Reclaiming the Large Foundational Engineering Classroom: Instructors' Needs and Aspirations

Michelle Soledad
Department of Engineering Education
Virginia Tech
Ateneo de Davao University
Blacksburg, VA, USA
soledadmm@vt.edu

Dr. Homero Murzi
Department of Engineering Education
Virginia Tech
Blacksburg, VA, USA
hmurzi@vt.edu

Dr. Jacob R. Grohs
Department of Engineering Education
Virginia Tech
Blacksburg, VA, USA
jrgrohs@vt.edu

Dr. David Knight
Department of Engineering Education
Virginia Tech
Blacksburg, VA, USA
dbknight@vt.edu

Dr. Scott W. Case
Department of Biomedical Engineering and Mechanics
Virginia Tech
Blacksburg, VA, USA
scase@vt.edu

Natasha Smith
Department of Engineering Education
Virginia Tech
Blacksburg, VA, USA
noliver@vt.edu

***Abstract*—This Work-In-Progress research paper presents preliminary results and next steps of a study that aims to identify institutional data and resources that instructors find helpful in facilitating learning in large foundational engineering courses. The work is motivated by resource-driven compromises made in response to increasing engineering student populations. One such compromise is teaching some courses (usually foundational courses taken by students across multiple disciplines) in large sections, despite research suggesting that large class environments may correspond with unfavorable student learning experiences. Examples of courses often taught in large class environments are mathematics, physics, and mechanics. We are currently working with a cohort of instructors of foundational engineering courses as part of an NSF Institutional Transformation project. We have collected qualitative data through semi-structured interviews to explore the following research question: *What data and/or resources do STEM faculty teaching large foundational classes for undergraduate engineering identify as being useful to enhance students' experiences and outcomes a) within the classes that they teach, and b) across the multiple large foundational engineering classes taken by students?* Our inquiry and analysis are guided by Lattuca and Stark's Academic Plan Model. Preliminary analysis indicated that instructors would like more opportunities to interact and collaborate with instructors from other departments. These results will inform activities for our Large Foundational Courses Summit scheduled for Summer 2018 as part of the project.**

Keywords*—*large classes, foundational engineering courses, instructors' needs, Academic Plan Model

I. Introduction

Student enrollments in engineering programs have grown over the years, due in part to the projected need for more scientists and engineers [1]. This increase in student population, however, has led to compromises meant to effectively manage costs and resources, especially for large institutions. One such compromise is to teach some courses in large sections despite research suggesting that large class environments may correspond with unfavorable student learning experiences [2]. In engineering curricula, critical foundational courses, such as mathematics, physics, and mechanics, are often taught in large class environments because they are taken by students across multiple engineering disciplines and thus provide an opportunity to maximize resources and faculty contact hours.

We are currently working with instructors of foundational courses for undergraduate engineering as part of a National Science Foundation (NSF) Improving Undergraduate Stem Education (IUSE) Institutional Transformation project, exploring the following research question: *What data and/or resources do STEM faculty teaching large foundational classes for undergraduate engineering identify as being useful to enhance students' experiences and outcomes a) within the classes that they teach, and b) across the multiple large foundational engineering classes taken by students?* Our inquiry and analysis are guided by the Academic Plan Model, which acknowledges the important role that instructors play in fostering positive educational environments for engineering students.

II. Perspectives from Literature

A. The Academic Plan Model

The Academic Plan Model [3] (*Fig. 1*) was developed as a means of thinking about and defining academic curricula, in response to "a lack of comprehensive definition of curriculum" (p. 4). Presenting curriculum in the context of a plan provides a holistic and comprehensive overview of the learning environment, the elements that interact and comprise it, and the

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factors that influence curricular decisions. An academic plan may be developed for different organizational levels in an institution: for a course, degree program, a college, or the institution as a whole. The model acknowledges various key players in the educational environment, including instructors. It explicitly shows that various factors may influence the curricular decisions that instructors make, that instructors themselves affect the educational environment, and that consequently, their decisions impact students' educational outcomes. However, creating educational environments that foster positive learning experiences, a responsibility placed mainly on the shoulders of instructors, includes non-academic and non-engineering considerations (e.g., student characteristics) for which instructors of engineering courses may not have the appropriate support and resources [4], [5].

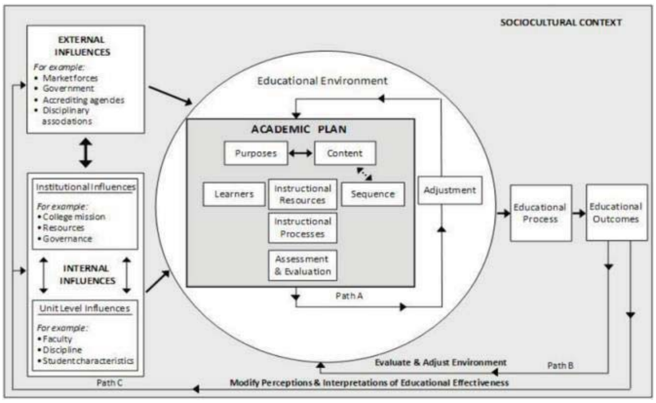

Figure 1. The Academic Plan Model (Lattuca & Stark, 2009, p. 5)

The Academic Plan Model [3] provides context for the large foundational engineering course phenomenon. External (e.g. market- and society-driven needs that call for more engineers and lead to increasing enrolments, [1]) and internal (e.g., institutional resources) influences have interacted to lead to increasing enrollments, hence creating a need for the large class educational environment in foundational engineering courses. Thinking about the large foundational engineering class through the Academic Plan Model is a way to visualize the interacting factors affecting that environment and how these factors may be explored to identify opportunities for improvement. This view aligns with why Lattuca and Stark presented the curriculum as an academic plan: "to identify the critical decision points that, if effectively addressed, will enhance the academic experience of students" [3] (p.4).

B. Large classes and continuous improvement in higher education

Large class sizes have increasingly become the norm in higher education institutions that grapple with increasing student populations and rising operational costs [1], [2], despite evidence that show decreased engagement, motivation, and achievement among students [6]–[8]. Instructors report difficulty establishing rapport and a growing inability to monitor students' academic performance and provide quality feedback [9], [10]. In engineering programs, the stakes for students increase as section sizes in foundational courses become larger; there is growing evidence that these courses represent barriers to student success and persistence [11], [12].

The educational environment that students find themselves in as they take foundational engineering classes is in conflict with the learning experience that they value and expect [13]. Literature suggests that engineering classrooms should be *learner-centered* [14]. In this setting, instructors assume the role of *facilitator of learning*, adopting active learning pedagogies that "help students understand, evaluate, and take responsibility for their own learning" [14] (p. 1150). However, studies have shown that instructional strategies of faculty remain largely unchanged [15] and that widespread change is hindered [16]. The limitations and challenges posed by large class sizes (e.g. defaulting to the lecture format) often miscast educational environments as mostly static, in contrast to the Academic Plan Model [3] on which we ground this study. Static conceptions disempower instructors and break feedback loops that are vital to continuous improvement processes [17], [18].

III. METHODOLOGY

We conducted semi-structured interviews with a cohort of instructors participating in our NSF-funded project. We examined faculty needs for facilitating learning in large foundational engineering class environments by qualitatively analyzing interview transcripts. Data collection and analysis used a single case study approach, guided by the Academic Plan Model. The boundaries that define the case for this study are the eight individuals who have experienced teaching different large foundational engineering courses.

A. Participants

The participants are instructors of foundational engineering courses commonly taught in large class sizes. We analyzed data from eight participants who are currently teaching, have taught, and/or have managed the following foundational engineering courses: foundations of engineering, mathematics, physics, and engineering mechanics (Table I). Pseudonyms are used to ensure participants' anonymity.

TABLE I. PARTICIPANT INFORMATION

Pseudonym	Gender
Victoria	Female
Marie	Female
Kevin	Male
Mike	Male
Valerie	Female
Monica	Female
Diane	Female
William	Male

B. Data Collection

Semi-structured interviews were conducted at the beginning of the fall 2017 semester. The protocol included prompts that allowed participants to share their experiences teaching foundational engineering courses, their beliefs on

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information and resources that they found helpful, and how they may use such data to effectively facilitate the learning process. Table II shows the interview prompts that were designed to elicit responses of interest to us.

Each interview was about one hour long and conducted in person. All participants were asked to sign an Institutional Review Board (IRB)-approved informed consent form before the interview. Audio recordings and field notes were taken during each interview, and recordings were transcribed by a professional transcription service.

TABLE II. INTERVIEW PROMPTS

What are the things that you care about the most when you are teaching a class? Do you feel that you have all the resources that you need to allow you to do the things that you care about in class? What are the things that you get to do given your current class size/s? What are the things you cannot do/find difficulty doing?
Please describe how you are planning/planned for class: • What information/data did you use to make decisions? • Where did you get this information/data? • What role do students (information/data from students) play in making these decisions?
What support services/resources/data/information for teaching a large class do you have access to/are provided to you right now? What data/information about students do you have access to/are provided to you right now? What kind of data/information do you informally collect/observe/take note of? How do you use these support services/resources/data/information? If I had the authority to provide you with any support services/resources/data/information that you need to create the learning environment that you want for your students, what would you ask from me? Why?

Primary data sources. Transcripts of the semi-structured interviews conducted with participants serve as the primary data source for this study.

Additional data sources. Additional data sources include field notes taken during the interview process and memos written during the initial read-through of the interview transcripts. Participants also provided artifacts, such as course syllabi, topic sequence, test schedules, and department-specific/instructor-designed surveys, which also serve as additional data sources.

C. Data Analysis

The interview transcripts are being analyzed using an inductive/deductive approach [19]. Data analysis will consist of two coding cycles, conducted concurrently and independently by two researchers. For this Work-In-Progress paper, we conducted the first coding cycle following an inductive approach, consisting of: 1) initial reading of interview transcripts; 2) assigning labels to meaningful statements; 3) writing memos; and 4) allowing patterns to emerge across participant data. Second cycle coding will follow a deductive approach, discussed in the succeeding section.

Peer auditing meetings were conducted periodically by the two researchers to discuss coding decisions and definitions throughout the coding process [20].

IV. PRELIMINARY RESULTS AND NEXT STEPS

The interview protocol prompted participants to share their experiences, needs, and aspirations in facilitating learning in the context of the courses that they taught. Recalling strategies that they employed and resources that they had access to allowed participants to reflect about data and resources that they *identify as useful to enhancing students' experiences and outcomes*, addressing our research question. Preliminary results generated by the first cycle coding clustered data around four themes: *instructional resources*, *instructional processes*, *learners*, and *adjustments*. Next steps for this work will include second cycle coding, focusing on participants' needs, and using preliminary results to inform activities for a summit on teaching large foundational engineering courses.

A. Preliminary Results

First cycle of coding generated 109 labels that may be clustered around four themes. We allowed the themes to emerge from the data but observed that they clustered around some elements of the Academic Plan Model. We thus used the elements as labels for the emergent themes related to their teaching experiences in large foundational engineering courses, shown in Table III.

TABLE III. EMERGENT THEMES

Theme	Description
Instructional resources	Participants' descriptions of the learning materials and technologies that they are currently using; are currently available to them; or that they need but are not available/accessible to them.
Instructional processes	Participants' descriptions of the activities and practices that they use to facilitate the learning process; or activities that they aspire for but currently unable to practice due to perceived barriers and limitations.
Learners	Participants' beliefs about their students: abilities, interests, behaviors, attitudes and challenges.
Adjustments	Participants' descriptions of their efforts towards improving their practices for facilitating learning.

Most participants shared making *adjustments* (to the course) *based on student feedback*. *Adjustments* included changes to the pace of the class, amount of time spent on a topic, and the number and type of problems included in homework assignments. *Student feedback* ranged from student performance in homework assignments and tests, the quality of classroom discussions, and responses to mid-semester surveys when applicable. Mike, for example, shared: *"In the classroom, if students are responsive and they're solving problems easily and they're getting the right answer, they probably understand it. If students are afraid to answer questions, if nobody can give me the right answer to a* *question, we probably have to do a second one. The one that I would have them solve, I'll end up explaining it, but I'll make them do another one until they can solve it… It gives me an idea of whether they know what they're doing or not. I'll try to pick up on that in the classroom and adjust it on the fly."*

The most common aspiration that participants articulated and *identified as useful to enhancing students' experiences and outcomes* is *interaction and collaboration with other departments*. Kevin, for example, shared: *"As a resource that I would like, like from the department, from the university, is maybe to afford us some time to connect with colleagues outside of the department when we're teaching a class that services other departments, to get some input from those departments on why their students are in my room."*

B. Next Steps

The next step for data analysis is to proceed with second cycle coding. Second cycle coding will follow a deductive approach, and will include closely examining the patterns that emerged from the data and consulting literature to determine whether observations are supported by prior work or highlight a gap in literature. This stage of analysis will be conducted independently and concurrently by two researchers. As with first cycle coding, case analysis meetings will be held periodically to discuss findings.

Analysis will pay particular attention to participants' *needs and aspirations*, specifically needs commonly articulated across the different departments represented by the participants. We will also take note of the frequency at which these needs are expressed across the interview transcripts. Additional data sources, including field notes, memos generated during first cycle coding, and the artifacts provided by the participants will be examined to support and corroborate findings from the analysis of the primary source of data (interview transcripts). The findings from this qualitative analysis will be used to inform the program of activities for a summit on teaching large foundational engineering courses, in conjunction with the findings from a quantitative analysis of institutional data conducted as part of this NSF project. Ultimately, the goal of the project is to provide departments and instructors of large foundational engineering courses with feedback mechanisms, based on instructors' needs and using institutional data, to support faculty as they facilitate learning, foster positive learning experiences, and create effective learning environments for their students.

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REFERENCES

[1] National Science Board, "Science and Engineering Indicators 2014," National Science Foundation, 2014.

[2] C. Mulryan-Kyne, "Teaching large classes at college and university level: challenges and opportunities," *Teach. High. Educ.*, vol. 15, no. 2, pp. 175–185, Apr. 2010.

[3] L. R. Lattuca, and J. S. Stark, "Learners," in *Shaping the College Curriculum*, 2nd Ed., San Francisco, CA: Jossey-Bass, 2009, pp. 145–181.

[4] M. Borrego and C. Henderson, "Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies," *J. Eng. Educ.*, vol. 103, no. 2, pp. 220–252, 2014.

[5] L. A. Schreiner, "The critical role of faculty and faculty development in sophomore success," in *Helping sophomores succeed: Understanding and improving the second-year experience*, M. S. Hunter, B. F. Tobolowsky, J. N. Gardner, S. E. Evenbeck, J. A. Pattengale, M. A. Schaller, and L. A. Schreiner, Eds. San Francisco, CA: Jossey-Bass, 2010, pp. 129–145.

[6] E. Carbone, "Students Behaving Badly in Large Classes," *New Dir. Teach. Learn.*, vol. 1999, no. 77, pp. 35–43, 1999.

[7] E. Carbone and J. Greenberg, "Teaching Large Classes: Unpacking the Problem and Responding Creatively," in *To Improve the Academy*, vol. 17, M. Kaplan, Ed. Stillwater, OK: New Forums Press and the Professional and Organizational Development Network in Higher Education, 1998, pp. 311–326.

[8] G. Gibbs and A. Jenkins, *Teaching large classes in higher education: how to maintain quality with reduced resources*. London: Kogan Page, 1992.

[9] A. Ward and A. Jenkins, "The problems of learning and teaching in large classes," in *Teaching large classes in higher education: How to maintain quality with reduced resources*, G. Gibbs and A. Jenkins, Eds. London: Kogan Page Ltd, 1992, pp. 23–36.

[10] J. Cuseo, "The empirical case against large class size: adverse effects on the teaching, learning, and retention of first-year students," *J. Fac. Dev.*, vol. 21, no. 1, pp. 5–21, 2007.

[11] J. Grohs, T. Kinoshita, B. Novoselich, and D. Knight, "Exploring Learner Engagement and Achievement in Large Undergraduate Engineering Mechanics Courses," 2015, p. 26.729.1-26.729.11.

[12] S. M. Lord and J. C. Chen, "Curriculum Design in the Middle Years," in *Cambridge handbook of engineering education research*, New York, NY: Cambridge University Press, 2014, pp. 181–195.

[13] J. Gainen, "Barriers to success in quantitative gatekeeper courses," *New Dir. Teach. Learn.*, vol. 1995, no. 61, pp. 5–14, 1995.

[14] G. W. Ellis, A. N. Rudnitsky, and G. E. Scordilis, "Finding Meaning in the Classroom: Learner-Centered Approaches that Engage Students in Engineering," *Int. J. Eng. Educ.*, vol. 21, no. 6, pp. 1148–1158, 2005.

[15] Committee on Barriers and Opportunities in Completing 2-Year and 4-Year STEM Degrees, Board on Science Education, Policy and Global Affairs, National Academy of Engineering, and National Academies of Sciences,

Engineering, and Medicine, *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Students' Diverse Pathways*. Washington, D.C.: National Academies Press, 2016.
[16] M. Borrego, J. E. Froyd, and T. S. Hall, "Diffusion of engineering education innovations: A survey of awareness and adoption rates in US engineering departments," *J. Eng. Educ.*, vol. 99, no. 3, pp. 185–207, 2010.
[17] C. Temponi, "Continuous improvement framework: implications for academia," *Qual. Assur. Educ.*, vol. 13, no. 1, pp. 17–36, 2005.
[18] S. Venkatraman, "A framework for implementing TQM in higher education programs," *Qual. Assur. Educ.*, vol. 15, no. 1, pp. 92–112, 2007.
[19] J. Saldana, *The Coding Manual for Qualitative Researchers*, 3rd ed. SAGE Publications, 2016.
[20] M. B. Miles, A. M. Huberman, and J. Saldaña, *Qualitative data analysis: A methods sourcebook*, 3rd ed. Thousand Oaks, California: SAGE Publications, Incorporated, 2013.