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Aileen Huang-Saad, Jan Stegemann & Lonnie Shea

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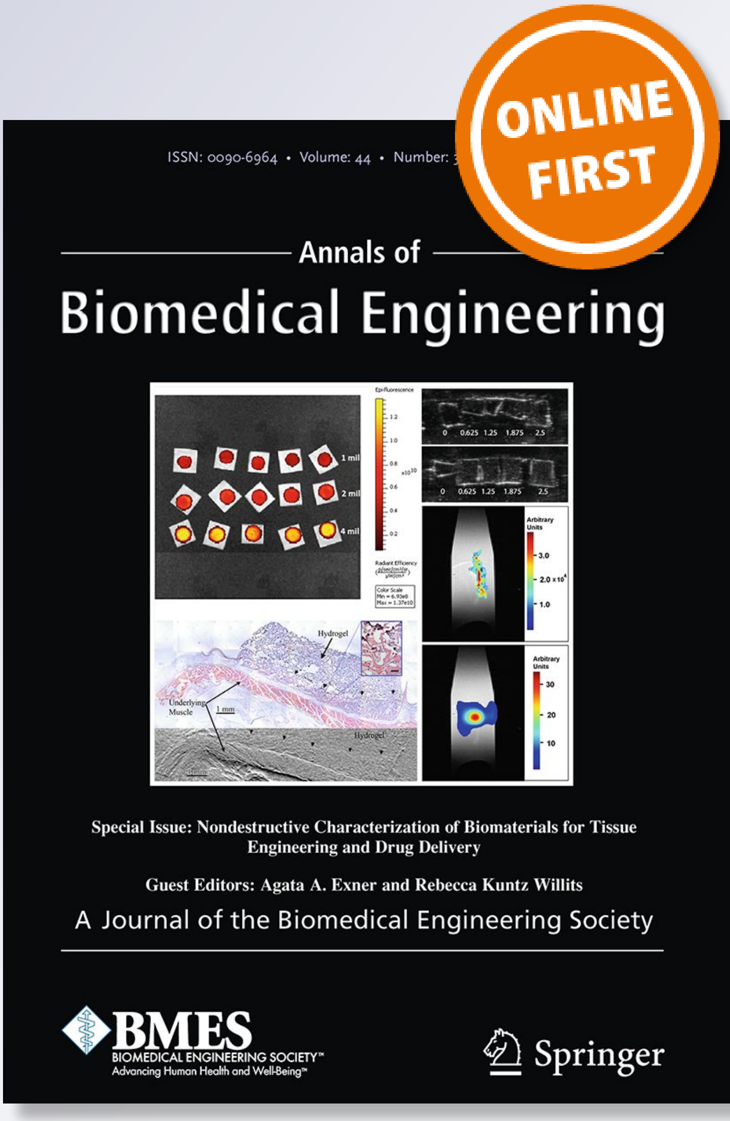

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Original Article

Developing a Model for Integrating Professional Practice and Evidence-Based Teaching Practices into BME Curriculum

AILEEN HUANG-SAAD, JAN STEGEMANN, and LONNIE SHEA

Department of Biomedical Engineering, University of Michigan, Ann Arbor, MI 48109, USA

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Abstract—Undergraduate biomedical engineering (BME) programs typically consist of courses from several different academic departments combined with BME-specific courses taught by faculty trained in a variety of disciplines. While some students embrace this diversity in courses and disciplinary perspectives, many students struggle with how to translate these experiences into career opportunities. BME students are often concerned that they are perceived as a "jack of all trades, master of none." In 2016, our department sought to find new ways to integrate BME professional practice into our curriculum. Informed by organizational change theory, we asked: (1) is there potential for change; (2) what strategies facilitate change; and (3) how can these strategies be implemented? As a result, we developed an Instructional Design Sequence, a new approach to instruction in which students, post docs, and faculty create short Modules that use evidence-based teaching practices to expose BME students to BME professional practice. This paper describes how the Sequence was conceptualized and demonstrates how theory can be used to inform practice. The resultant Sequence is a transferrable model for transforming engineering education, offering a mechanism for integrating new career relevant curriculum into undergraduate curriculum, while training future educators in instructional evidence-based practices.

Keywords—Undergraduate education, Biomedical engineering, Organizational change, Professional formation.

INTRODUCTION

Biomedical engineering (BME) programs were first established in the 1970s,[7,23] born from recognition that engineers need to help solve emerging biologically-based problems that impact medical device design, therapeutics, diagnostics, and basic discovery. In 2015, CNN Money ranked BME as one of the top 50 jobs in America with a 24% 10-year growth potential,[6] and the Bureau of Labor Statistics projects a 4% increase in BME jobs by 2028.[13] As of 2018, 117 ABET accredited 4-year undergraduate programs existed in the U.S.,[7] close to a 58% increase since 2006.[24]

Despite the fact that economic indicators point to continued growth in the field of BME for graduates with 4-year degrees, BME students are reporting significant challenges in competing for jobs and finding post-undergraduate employment.[5] Students report that industry recruiters are not familiar with BME and tend to opt for engineers with degrees from traditional engineering fields that they can train in biology. Graduates of 4-year BME programs frequently express concern that their degree has set them up to be the "jacks of all trades, masters of none".[5]

BME programs are therefore in great need of identifying strategies that promote professional formation, the acquisition of knowledge, skills, social practices, and discourse of biomedical engineers.[34] Moreover, these strategies must be implemented in a challenging environment in which technology and stakeholder (e.g. industry, medical schools, regulatory agencies) priorities are changing rapidly. In 2016, our department sought to develop an instructional change strategy that would promote professional formation in early career BME students. To develop the strategy, we explored three questions: (1) is there potential for change; (2) what are the steps for change; and (3) how can these steps be implemented? As a result of our findings, the department created the BME Instructional Design Sequence. The purpose of this paper is to describe how we used organizational change theory to

Address correspondence to Aileen Huang-Saad, Department of Biomedical Engineering, University of Michigan, Ann Arbor, MI 48109, USA. Electronic mail: aileenhs@umich.edu

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inform the conceptualization of the Instructional Design Sequence. The resultant Sequence is a transferrable model for transforming engineering education, offering a mechanism for integrating new career relevant curriculum into undergraduate curriculum, while training future educators in instructional evidence-based practices.

Background

Change is a significant undertaking for any organization and success is dependent on the alignment of the strategy, theories, and the organization. Instructional change is even more complicated in higher education. Effective change strategies must be "aligned with or seek to change the beliefs of the individuals involved; involve long-term interventions, lasting at least one semester; require understanding a college or university as a complex system and designing a strategy that is compatible with this system".[20]

Evaluating the Potential for Change

Successful, sustainable change is unlikely if the environment and its members do not see a need for change. Kurt Lewin, theorized that group behavior is a result of the interactions between the environment or 'field', group structures, and the individuals of the group. He argued that social situations are a balance of restraining and driving forces. Change "takes place when an imbalance occurs between the sum of the forces against change (Restraining Forces) and the sum of the forces for change (Driving Forces)".[29] In an effort to operationalize this theory, Lewin created his "force field analysis." Force field analysis is investigative and often used to diagnose a problem by identifying "forces" that influence a problem by driving or impeding change. With a clear understanding of the restraining forces, organizations can seek to translate the restraining forces into goals to drive change, thus promoting change (Fig. 1).

Strategies that Facilitate Change

For years, there have been national calls for engineering education reform,[1,30,31,37] seeking to both infuse more real world experiences into engineering education[31] and the adoption of more evidence-based practices in instruction.[32] Nonetheless, change has been slow, particularly with respect to the adoption of evidence-based practices for instruction.[10,35] Recognizing that the change process is complex, researchers studied STEM instructional change to develop a literature base of instructional change efforts to inform future practice.[9,10,20] Their research showed that change agents need to consider a diversity of perspectives for robust change.[10] A review of 191 STEM instructional change papers identified four categories of instructional change strategies (Fig. 2)[20]: (1) Disseminating curriculum and pedagogy; (2) Developing reflective teachers; (3) Enacting policy; and 4) Developing shared vision. According to the model, change impacts individuals or the environment and is either determined in advance (prescribed) or emerges during the change process (emergent).[20] The review found that top-down management and disseminating best practice materials in isolation are ineffective change strategies.[20] Given the complexity of educational environments, Henderson *et al.* suggested that effective, change strategies should span more than one category, facilitating both prescribed and emergent change.

Prescriptive change is defined as change that is planned.[10] For example, efforts that seek to improve engineering teaching and learning using research based instructional practices, may prescribe specific interventions or pedagogical approaches.[8] Nonetheless, prescriptive change is not sufficient for sustainable change.[20] Such change should also emerge through the change process itself.[20] But how is emergent change managed in academics, a complex organization of individuals producing knowledge? Change strategies need to consider the human dimension[4] and institutional culture.[25] Problems arise when institutional culture clashes with proposed changes.[25] "Policies that seek uniformity and deter individualized solutions are not likely to be effective in promoting change".[25]

Complexity Leadership Theory (CLT) is a leadership framework that recognizes both authority and the network of humans within an organization.[38] CLT accounts for how different individuals in an organization interact and play a role in outcomes that are adaptable and innovative for today's knowledge era. Typical leadership theory is grounded in bureaucratic frameworks more appropriate for the technical problems of the industrial age rather than adaptive challenges that are more typical of the knowledge era.[38] In contrast, CLT "recognizes that leadership is too complex to be described as only the act of an individual or individuals; rather, it is a complex interplay of many interacting forces".[38] According to CLT, leadership in the knowledge era should be: (1) administrative, (2) enabling and (3) adaptive. Administrative roles are the more familiar bureaucratic roles in organizations, where individuals are formally tasked with planning, vision setting, and managing people. Enabling leadership refers to structures that enable creative problem solving, adaptability and learning; and adaptive leadership refers to generating a dynamic that is responsive to the resultant emergent changes.

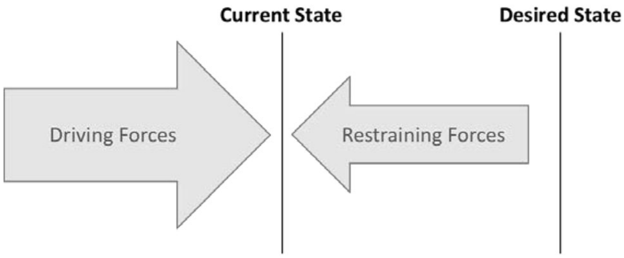

FIGURE 1. Visualization of Lewin's field theory: force field analysis.

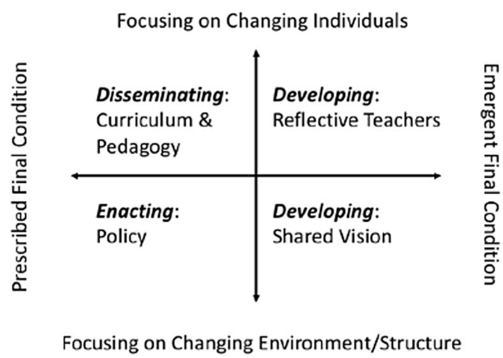

FIGURE 2. Henderson *et al.*'s[20] four categories of instructional change strategies.

While there are no definitive rules on how to bring about emergent change based on CLT, there are practical guidelines for administrative leadership.[15,26] A commonly used administrative practice for bringing about emergent organizational change in business is Kotter's Eight Stage Process for Successful Organizational Transformation.[26] By observing over 100 organizations trying to implement change, Kotter identified eight fundamental errors organization encounter through the process. Based on these observations, Kotter defined eight practical stages for organizational change: (1) Establish a Sense of Urgency; (2) Form a Powerful Guiding Coalition; (3) Create a Vision; (4) Communicate the Vision, (5) Empower Others to Act on the Vision; (6) Plan for and Create Short-Term Wins; (7) Consolidate Improvements and Produce Still More Change; and (8) Institutionalize New Approaches.

METHODS

Context

Like most BME departments, the University of Michigan (U-M) BME Department is highly interdisciplinary. The undergraduate program was formed in 1996 with less than 10 faculty. In 2010, the program officially partnered with the U-M Medical School and launched efforts to grow to 35 core-faculty by 2020. As of Fall 2016, the 28-core faculty were spread across 3 different campuses: the medical school, engineering, and the north campus research complex. Ninety five percent (95%) of the core faculty had bachelor's degrees from non-BME departments and 50% hold non-BME doctorates. The interdisciplinary nature of the faculty is not unique, given the nascence of BME education and the inherent multidisciplinary nature of the field itself. While the faculty come from a diverse range of backgrounds, they are responsible for collaborating on the delivery a core undergraduate curriculum for BME students.

Information Gathering

During the Fall of 2016, information was collected from department stakeholders (students, alumni, industry partners, and faculty) in the form of surveys and focus groups. The faculty and alumni surveys were distributed electronically. The purpose of the surveys was to explore faculty and alumni perspectives on teaching and learning in the department. Focus groups were also held with current departmental undergraduates and the department's Industry Advisory Board.

BME Faculty Survey

The faculty survey was adapted from previously published surveys on advising interactions with undergraduates, engagement with curriculum, perceptions of teaching, views on engineering education, educational beliefs and attitudes, organizational culture with respect to teaching, perceptions of biomedical engineering, and demographics.[9,27,33]

BME Alumni Survey

The alumni survey was also adapted from previously published surveys[9,27,33] and specifically explored student departmental engagement, career intentions, perception of impact of educational experience, and formative assessment for curriculum feedback.

Focus Groups

Focus groups were held to obtain feedback from current BME undergraduates. Focus groups were facilitated by undergraduate upperclassman volunteers. All facilitators were provided with a series of open-ended questions that related to learning more about students' decisions to pursue BME as a major, student perceptions of future goals, perceptions of the BME community, and perceptions of current curriculum.

Industry Focus Group

The department has an Industry Advisory Board that meets annually to offer guidance and insight to the department. Members of the committee were asked what they look for in BME graduates when considering them for employment.

Force Field Analysis

Information collected during the Fall of 2016 was used to perform a force field analysis to determine if there was the potential for instructional change.[28] Driving forces for change were categorized with respect to stakeholder, students, faculty, and industry partners.

Designing for Instructional Change

Based on the results from the force field analysis and guided by Complexity Leadership Theory and Kotter's Eight Stage Process for Organizational Transformation, we systematically worked with members of the department to implement an instructional change strategy that spanned all four categories of Henderson *et al.*'s instructional change strategies. The resultant Instructional Design Sequence seeks to increase student exposure to BME professional practice and use of evidence-based instructional practice into the department.

RESULTS

Information Gathering Results

Faculty

Twenty-six of the 28 core BME faculty responded to the survey. Over 50% of the faculty indicated that they would like to change the curriculum. Seventy-three percent (73%) of the faculty indicated that they do not make changes to their teaching because they lack time. Feedback from the new hires indicated that they would like to have had departmental mentorship for their first few years of teaching. When BME faculty were asked "why do students enroll in BME," there was no shared understanding of student motivation. Overall, there was a desire for more community across the department.

Alumni

Six hundred sixty-four (664) alumni that graduated from the department between 2006 and 2016 were surveyed about their U-M BME experience, career intentions, and perceptions of teaching from the department. One hundred twenty-three (123) alumni responded to the survey (18.5% response rate) sent to their alumni email addresses. The 18.5% response rate was considered a good response rate given the limited number of alumni who are still actively using their alumni accounts.

While close to 40% of the students had originally intended to pursue a medical degree after college, only 26% enrolled in medical school. Conversely, while 17% of the respondents intended to enter industry when they declared BME as a major, 45% were in industry or government positions after graduation. Eighty-five percent (85%) of respondents indicated that the lectures were the most prominent method of teaching when they were in the BME department, yet only 39% felt lectures were impactful for their learning experience. In contrast, 64% indicated that hands-on learning had the most impact on their learning, yet they only experienced hands-on learning for 5% of their learning experience. When asked what classes impacted their current careers, the top three classes were upper level classes: senior design, quantitative physiology and bioinstrumentation. Both senior design and bioinstrumentation are hands-on, problem-based learning classes. When asked for suggestions to improve the curriculum, the most prominent request was for more career guidance and assistance in synthesizing the curriculum across the many disparate courses they were required to pursue for their degrees. (Example quote: "It was hard to tell how classes related.")

Students

Current student focus groups revealed that students were often not taking BME centered courses until their junior year. This was largely due to the large number of pre-requisites required by the degree. Students would like to have greater exposure to BME coursework earlier to learn more about the degree and career opportunities. Students also indicated that there was little cross-fertilization between classes. Students asked for more faculty interaction, exposure to faculty research, and hands-on learning experiences.

Industry Advisory Board

During the 2016 Industry Advisory Board meeting, the board was specifically asked what they looked for when considering hiring BME graduates. The Industry Advisory Board consisted of director level and C-suite individuals from the healthcare industry (imaging, cardiovascular, pulmonary, and devices). The companies they represented included public, fortune 500 companies and smaller privately held companies. While the Board felt that there had been significant educational advances with regard to needs finding, they indicated that they would like to see more systems engineering training, awareness of the regulatory process (FDA design control/Risk management), and design for reliability and manufacturability.

Force Field Analysis

Results from the surveys and focus groups were used to populate a force field analysis[29] for determining the likelihood of departmental change. Table 1 shows driving and restraining forces based on the data collected. Delineation of the restraining forces helped identify potential challenges for change, many of which had the potential to be reduced. This, in addition to the apparent imbalance of driving forces versus restraining forces, suggested that the department was ready for change,[14] specifically instructional change. Thus, the driving and restraining forces were used to inform the resultant change strategy, as efforts were made to strengthen the driving forces and decrease the restraining forces.[29]

Designing for Instructional Change Through the Lens of Theory

Based on the force field results and guided by Complexity Leadership Theory and Kotter's Eight Stage Process for Organizational Transformation, an instructional change strategy for the department was developed to increase student exposure to BME professional practice and use of evidence-based instructional practice into the department, the Instructional Design Sequence (Fig. 3).

Lewin's Force Field Informed Change

The first step in developing the change strategy was to reduce the restraining forces, which were largely challenges faced by faculty. Specifically, faculty lack of exposure to evidence-based teaching practices and incentive to change practice. While it is commonly agreed upon that higher education teaching needs to change, change has not been widely embraced.[35] This slow adoption may result from lack of awareness of active learning effectiveness, a lack of trust of the data, or overall resistance to change.[18] Instructor survey results were consistent with the literature. Research also indicates that faculty will often teach the way in which they were taught,[2,11] which is why most faculty revert to traditional lecture-based practice. In an effort to reduce these restraining forces, an Incubator for faculty to develop new curriculum was conceptualized. Each year, select faculty could dedicate one semester to developing new curricular Modules for first and second year BME students while learning about evidence-based teaching practices. The focus on first and second year BME students also addressed students' desire for more active learning classes and a better understanding of what BME is. Participation in the Incubator would count towards the faculty's teaching responsibility for the semester, allowing the faculty to prioritize curriculum development.

Driving forces were also used to inform the change strategy. Upon conception, the goal of the Incubator was to teach faculty about evidence-based practices using problem-based learning, which itself is an evidence-based practice. Because students and faculty surveys indicated the need for more community and students wanted more engagement with faculty, it was decided to offer the Incubator as a credit-bearing course and include undergraduates as co-creators. Undergraduates are not only the most familiar with the curriculum and current needs of BME students, but students as co-creators of teaching approaches and course design has been shown to beneficial in higher education.[12] As a result, graduate students and post docs were also included in the Incubator. While graduate students and post docs were not a part of the initial surveys, there were several reasons to include them in the Incubator. First, BME undergraduates, graduate students, and post docs are important members of the community and their personal experiences with curriculum and pedagogy have much to contribute to curriculum development. Additionally, there is extensive literature that confirms the need to provide graduate students and post docs, future faculty members, with training in evidence-based teaching practices for long term impact on higher education.[17,36]

The curriculum for the Incubator was also informed by the force field analysis. The Incubator Course would be developed and taught by an engineering education faculty member using active learning. Incubator teams would learn about education theory and pedagogy while going through an instructional design process to create 1 credit, 4-week BME-in-Practice Modules. Module topics would be dependent on information gathered from BME stakeholders, individuals that employee undergraduate BME students. All Incubator participants would be required to participate in the interview process.

Finally, to ensure that undergraduates would benefit from the newly created curriculum, the Incubator was expanded into a two-semester sequence. The two-semester sequence would allow the multigenerational teams of undergraduates, graduate students, post docs, and faculty, first develop Modules in the Incubator and then launch the Modules the following semester. As a result, the Instructional Design Sequence was conceived. Specific examples of how the driving forces

TABLE 1. Lewin's force field analysis to change for U-M BME.

DRIVING FORCES →	← RESTRAINING FORCES
Students* want:** • More active learning in BME • A synthesis of disparate courses • A better understanding of what BME is • More career guidance • More interaction with faculty ***Faculty* want:** • Deeper student understanding of the material • A stronger U-M BME community • To be exposed to effective teaching practices [New faculty] • A teaching community ***Industry wants: • Students able to handle open-ended problems • To resolve disconnect between academia and post-graduation employer needs ***Other factors:*** • *Student* graduates feel as if they are the "jacks of all trades, masters of none," making them feel as if their job search is more difficult • *Faculty* and *students* want more community within a geographically dispersed department • Anticipated *faculty* growth of 30% • Current *faculty* turnover offers opportunity for cultural change • Climate survey of *faculty and staff* suggests desire for cultural change • National push for cultivating 21st century skills and use of evidence-based practices in higher education • U-M model of embedding engineering education *faculty* in discipline departments • Institutional/Departmental goal to increase *faculty* teaching scores	• The perception that historical modes of instruction were effective, and hence reform is unnecessary • Most engineering *faculty* are trained to be researchers, not teachers • Most *faculty* rewards are for research, making it counter-productive to invest time in teaching • Lack of disadvantages for ineffective instruction • Autonomy among *faculty* with respect to scholarly activity, including teaching • Lack of training opportunities in STEM education for college *faculty* • Perception that entry-level courses are less rigorous, so *faculty* devote less attention to them • Entry-level courses are commonly not directly related to *faculty* research • We rely on *faculty* self-selecting instructional assistance • *Faculty* have different teaching requirements based on their appointments • Some *faculty* do not believe in evidence-based teaching practices

were incorporated into the design of the Sequence are presented in Table 2.

Facilitating Change

Two change strategies, Kotter's and CLT, were used to facilitate departmental change while conscientiously using tactics that span the Henderson *et al.*'s[20] entire change space for comprehensive, sustainable change. Kotter's 8-stage Model[25,26] was used as a form of prescriptive change and Complexity Leadership Theory was used to engage instructors in creating a shared vision.

The Department spent six months working towards change before the launch of the Incubator Design Sequence. Spawned by growth in new faculty, the addi-

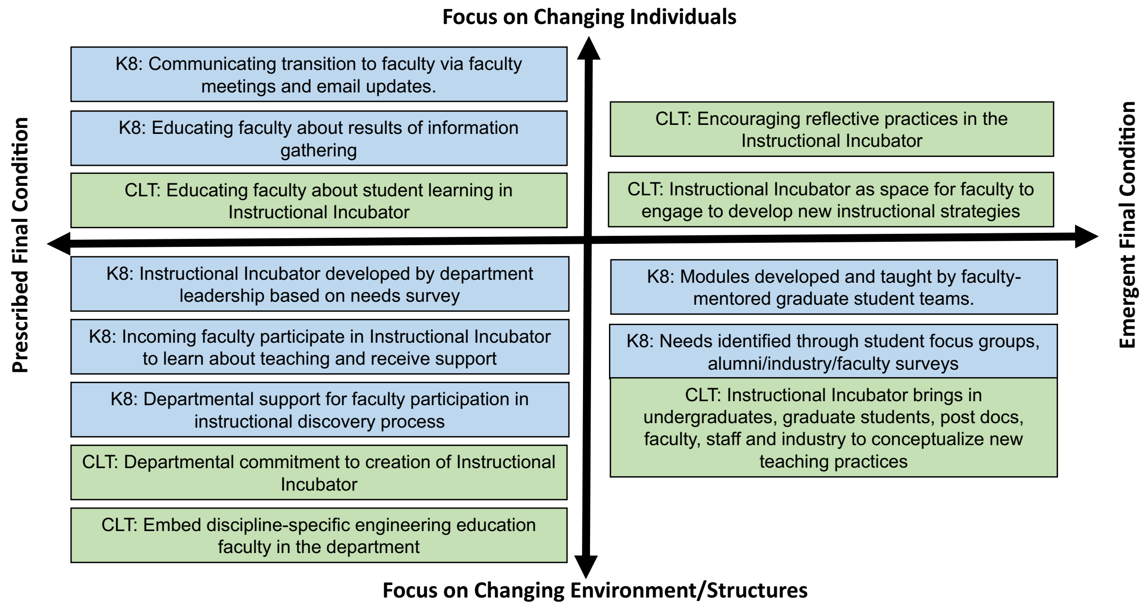

FIGURE 3. Implementation of Kotter's 8-stage model (K8) and Complexity Leadership Theory (CLT).

TABLE 2. Examples of how driving forces and the literature were used to create actionable solutions.

Problem	Actionable Solution
Undergraduate students	
Students want more hands-on experiences specific to BME early in their academic careers	Create hands-on modules for 1st and 2nd year students
Students often do not understand what BME is—they want career guidance	Offer classes that expose students to skills necessary for post graduate BME opportunities and help them get internships earlier in their career
Students want more 1:1 interaction with graduate students and faculty	Create venue for students to interact with faculty and graduate students with purpose
Students want a sense of community	Create a venue for students, faculty, and graduate students to work in small groups
Students want to be able to give input to their curriculum	Include students in curriculum reform
Graduate students	
Graduate students interested in teaching want exposure to effective teaching practices	Provide a venue for students to learn about effective teaching practices
Faculty	
New faculty would like more support when they start teaching	Have new faculty participate in a supportive environment that informs them about effective teaching practices
Faculty prefer teaching communities, faculty feel isolated when teaching	Create faculty teaching communities
Research faculty do not know about BME student post graduate opportunities	Have faculty learn about post graduate opportunities by interviewing BME stakeholders
Curriculum	
Curriculum is not traditionally adaptive to the changing needs of BME in practice	Create mechanism for classes to come online and offline when irrelevant
Interdisciplinary nature of faculty makes it challenging to create a sense of belonging for students and faculty	Create a venue where faculty can come together and co-create curriculum
Faculty have limited time to create new classes	Share the burden of course creation across the department

tion of an education researcher to the core faculty, and student feedback, efforts were made to examine approaches for instructional change. Facilitated by potential funding prospects, a *sense of urgency* was created within the department (Stage 1). Recognizing that no one individual can create change, the instructor and alumni surveys, climate surveys, student focus groups (Stage 2: *Creating the guiding coalition*), and

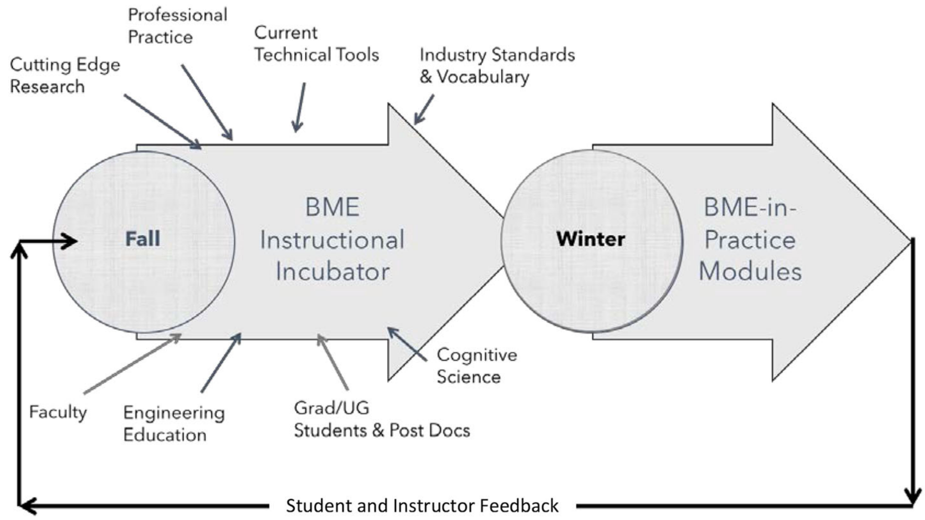

FIGURE 4. Visualization of instructional design sequence.

faculty meetings were used to *develop a change vision* (Stage 3). The vision was created, iterated upon and *communicated for buy-in* (Stage 4) through frequent email updates of progress and monthly meetings with faculty throughout the term. As a result of these meetings, the department agreed to *empower broad-based action* (Stage 5) through the Incubator Design Sequence.

Without faculty buy-in and motivation, initiatives will fail. Acknowledging this culture, emergent change was facilitated through the Instructional Design Sequence. In this case, interdisciplinary instructional change was catalyzed by bringing faculty together to pursue a common goal to change instruction.

While the creation of the Instructional Incubator itself was prescriptive, it did not dictate the resulting BME-in-Practice Module curriculum, leaving that to be emergent. Importantly, the Incubator addressed barriers to instructional change, and acknowledged the time needed for curriculum development using effective learning practices, and was created to acculturate a new departmental norm. The deliberate creation of truly integrative team teaching also leveraged the value of team taught courses for collaborative knowledge construction.[3,19,28] Team taught courses were defined as conception and delivery by a team, as opposed to asynchronous teaching where each faculty member delivers content in isolation of the other content in the course.

The long-term commitment of the department to the Incubator and its use of iterative design created an opportunity for continued emergent change shared by all of the department stakeholders. Figure 3 shows the tactics used, and how elements of both Kotter's model (K, blue boxes) and Complexity Leadership Theory (CLT, green boxes) span across all of Henderson's change categories, to ensure effective change.

The BME Instructional Design Sequence

The resultant Instructional Design Sequence is a two-semester course sequence, including an Incubator (Fall) and resultant BME-in-Practice Modules (Winter) (Fig. 4). In the Fall semester, upper level BME undergraduates and graduate students enroll in the Incubator course for credit to work with post docs, and faculty in creating the BME-in-Practice Modules. The Incubator undergraduates, graduate students, post docs, and faculty are referred to as participants throughout the rest of the paper. The course meets two times per week for 1 hour and 20 minutes. As a part of the Incubator course, participants are tasked with interviewing BME stakeholders and early career BME students to identify the important skills and knowledge required of BME graduates (Instructional Discovery) and learning about instructional evidence-based practice. Based on their Instructional Discovery process and understanding of instructional evidence-based practices, participants work together as teams to create 1-credit BME-in-Practice Modules designed for early career BME students. The format of this instructional design project is similar to that of senior design courses, where student teams have course time to work on their design project and seek mentorship from faculty. Incubator participants are then given the opportunity to teach their Modules during the Winter term while mentored by BME faculty.

Each year Incubator teams have the option to iterate on Modules created the year before or create novel courses based on what they learned during their

TABLE 3. BME-in-practice modules.

AY2017–18	AY2018–19
Introduction to Medical Product Design Iteration and Validation	Introduction to Medical Product Design[a]
Building a Tumor, an Introduction to Tissue Engineering	Engineering the Cellular Microenvironment: An Introduction to Tissue Engineering[a]
Introduction to Neural Engineering and Modeling	Wrangling with Regulations: Introduction to Regulatory Science
Computational Cell Signaling: Roadmap to Drug Development[b,c]	
Design "Crash" Course: Computer-Aided Design, Rapid Prototyping, and Failure Analysis[b]	
Biomechanical Design and Rapid Prototyping[b]	

[a]Iterated courses from previous year.
[b]Not offered because of scheduling conflicts with the teaching team.
[c]Offered in Winter 2019.

Instructional Discovery process. This mechanism offers a dynamic approach to curriculum development that consistently integrates current best professional practices, allowing for the creation of new curriculum or iterative enhancement of previous offerings.

The Incubator was piloted for the first time in Fall 2017 by the first author and iterated upon in 2018. To date, 36 individuals have participated in the Incubator, seven BME-in-Practice Modules were offered to students, and 50 unique students enrolled in the BME-in-Practice Modules. Of the 36 Incubator participants, there were 27 graduate students, three 4th year students, three post docs, and three BME faculty members. A School of Education graduate student also participated as a graduate student instructor in the first year. As a part of the Instructional Discovery process, participants interviewed sophomore-level undergraduate students and BME stakeholders, reviewed BME experiential courses at other universities, and observed classes. Students drew on these findings to develop their 1-credit Modules.

Over the first 2 years of implementation, students created nine 1-credit BME-in-Practice Modules to meet the needs of BME undergraduates and BME stakeholders (Table 3). Student teams publicly presented their course teaching philosophies and designs to department faculty at the end of the term. Two Modules developed in 2018 were iterations of Modules developed in 2017, Introduction to Medical Product Design and Introduction to Tissue Engineering. Seven of the nine Modules were offered by the post doc/student teams during the 2017 and 2018 Winter terms (three in 2017, four in 2018). Students were able to use Module enrollment towards their concentration requirements. Two teams were not able to launch their Modules because of scheduling conflicts. One of the 2017 teams opted to launch their Module in the Winter of 2019. While the Modules were initially intended for first and second year BME students, students from all levels enrolled (first year through graduate student).[22]

DISCUSSION

The creation of the Instructional Design Sequence was motivated by the need to address the disconnect between student perceptions of their BME education and preparation for professional practice. We systematically explored the current state of the department using organizational change theory to unpack the problem to be solved and create a solution. This work demonstrates how theory can be used to inform practice in academics. The resultant solution, the Instructional Design Sequence, has the potential to become a novel, transferrable mechanism for bringing together interdisciplinary faculty and creating a shared vision of interdisciplinary instruction and a professional identity for an interdisciplinary department.[22]

Academic institutions are complex environments.[20] Unlike in business, academic units have less of an ability to influence change with traditional incentives or disincentives, such as financial incentives, top down leadership, or threat of termination. Change must consider individual motivations and examine ways to influence behavioral change. Recognizing that change is reliant on the behavior of individuals in the department and a dynamic balance of forces, Lewin's force field analysis was used to explore the balance of forces in 2016. Lewin states that "change takes place when an imbalance occurs between the sum of the forces against change (Restraining Forces) and the sum of the forces for change (Driving Forces)" and the change strategy is dependent on the ability to reduce the restraining forces to strengthen the driving forces. Interview and survey results indicated that the imbalance of forces was most significant with respect to instruction. By identifying instructional restraining forces, it was possible to conceptualize a solution to reduce the restraining forces, thus, creating an imbalance of forces and enacting change.[14] While this is not a purely quantitative analysis, it offers a strategy for identifying potential barriers to change and provides organizations guidance in how to promot change.

Henderson *et al.*'s Four Quadrant Categorization of Instructional Change indicates that successful change should employ prescriptive and emergent tactics that impact individuals and the department. Kotter's Eight Stage Process for Organizational Transformation was used to guide administrative emergent change, prioritizing the change process. The department systematically worked together to conceptualize an instructional change model, which resulted in the Instructional Design Sequence. Responding to the results from the interviews, focus groups and surveys and student concerns of being a "jack of all trades, master of none," the department was able to create a shared model to integrate professional practice and evidence-based teaching practices into the curriculum at all levels, undergraduates, graduate students, post docs, and faculty. The department sought to create a culture in which interdisciplinary faculty and their students and post docs are empowered to work together to create curriculum responsive to the rapidly changing professional environment.

The annual offering of the sequence enables multi-generational groups of students, post docs, and faculty the opportunity to act on the vision in ways in which they saw fit. As suggested by Complexity Leadership Theory, in a complex environment, individuals need to be enabled to make their own change and it must be adaptive. Each year, new faculty joining the department are introduced to the department by participating in the Instructional Design Sequence as their first teaching assignment. This allows new faculty to get to know the students and learn about the current curriculum, the changing needs of professional practice, and student learning theory. Each year, new Incubator participants have the ability to either iterate on previous Modules created or create new Modules.

The Incubator also seeks to bring about emergent change in individual faculty by addressing barriers to instructional change. While higher education faculty agree that higher education teaching needs to change, change has not been widely embraced.[18] This slow adoption may result from faculty lack of awareness of active learning effectiveness, a lack of trust of the data or overall resistance to change.[18] In an attempt to address these challenges, most institutions have created centers for teaching and learning on their campuses to support instructors,[16] bridging the gap between theory and practice. While these organizations have been impactful, they are still dependent on faculty self-selecting into these resource opportunities and do not address fundamental situational constraints identified by Henderson and Dancy including: expectations of content coverage, lack of instructor time, departmental norms and expectation of course content.[21]

The Incubator was created to acknowledge the time needed for developing curriculum and effective learning practices, and was designed to acculturate a new departmental norm that values evidence-based teaching practices and incorporating BME professional practice into curriculum. The course is also taught using the active learning pedagogical approaches that have been shown to be more effective at engaging students. Research indicates that faculty tend to teach the way in which the way they were taught[2,11] and there are instructor belief barriers[9] to new approaches that support student learning. Thus, exposure to this teaching practice attempts to address these challenges to transform teaching in higher education. The deliberate creation of truly integrative team teaching also leverages the value of team taught courses for collaborative knowledge construction.[3,19,28] We define team taught courses as conception and delivery by a team, as opposed to asynchronous teaching where each faculty member delivers content in isolation of the other content in the course.

CONCLUSION

In this paper, we described how we used organizational change theory to inform the conceptualization of an approach to instructional change in a BME department. The resultant Instructional Design Sequence offers departments a mechanism for integrating new career relevant curriculum into undergraduate curriculum, while training future educators in instructional evidence-based practices.

ELECTRONIC SUPPLEMENTARY MATERIAL

The online version of this article (https://doi.org/10.1007/s10439-019-02427-6) contains supplementary material, which is available to authorized users.

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ACCESSING MATERIALS

The BME Incubator course materials are available on the TEEL website: https://www.teel.bme.umich.edu.

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