RIEF: What Motivates Faculty to Integrate Sustainability in Engineering Curriculum - A Qualitative System Dynamics Model

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Introduction

Training the nation's engineers to understand sustainability is key to fostering competitive technological innovation. Still, sustainability education remains mostly absent in undergraduate engineering education. One reason for this persistent challenge is that academic change, particularly around curriculum and instruction, is a complex and dynamic process. Faculty, who play a central role in enacting change, operate within institutional systems shaped by competing demands, incentive structures, and cultural norms [1]. Without a clear understanding of what motivates faculty to act, efforts to promote meaningful and lasting curricular innovation are unlikely to succeed. This project, funded by the NSF Research Initiation in Engineering Formation (RIEF) program [2], investigates the conditions that influence faculty motivation to incorporate sustainability into undergraduate engineering courses.

Systemic change in engineering education, "must ultimately be enacted at the personal level as individual faculty enter classrooms [and] interact with students" [3]. Regardless of who promotes curricular or instructional change, individual faculty must implement the changes. Understanding systemic change requires addressing the complexity of the academic system [4], particularly understanding the multiple factors that influence decisions, motivators, and actions of agents within the system. We employ a systems engineering approach to explore complexity by addressing the interconnectedness of the components in the academic system [5]. Our goals are (1) to identify factors in the academic system that influence faculty motivation to integrate sustainability principles into their teaching; and (2) to understand the dynamics among these factors using qualitative system dynamics modeling [6]. This poster presents a subset of these loops that we felt would lead to rich discussion with faculty about their own relatability to these dynamics.

Methodology

We created a qualitative system dynamics model to identify the complex factors influencing faculty motivation to integrate sustainability principles into academic curricula (referred to moving forward as "faculty motivation"). We created the model via a content analysis of 11 peer-reviewed documents—selected for their focus on drivers and barriers in sustainability and engineering education—to map causal relationships between systemic variables. By synthesizing these connections into causal loop diagrams (CLDs), we demonstrate how specific pathways reinforce or inhibit motivation, showing how the academic system and faculty engagement are mutually influential.

Results

The following model illustrates the system of factors that influence faculty motivation (Figure 1). The model consists of a series of CLDs that illustrate relationships among system factors, and how these factors reinforce or hinder faculty motivation. From literature, we identified four main feedback loops that drive faculty motivation: 1) access to resources related to sustainability

instruction, 2) the engagement of faculty with the sustainability community, 3) faculty's value of sustainability in academia, and 4) the institutionalization of policies and resources. The following paragraphs describe the casual loops within the model.

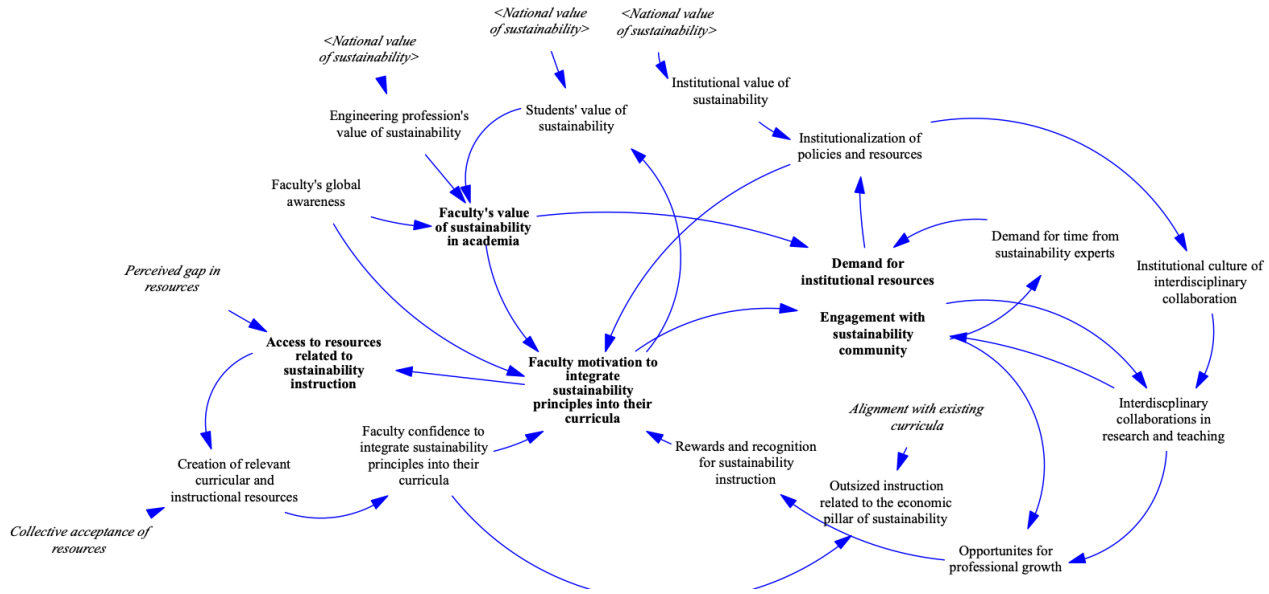

Figure 1. System dynamics diagram that describes the feedback loops that impact faculty motivation.

1. *Access to resources for sustainability instruction*. Successful integration of sustainability into curricula requires that faculty possess pedagogical knowledge and skills related to the field. In literature, faculty, however, reported that they do not feel they possess these skills; perceive sustainability as an "emerging field" demanding a "serious didactical re-orientation" [8], emphasizing the vital need for reliable resources for instruction [11]. These resources include peer-reviewed modules, lesson plans, and texts [12, 13] that faculty accept. Greater access to such materials enables faculty to build their pedagogical knowledge and skills in sustainability, increasing their teaching confidence and motivation to incorporate sustainability into the classroom [14]. This motivation can spur faculty to create relevant resources themselves [11], especially when they perceive existing materials as limited, ultimately expanding the pool of accessible teaching resources. This cycle is strongly supported by faculty-driven, "bottom-up" initiatives for curriculum integration [15].

We identified faculty confidence to be a key variable in this dynamic. The perceived complexity of sustainability, as an emerging field, can hinder faculty motivation to integrate these principles into their curricula. Focusing instruction on familiar topics, particularly related to economics, a topic that is already part of traditional engineering curricula, eases implementation and thus reduces instructional change required to integrate sustainability topics into the classroom. However, this has an unexpected negative impact on student learning, as it results in students developing a narrow understanding of sustainability. Students overvalue the economic pillar of sustainability, without valuing the social and environmental pillars [7, 8].

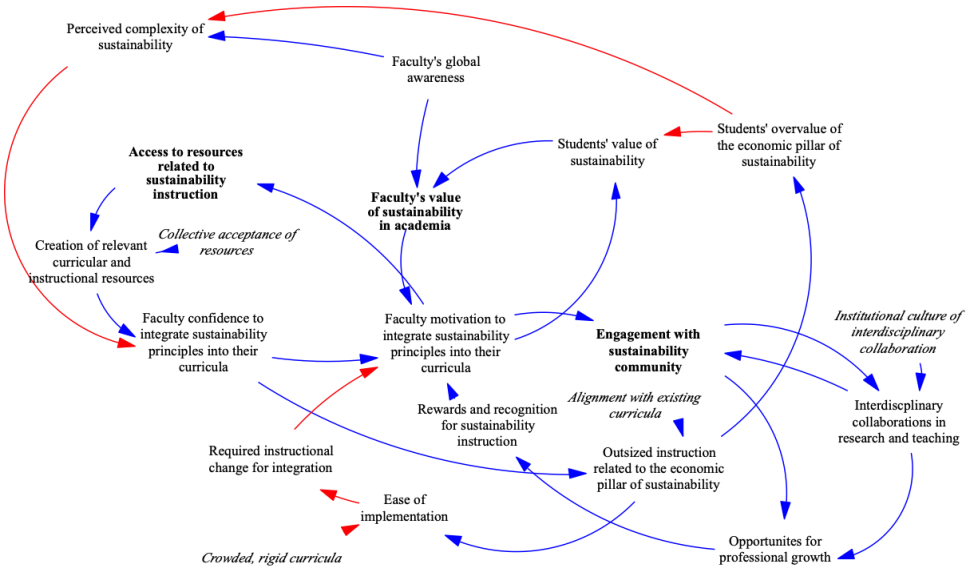

Figure 2. Dynamics that impact faculty confidence to integrate sustainability into their curricula.

2. *Engagement with the sustainability community*. Faculty motivation to integrate sustainability into the curriculum increases their likelihood of engaging with the broader sustainability community. These peer-to-peer interactions are vital for promoting change within academia, as they reduce discomfort with topics through resource-sharing and professional development, such as collaborations in teaching and research [16]. Such opportunities enhance the importance faculty place on their pedagogical knowledge and skills related to sustainability [14]. Furthermore, this professional growth can lead to faculty recognition, such as through awards for teaching excellence [8, 17]. Consistent institutional recognition and rewards are significant reinforcers of instructional change [18].

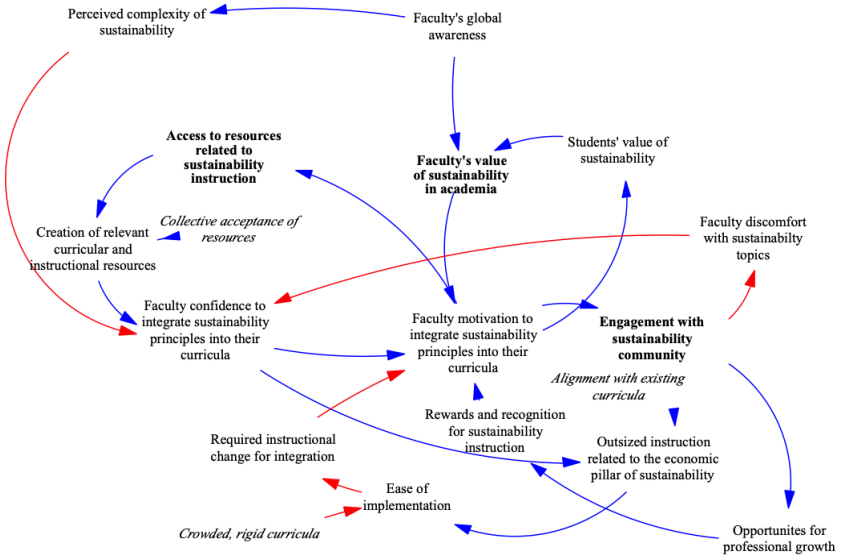

Figure 3. Dynamics impact reinforce faculty engagement with the sustainability community.

3. Faculty's value of sustainability within academia. Faculty motivation to incorporate sustainability into the curriculum is rooted in an intrinsic belief in its importance to engineering [11]. This value is then communicated to students through instructional time dedicated to the topic, which, in turn, influences students to place greater importance on sustainability and its integration into engineering education [16]. This dynamic is reinforced by faculty's global awareness and is shaped by two external influences [17]. First, the engineering profession's value for sustainability, which increases faculty awareness that graduates require a strong foundation in sustainability to be successful employees capable of addressing real-world problems. Second, the national cultural context, as strong sustainable practices within the national culture make the integration of sustainability feel naturally aligned with the views of both faculty as educators and students as future engineers.

4. *Institutionalization of policies and resources*. Faculty value of sustainability is linked to a reinforcing cycle that promotes motivation. As faculty increasingly value sustainability, the need for institutional support also rises [11]. This support encompasses resources like funding and training for curriculum and instructional development [8, 17]. When this demand aligns with an institution's prioritization of sustainability [7], it can result in the formal institutionalization of policies and resources that support sustainability-related instruction. Such reliable institutional backing is recognized as a powerful catalyst for change, especially in national settings where such efforts might otherwise face obstacles [17].

Discussion

Our literature review allowed us to build a preliminary understanding of the factors that impact faculty motivation to integrate sustainability into engineering curricula. We identified four loops of faculty motivation: 1) the access to resources related to sustainability instruction, 2) the engagement of faculty with the sustainability community, 3) faculty's value of sustainability in academia, and 4) the institutionalization of policies and resources.

We acknowledge the limitations of our study in only discussing a few of the drivers of faculty motivation; in future work, we will further explore drivers not yet presented, as well as the barriers to integration of sustainability in the curricula. Future integration of empirical data to enhance these models will serve as the foundation for actionable recommendations to institutional leaders and educators, identifying potential leverage points that support or inhibit faculty motivation. During the poster session, we will present the most interesting feedback loops we found in our model and have a discussion with the participants about their reactions, and relatability with these dynamics. We would engage visitors in a discussion regarding their reactions to these dynamics and their perceived relatability.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 2508684. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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