Getting Started: Initiating Systemic Engineering Design Changes in an Undergraduate Curriculum (Special Session)

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***Abstract*—In this special session, the moderators will lead an accessible and collaborative discussion on how to make systemic changes to design instruction, particularly during the second and third years, in an undergraduate engineering curriculum. Participants will assess the environments at their home institutions, identify underutilized resources, and generate ideas toward the implementation of more design-rich curricula. The moderators will share examples from their own work, hoping that participants will adapt successful approaches for their own efforts to initiate or lead curricular change.**

Keywords—engineering design, curriculum development, programmatic change, biomedical engineering

I. Session Facilitators

Dr. Sharon Miller is a Clinical Associate Professor of Biomedical Engineering (BME) at Indiana University-Purdue University Indianapolis (IUPUI) Dr. Miller currently serves the IUPUI BME Department as Associate Chair and Director of the Undergraduate Program helping develop and implement curricular changes to embed design, ethics, and technical communication throughout a BME curriculum. Prior to joining the faculty at IUPUI, Dr. Miller's P-20 educational efforts included curriculum writing and program development for the John C. Dunham STEM Partnership School and Michael J. Birck Center for Innovation. Since joining IUPUI, Dr. Miller has been awarded internal and external grants to realize curriculum changes throughout the undergraduate BME program.

Dr. Steven Higbee is a Clinical Assistant Professor of Biomedical Engineering at IUPUI. Dr. Higbee serves the IUPUI BME Department as a non-tenure track faculty member and Coordinator for Undergraduate Research in BME. In these roles, he teaches several courses throughout the BME program, works to improve and develop new curriculum, connects students with undergraduate research opportunities across campus, and serves as an academic advisor. He teaches an introductory engineering course with significant BME design elements as part of a freshman Themed Learning Community, which he developed with colleagues in Engineering and Biology. Dr. Higbee has collaborated with Dr. Miller in the securing grant funding focused on BME education and curriculum development.

II. Introduction

Implementing active learning throughout an undergraduate engineering curriculum has the potential to bring about significant improvements in student learning [1]–[4]. Emphasizing design throughout an undergraduate curriculum is identified as one of the five major shifts in engineering education, allowing students to be active participants in their own learning [5]. Practicing engineering design throughout an undergraduate curriculum can be challenging and can feel disconnected to the theoretical concepts often delivered during second and third year coursework. Still, programmatic changes that include an emphasis on design can be difficult to initiate, implement, and assess and often require a systematic method to realize change [6], [7]. Additionally, perceived faculty barriers can preclude active learning implementation within the classroom [8], [9].

This special session is designed to help participants solidify strategies to use when implementing program-level changes related to engineering design within an undergraduate curriculum. Our efforts will help participants connect 200- and 300-level topics with design efforts present in first and final years to create continuous design experiences throughout an undergraduate curriculum. Limited experience and/or perspective can stifle faculty, especially those newer to teaching, in efforts to realize or lead curricular change. Our session intends to inform and motivate these faculty and to provide a space for curricular ideation around engineering design.

III. Session Goals and Description

The overall goal of this session is to foster an engaging discussion about embedding engineering design throughout an undergraduate curriculum. The session will intentionally use student and faculty feedback to share instructional approaches and tools that scaffold toward capstone experiences. We will also highlight implementation obstacles including linking changes with specific course-level learning objectives, securing space and resources for student project-work, and procuring faculty buy-in. Thus, our session goals are to:

- Share effective strategies to implement curricular change, particularly at the 200- and 300-levels
- Guide participant implementation planning by sharing our own student and colleague feedback as lessons learned

This special session is designed to help participants develop strategies to implement program-level changes in the delivery

and assessment of engineering design curriculum. We will share the takeaways from our experience with embedding design in an undergraduate biomedical engineering program at an urban research university.

A. *Session Goal 1: Share Effective Strategies to Implement Curricular Change at the 200- and 300-levels*

Our session will highlight effective program change strategies from the literature (e.g., faculty discussion [10], increased perspectives [11], long-term curricular interventions [12]) and integrate how we emphasized engineering design throughout a biomedical engineering curriculum. We will highlight our successes and lessons learned for faculty and colleagues newer to curriculum development or looking to ignite or sustain engineering design ideas alongside faculty and colleagues. Specifically, we encourage individuals that contribute toward capstone design courses or a design course sequence to attend. Additionally, engineering instructors and program directors from varied engineering disciplines who seek to reflect on the design curriculum within their programs will also benefit.

B. *Session Goal 2: Use Our Own Student and Faculty Feedback to Guide Participant Implementation Planning*

Our session will be organized and presented around student and faculty feedback that we have received to address the development, delivery, and sustained implementation of design curriculum and assessment tools that scaffold throughout an undergraduate engineering curriculum. Our approach simultaneously targets programmatic goals (e.g., building design competencies, developing technical skills) and course-level learning objectives. Further, we have leveraged varied resources, from community partnerships to institutional and extramural funding opportunities, to make our programmatic improvements possible. Participants will leave with ideas to transform and sustain their design curricula. Examples of shared lessons include:

- Using a common design rubric throughout the curriculum to facilitate the tracking of student design skills. We will show data to illustrate how attendees can use such a rubric in their own programs [13].
- Leveraging community partners and institutional funding opportunities to create dynamic new design-oriented experiences for students [14], [15]. We will highlight our experiences, including an example of how students within our program have contributed.
- Collecting rich student assessment data and feedback can propel efforts to secure extramural funding organizations and appease skeptical faculty. We will share how our campus supports new ideas for curriculum development and educational research.

IV. Session Agenda

We will collect and immediately share data from session participants in order to learn about the current state of design instruction, assessment, and resources at represented institutions. We will give a brief overview of the strategies we implemented to map our curriculum, identifying touchpoints related to design (specifically where we inserted 200- and 300-level design projects), various technical skills, and other core curricular components. Participants will be broken into groups to participate in more intimate conversations about successes and challenges in their programs and core topics relevant to embedding design. Individual groups will report out key observations, and we will collect all group notes for distribution after the session.

A second conversation will be oriented around the learning spaces, resources, and partnerships that support program-wide design education. Participants will identify underutilized resources, spaces, and people in relation to design on their campuses. After a collective discussion on identified themes, we will share our approach in these areas. Participants will then have time to consider their own curriculum, completing an activity to identify action items that could advance design instruction in their programs.

We intend to moderate, not lecture, by using varied techniques to lead a conversation among all session participants. Brief digital surveys and notecards will be used to quickly gather participant information. By guiding our initial discussion with audience information, we will engage our audience from the start. We will organize breakout groups around pre-planned topics (design rubrics, learning spaces, etc.) as well as topics that may arise during the session. Handouts (e.g., planning grids, checklists) will be filled out in teams to promote curricular discussions and networking with peers from different institutions. Our session is outlined below.

1) Design Educator Information

- Introduction of speakers and session goals
- Survey I: Quick poll to learn about attendees

2) Effective Strategies for Curricular Change

- Session facilitators will lead an accessible discussion on sustaining curricular change.
- Breakout I: attendees will identify different strategies, resources, and partners that can help implement design projects or assignments. Session facilitators will then lead a report out.

3) Multiple Perspective Taking

- Session facilitators will provide categorical examples of data driven tools and assessments that can help leverage curricular change.
  - Students and Employers: Exit surveys, retention, and skills upon job entry
  - Faculty: 200- and 300-level Engineering design outcomes, assessment language
  - University and Community: Learning spaces and design partnerships
- Survey II: Guiding participants in identifying underutilized resources on their campuses. Session facilitators will then lead a report out.

4) Leaving with an Action Item

- Breakout II: attendees will participate in idea generation (think-pair-share style) and prioritization (checklist)
- Session facilitators will lead a final report out, session summary, and session evaluation.

V. Impact

The main session outcome is for participants to work through, identify, and leave with ideas on how to implement changes toward a design-rich curriculum. Participants will broaden their perspectives and develop an actionable item to help their own departments initiate or lead curricular change. Our session should motivate these faculty and provide a space for curricular innovation. Participant feedback on the surveys and worksheets will also help the session organizers in their development of faculty tools that help prioritize design improvement goals and catalyze faculty to realize such changes.

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References

[1] R. M. Felder, R. Brent, and M. J. Prince, "Engineering Instructional Development: Programs, Best Practices, and Recommendations," *J. Eng. Educ.*, vol. 100, no. 1, pp. 89–122, 2011, doi: 10.1002/j.2168-9830.2011.tb00005.x.

[2] R. M. Felder, G. N. Felder, and E. J. Dietz, "A Longitudinal Study of Engineering Student Performance and Retention. V. Comparisons with Traditionally-Taught Students," *J. Eng. Educ.*, vol. 87, no. 4, pp. 469–480, 1998, doi: 10.1002/j.2168-9830.1998.tb00381.x.

[3] P. S. Ralston, T. R. Tretter, and M. K. Brown, "Implementing Collaborative Learning across the Engineering Curriculum," *J. Scholarsh. Teach. Learn.*, vol. 17, no. 3, pp. 89–108, Jul. 2017, doi: 10.14434/v17i3.21323.

[4] S. Freeman *et al.*, "Active learning increases student performance in science, engineering, and mathematics," *Proc. Natl. Acad. Sci.*, vol. 111, no. 23, p. 8410, Jun. 2014, doi: 10.1073/pnas.1319030111.

[5] J. E. Froyd, P. C. Wankat, and K. A. Smith, "Five Major Shifts in 100 Years of Engineering Education," *Proc. IEEE*, vol. 100, no. Special Centennial Issue, pp. 1344–1360, May 2012, doi: 10.1109/JPROC.2012.2190167.

[6] J. Froyd, J. Layne, and K. Watson, "Issues regarding change in engineering education," in *Proceedings. Frontiers in Education. 36th Annual Conference*, 2006, pp. 3–8.

[7] A. Kolmos, R. G. Hadgraft, and J. E. Holgaard, "Response strategies for curriculum change in engineering," *Int. J. Technol. Des. Educ.*, vol. 26, no. 3, pp. 391–411, Aug. 2016, doi: 10.1007/s10798-015-9319-y.

[8] J. Michael, "Faculty Perceptions about Barriers to Active Learning," *Coll. Teach.*, vol. 55, no. 2, pp. 42–47, 2007.

[9] D. W. Sunal *et al.*, "Teaching science in higher education: Faculty professional development and barriers to change," *Sch. Sci. Math.*, vol. 101, no. 5, pp. 246–257, 2001.

[10] J. J. Walczyk, L. L. Ramsey, and P. Zha, "Obstacles to instructional innovation according to college science and mathematics faculty," *J. Res. Sci. Teach.*, vol. 44, no. 1, pp. 85–106, 2007, doi: 10.1002/tea.20119.

[11] 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, doi: 10.1002/jee.20040.

[12] C. Henderson, A. Beach, and N. Finkelstein, "Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature," *J. Res. Sci. Teach.*, vol. 48, no. 8, pp. 952–984, 2011, doi: 10.1002/tea.20439.

[13] S. Higbee and S. Miller, "Work in Progress: Tracking Capstone Project Quality in an Engineering Curriculum Embedded with Design," in *Frontiers in Education*, Uppsala, Sweden, Oct. 2020. Forthcoming.

[14] S. Higbee and S. Miller, "Work in Progress: Vertical Integration of Engineering Design in an Undergraduate BME Curriculum," in *2019 ASEE Annual Conference & Exposition*, Tampa, Florida, Jun. 2019.

[15] S. Higbee and S. Miller, "Biomedical Engineering Students Gain Design Knowledge and Report Increased Confidence When Continually Challenged with Integrated Design Projects," in *2020 ASEE Annual Conference & Exposition*, Virtual, Jun. 2020.