i.e., class-related research fueling non-class-related research). However, the findings related to Mentors (M) simultaneously support the importance of establishing a relationship with a research advisor (faculty mentor) early in the program, as will be further discussed below. In addition, the only consistent trough (with a value of response code less than zero) across participants was for the External Factor (EF) category, which primarily related to the impact of Covid-19 on their researcher development, as will also be further discussed below. One departure from the similar response pattern across participants was for the Project and Assignments (PA) activity code; for some participants this was a strong peak (relative to their responses to other activity codes), for others it was less prominent.

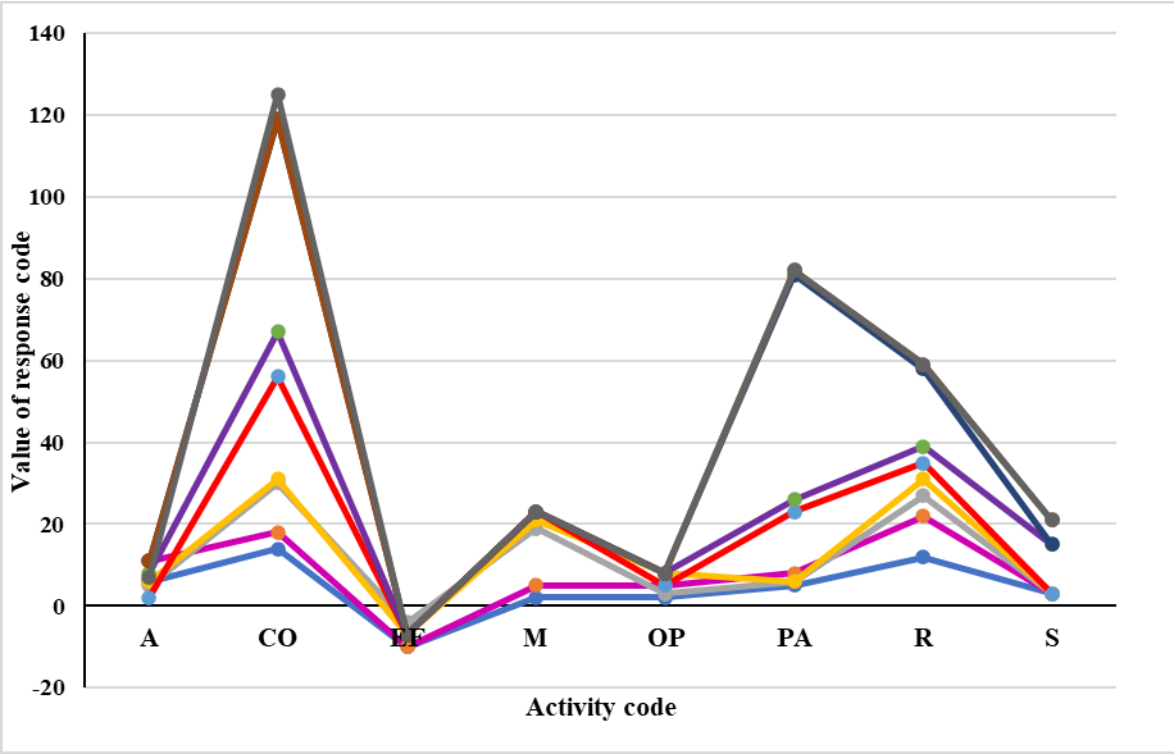

Figure 2. Aggregate scaled response value by activity code for all participants

Figure 3 displays a similar stacked line chart to Figure 2 but focusing on subcodes to provide more details on the responses (again, each line represents a different participant). As before, one of the most striking features is the overall similarity of response patterns across participants, and the details of the subcodes help explain the peak and trough response pattern observed for certain activity codes discussed above. For instance, here it can be seen that two subcodes are largely responsible for the peak related to Course (CO): instructor interaction (CO9) and course topics (CO2). Whereas, the peak related to Project and Assignments (PA) for some participants is clearly linked to individual assignments (PA1), although most strongly influenced by two participants who are relatively further

along in their academic program than others (i.e., the two lines with the highest values). Further, this PA1 peak is in stark contact to the next subcode, group assignments (PA2), which is trending negative. Meanwhile, the peak related to Research (R) is primarily due to independent research (R2), which in this specific data set occurred largely within the class setting (e.g., an independent research paper for a particular class). Further, as identified above, the peak related to Mentoring (M) is largely driven by faculty mentoring (M1), although university academic support (M3) is also important. Finally, as discussed above, the data reveal that the trough related to External Factor (EF) is primarily linked to Covid-19 (EF2) as the impact of other factors is more variable across participants. In addition to further illumination of the responses for the activity codes, examination of the subcode data revealed an interesting pattern where several individual overall program codes have negative response patterns – matriculation (bureaucratic & academic issues before first class) (OP2), fellowship requirements (OP3), and bureaucratic and administrative issues after first class (OP4) - even though the aggregate value of the response code for Overall Program (OP) is (slightly) positive as shown in Figure 2. As can be seen by the subcode names, all of these reflect activities that participants viewed as either bureaucratic or administrative hurdles to their success. The next section discusses the overall study conclusions, limitations, and future research opportunities.

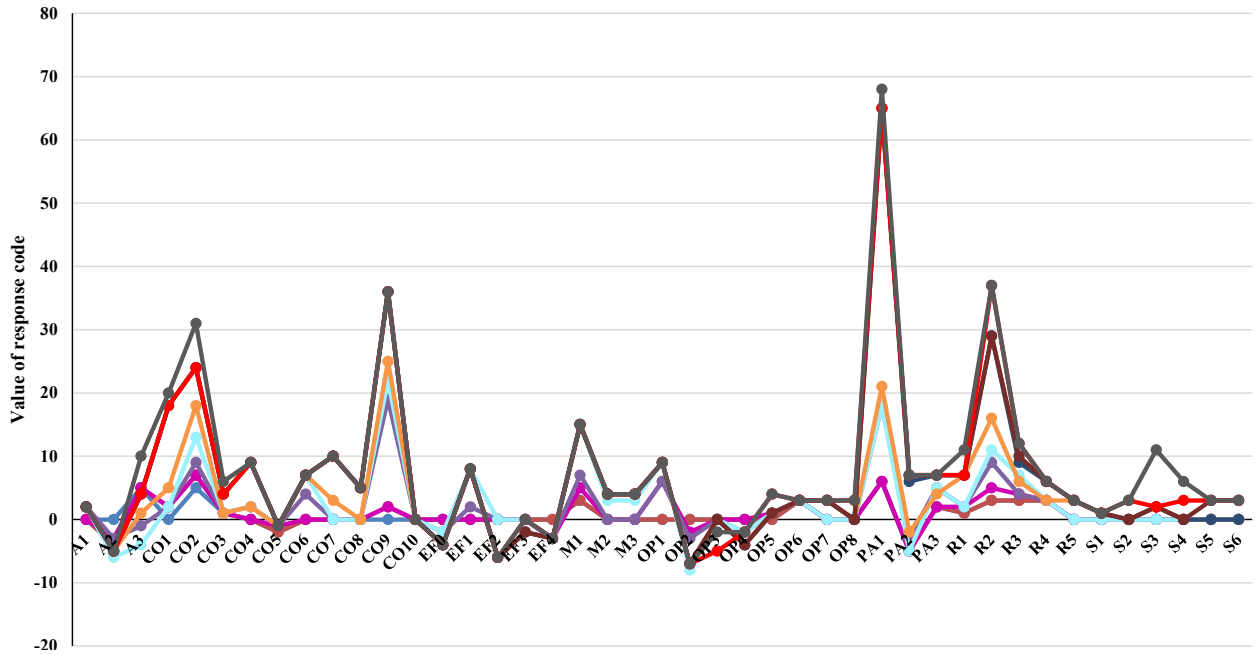

Figure 3. Aggregate scaled by activity subcode for all participants

Summary and Conclusions

Study findings indicated that, overall, positive comments dominated negative and neutral comments in frequency; however, while positive comments declined over time (as expected, as there were relatively few participants who could comment on later semesters since most were early in their programs), negative and neutral comments remained more stable. Another key finding was the highly similar response pattern across participants at both the code and subcode level. When looking at the aggregate of all the responses, refer back to Figures 2 and 3, it can be observed that the responses,

whether small, moderate, or of large shifts, seems to follow consistent undulations in response. There are little to no response sequences that register divergent responses. Though these results are still preliminary, it warrants further investigation to determine whether this same degree of consistency across participants continues in future research.

When considering the findings related to the relative "importance" of different codes and subcodes, many of the study results provide evidence-based support for common design elements of doctoral programs. For example, the findings suggest that the common strategy of "front loading" of any coursework is effective in piquing initial research interest and initiating the development of research capabilities, particularly if these courses contain independent research opportunities. In addition, it is a common strategy for many faculty to actively recruit incoming doctoral students to their research groups, and the findings suggest that such initiation of research collaboration at the beginning of the student's program is also highly impactful. However, the findings also reveal some factors that may be unique to online doctoral education. For example, further consideration of the specific challenges experienced related to Overall Program (OP) indicate that these bureaucratic and administrative hurdles related to the matriculation process (OP2), fellowship applications (OP3), and other issues (OP4) may be exacerbated due to challenges related to attempting to communicate with on-campus parties as an off-campus student. Off-campus students cannot simply walk down the hall or to a certain campus building to ask another party a question, and getting help even from peers and advisors is subject to often asynchronous communication, including email and phone messages, and advance scheduling of any meetings. In addition, the fact the cohort in this study displayed such a strong preference for solo versus group work in course assignments may be reflective of the general challenges of scheduling team meetings and coordinating team assignment completion as a student who is also working full-time in a professional role. In addition, due to differences on a number of factors (e.g., work experience, generation, time available to complete assignments, etc.), differences in expectations regarding technical work quality, team interactions, and professionalism of reports and presentations, among others, may arise between distance and on-campus students. Although not a formal part of the data in this research study, assessment data collected by the department in question reveals that distance graduate students at both the master's and doctoral levels consistently report lower satisfaction in completing team assignments as part of their graduate work compared with on-campus students. (As teams in most courses simultaneously comprise both on-campus and off campus students, these two student groups seem to be having a very different experience on the same teams). Thus, it will be interesting to see whether the strong preference for solo rather than group work continues when on-campus doctoral students are added to the sample (this data collection has commenced and is ongoing).

Like all research endeavors, this study has limitations. Among these is the noted attrition rate between round 1 and round 2. While some attrition is expected for any longitudinal study, the majority of the participants had not yet (at the time of the writing of this paper) provided data for round 2. Thus, the research team is currently working on strategies to further encourage participation, including the testing of financial incentives as a recruitment and retention strategy. An additional limitation is that the majority of participants who provided data for this paper had been enrolled in their doctoral program for five semesters or less. Meanwhile, two who had been in the program longer often had the largest (in magnitude) values observed in Figures 2 and 3; that is, these participants with greater longevity in their doctoral program generally had the most pronounced peaks and troughs, although,

as previously discussed, the overall response pattern was consistent across other participants. This observation makes sense as more time in the program would generally be expected to yield more comments in the journey maps due to the longer time horizon. However, it would be interesting to test whether these two participants with greater longevity represent statistical outliers in terms of their responses. With the small current sample size (10 participants) such tests are not reliable and thus were not attempted, but they will be considered in future research. Another limitation is that the findings discussed in this paper are based on a single engineering doctoral program and may be influenced by the curricular design of that program. For example, most of the students in the current program took a significant number of traditional, classroom-based courses as part of their doctoral education (approximately 30 credit hours, depending on their graduate work prior to matriculation). This may have influenced the finding related to the effectiveness of coursework front-loading for research identity formation, and thus no definitive conclusions can be drawn regarding the relative effectiveness of doctoral education models that comprise a "research-only" approach, incorporating minimal or even no classroom-based courses. In addition, this study adopted a +3 to -3 scale to attempt to capture the relative importance of different activities based on the verbal codes assigned by participants indicating the affective impact of the activities ("very positive" to "very negative"). However, these codes may not accurately capture the relative difference between these response categories; further, affective impact is not necessarily fully reflective of importance. The dominance of positive comments (compared with negative or neutral comments) could potentially be influenced by a number of factors, including the specific program of study, the specific pool of participants (in particular participants less satisfied with the program may have declined to participate), and social desirability bias.

As indicated, one key area of future research includes the incorporation of findings from the on-campus cohort of students; this will allow the identification of any potential differences between on-campus and distance students with respect to the current study findings. In addition, future research will consider the other sources of study data (surveys, focus groups, interview) and additional semesters of data. Finally, the long-term objective of this research stream is to incorporate students from other majors and universities.

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