AUSTRALASIAN JOURNAL OF ENGINEERING EDUCATION
2020, VOL. 25, NO. 2, 165–176
https://doi.org/10.1080/22054952.2020.1864087

ARTICLE

Cultivating a culture of scholarly teaching and learning in a college of engineering: An ecological design approach

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ABSTRACT
This paper describes a novel institutional change model, embodied in the Engineering Education Transformations Institute at the University of Georgia, that was intentionally designed to build community and expertise around scholarly teaching and learning in engineering education. The model is informed by several theoretical constructs, including complex systems theory, the propagation paradigm, a strengths perspective, and ecological design principles. The goals of this paper are twofold. First, we introduce these theoretical constructs and describe how they inform both the organisational structure and day-to-day operations of the Institute. Second, drawing on data collected using ethnographic methods and a thinking with theory analytical approach, we share two practice examples that demonstrate some of the opportunities and challenges associated with our institutional change efforts. The first example shows how our Institute's programming enabled a teaching-focused faculty member to connect with others in our college in ways that dramatically enhanced his existing STEM (science, technology, engineering, and mathematics) outreach efforts to a local, resource-constrained high school. The second example demonstrates how complex systems theory and ecological design principles can be used to both create the conditions for scholarly teaching, learning, and research in engineering education, and provide a set of theoretical perspectives through which to better understand and solve challenges that arise in collaborative, educational research and practice settings.

ARTICLE HISTORY
Received 2 July 2020
Accepted 10 December 2020

KEYWORDS
Institutional change; scholarly teaching; educational development; faculty development; ecological design; complex systems

1. Introduction

Over the past two decades, there has been a significant increase in the production of engineering education research (Bernhard, 2018; Lima and Mesquita 2018; Nelson and Brennan 2018). Worldwide, this increase is reflected in the growing number of papers that are submitted to engineering education-focused conferences[1] and journal outlets; and, in the United States, the increasing number of new schools and departments of engineering education, as well as tenure-track[2] faculty positions in the field (Borrego and Bernhard 2011).

As the discipline of engineering education research matures, some scholars have observed a gap between engineering education research and educational practice (Froyd et al. 2013; Handelsman et al. 2004; Jamieson and Lohmann 2009; Landrum et al. 2017)[3]. As stated by Finelli, Daly, and Richardson (2014):

> Ample research provides evidence about the influence of effective teaching practices on student success. Yet the adoption of such practices has been slow at many institutions. Efforts to bridge the gap between research and practice are needed. (p. 331)

Some studies attribute this gap to a focus on the dissemination of evidence-based practices, as opposed to working with instructors to adapt evidence-based practices to 'fit' into new contexts (Froyd et al. 2017). Other research, however, points to the need for broader cultural change (Borrego, Froyd, and Hall 2010), for example at the level of the school or department, in order to *create the conditions* that enable and empower instructors to sustainably engage with scholarly teaching and learning practices (Henderson, Beach, and Finkelstein 2011).

In this paper, we introduce a novel institutional model, currently embodied in the Engineering Education Transformations Institute (EETI or 'the Institute') at the University of Georgia (UGA), that was designed to create such conditions (Morelock, Sochacka, and Walther 2020; Morelock, Walther, and Sochacka 2019). We describe our model as 'novel' based on its organisational structure – we offer a way to meaningfully and productively integrate engineering education researchers with technical and teaching-focused faculty members – and its theoretical underpinnings. We begin by detailing this organisational structure, the goals of the Institute, and the programming designed to support the professional development of faculty, staff,[4] and graduate students. We then introduce the theoretical constructs that informed the design of EETI, before sharing two practice examples, based on the collection and analysis of ethnographic data,

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that demonstrate some of the opportunities and challenges associated with our institutional change efforts.

2. Context

The Engineering Education Transformations Institute was established in 2016 (Morelock, Walther, and Sochacka 2019). It is an academic unit that sits across the three interdisciplinary schools[5] in the College of Engineering at UGA. The college houses approximately 90 research and instructional faculty, 30 staff members, 50 graduate students, and 2,500 undergraduate students. All faculty, staff, and graduate students are invited to participate in EETI programming. The EETI leadership team comprises a director (Walther) and two associate directors (Sochacka and Morelock).

The administrative structure of EETI differs from the more traditional approach in the United States of organising research faculty into a department or school, for example, a department or school of engineering education. Although there are clear advantages to establishing departments of engineering education, such as forming an identity as a research discipline, one potential disadvantage is that engineering education researchers are administratively, and oftentimes physically, separated from their technical peers. In our model, engineering education researchers belong both to an interdisciplinary school and are associated with an engineering education-focused unit that sits across the college and invites all faculty, staff, and graduate students to participate in its programming. Structured in this way, EETI provides an opportunity to productively integrate engineering education research and educational practice.

The three goals of the Institute are to:

1. Build capacity in engineering education by developing and nurturing a college-wide community of engineering personnel engaged in educational innovation, research, and outreach.

2. Integrate engineering education research and practice by providing encouragement and support for faculty, staff, and graduate students to engage in the Scholarship of Teaching and Learning (SoTL) – educational research designed to assess and improve teaching and learning initiatives. And,

3. Establish and grow an incentive structure that rewards faculty members who demonstrate an interest in teaching and learning, and provides resources that enable them to pursue innovative engineering education projects.

To achieve these goals, the Institute's semesterly programming includes:

Engineering Education Forums: Monthly lunchtime meetings (12.30–2pm). Attended by 25–35 participants (faculty, staff, and graduate students). A typical semester includes: an internal teaching and learning showcase structured around a common theme (3 x presenters); an expert panel focused on a shared topic of interest; an interactive workshop, typically based on an evidence-based practice teaching and learning technique or a broader topic such as diversity and inclusion; and an external invited speaker.

Teaching and Learning Communities: Weekly and biweekly formal and informal settings to discuss topics relevant to teaching and learning. Faculty Learning Communities (FLCs) meet biweekly over two semesters to dive deeply into a topic of shared interest, such as student motivation or metacognition. Peer mentoring meals are held weekly and provide an informal setting for community building and support. A book club meets every 2 weeks or once a month, depending on the semester, to discuss a relevant text.

Research Initiation Cohorts: EETI runs a weekly research incubator (the 'EETIncubator') and an annual Research Initiation Grant programme to support technical faculty, staff, and graduate students who wish to pursue research in engineering education. The EETIncubator follows a cohort model – a consistent group of 6–8 participants meet regularly to develop research skills and projects in engineering education.

Travel Fellowships: EETI provides support to enable technical faculty, i.e., faculty members whose primary area of research is not engineering education, to travel to educational conferences. Travel fellows are encouraged to share their experiences with the college community, oftentimes as part of a panel at one of the monthly forums.

In 2018–2019, over 50% of research and instructional faculty in the college participated in at least one aspect of the Institute's programming. EETI is financially supported by the college, which provides funding to run EETI programming (e.g., costs associated with inviting external guest speakers, catering for EETI events, Research Initiation Grants, and travel fellowships), as well as salary supplements for the leadership team.

3. Philosophical underpinnings

Philosophically, our institutional model is grounded in a propagation (versus a dissemination) paradigm (Froyd et al. 2017), informed by a strengths (Saleebey 2012) (versus a deficit) approach to existing instructional capacity, and broadly informed by complex systems theory (Laszlo 1996; Meadows and Wright 2008). This section describes these theoretical perspectives.

3.1. Using a strengths perspective to move from dissemination to propagation

In 2017, Froyd and colleagues published what we regard as a watershed article entitled 'From Dissemination to Propagation: A New Paradigm for Education Developers' (2017). In this article, the authors describe the gap between research and practice in STEM education as follows:

> Scholarly studies and national reports document failure of current efforts to achieve broad, sustained adoption of research-based instructional practices, despite compelling bodies of evidence supporting efficacy of many of these practices. (p. 35)

The article then distinguishes between two paradigms of educational change:

> A dissemination paradigm characterizes patterns of these current, failing efforts. Change agents, working within the dissemination paradigm, try to convince adopters that their innovations can help their students . . . Alternatively, change agents, working within the propagation paradigm, engage with adopters early and often to understand their instructional systems and interactively develop a strong product adaptable to specific contexts. (p. 35)

Froyd et al. further describe the dissemination paradigm as having a primary focus on evidence and outcomes, whereas the propagation paradigm focuses on fit and usability (Froyd et al. 2017). Similarly, while those who engage in dissemination may also focus on raising awareness, proponents of propagation prioritise supporting context-sensitive adaptation and adoption (Froyd et al. 2017). The shift away from dissemination and towards propagation aligns with the findings from Henderson, Beach, and Finkelstein's (2011) review of 191 studies that detailed efforts to facilitate changes to STEM instructional practices:

> One thing that we can conclude from [the articles we reviewed] is that two commonly used change strategies do not work: developing and testing 'best practice' curricular materials and then making these materials available to other faculty [i.e., dissemination] . . . and 'top-down' policy-making meant to influence instructional practices . . . On the other hand, several claims can be made about what makes change strategies successful. First, effective change strategies must be aligned [i.e., 'fit'] with or seek to change the beliefs of the individuals involved [see discussion of 'strengths perspective']. Second, change strategies need to involve long-term interventions, lasting a semester, a year, and longer. Third, colleges and universities are complex systems. Developing a successful change strategy means first understanding the system and then designing a strategy that is compatible with this system. (p. 978)

We pick up on Henderson et al.'s focus on complex systems, and on designing a strategy that is compatible with a particular system, in section 3.2.

The goals, activities, and values outlined in the propagation paradigm provide a conceptual and practical framework to bridge the engineering education research to educational practice gap. We note that this bridge is of a relational nature that involves close engagement between developers and adopters, instead of assuming that a dissemination product, such as a publication or '"best practice" curricular material' (Henderson, Beach, and Finkelstein 2011, 978) can serve that purpose.

Shifting from a dissemination to a propagation paradigm has important implications for how engineering education researchers, or educational/faculty developers, perceive, approach, and engage with instructional colleagues. In a dissemination paradigm, engineering education researchers may position themselves as experts who have a responsibility to, at best, educate instructors about evidence-based, best practices or, at worst, overcome instructors' apparent resistance to change (Borrego, Froyd, and Hall 2010), disinterest in educational research, or unwillingness to improve their teaching methods.

We do not believe this notion of experts and non-experts is compatible with the relational nature of the propagation paradigm. While engineering education researchers, or the developers of certain educational innovations, may be experts in their domain, instructors are similarly experts in their classrooms and, arguably, have the best under- standing of what will work or not work for them and for their students. We designed EETI's model to set aside the expert/non-expert model in favour of an orientation that is informed by a strengths perspective. According to Saleebey (2012), a strengths perspective rests on the assumption that strengths and resources exist in every environ- ment, and that change is best made through colla- borations with clients and client systems which leverage these strengths. Put in the context of our institutional model, we assume that each of our faculty members have individual and diverse strengths and resources related to teaching engi- neering. Our mission is to leverage these strengths and to provide opportunities for faculty members to develop in the directions they have an interest in. As such, EETI has no explicit agenda concern- ing the dissemination of specific teaching practices, e.g., project-based or active learning, flipped class- rooms etc. Rather, we seek to cultivate, or 'propa- gate,' a culture of scholarly teaching and learning where faculty members exercise choice in how to adapt relevant educational theories and evidence- based practices to their settings.

3.2. Complex systems theory

In order to, as Henderson, Beach, and Finkelstein (2011) and others suggest (National Science Foundation 2020), recognise that colleges and universities are complex systems, we must first understand what complex systems are. A review of the literature on such systems reveals a wide range of definitions and understandings. In our institutional model, we adopt the complex systems and systems thinking approaches encapsulated by the writings of Donella Meadows (Meadows 2019a, 2019b; Meadows and Wright 2008), Ervin Laszlo (1996), Fritjof Capra (Capra 1983, 1997, 2004; Capra and Luisi 2014), and Paul Cilliers (2002). Each of these authors discuss a number of core definitional aspects of complex systems, which we summarise as follows:

1. Complex systems theory focuses on the relationships between different elements in a system, the properties of the system, and the resulting systemic behaviour that emerges from the whole.
2. These emergent behaviours arise through the dynamic and recursive interaction of the system's parts and cannot be predicted or controlled.
3. At the same time, these behaviours are not random or chaotic.
4. The behaviours of complex systems are informed by history and context; in a human system, this includes shared values and ways of seeing the world.
5. Complex systems are always open and connected to, or nested within, other systems.

We add to this list a sixth definitional facet of complex systems that offers an explanation for persistent problems in STEM educational systems. As articulated by Vanasupa and Schlemer (2016):

> . . . apparent problems of lack of learning and lack of diversity are outcomes of a system functioning as designed rather than something "going wrong." Specifically, the interactions of individuals and groups of people who share the same goals, aggregate to produce the systems' culture. This culture functions to maintain itself over time. Stated hyperbolically, we in STEM are maintaining the status quo by rejecting advances in learning and eliminating diversity. (p.6)

The implications of these definitional aspects for our model are far reaching. For example, considering the first point, instead of focusing on specific evidence-based teaching and learning techniques (like promoting flipped classrooms), or other individual elements in the system (like individual courses), *we designed EETI to focus on building relationships* between faculty (tenured, tenure-track, and non-tenure track),[6] staff, and graduate students, and connecting those emerging social networks to sources of knowledge and expertise inside and outside of UGA, like UGA's Centre for Teaching and Learning and internationally recognised experts on particular topic areas. We have found, again and again, that productive and sustainable changes to teaching and learning approaches in our college emerge from the formation of such relationships. Put another way, rather than putting a published, evidence-based practice in an instructor's hands, we seek to build some kind of relationship around that practice, either with the initial developer of the practice (see prior discussion of the propagation paradigm) or with another person in the college who shares a similar interest and intent to professionally develop in that area.

We similarly acknowledge that our system – that is, our Institute – is nested within our College of Engineering, and is *open and connected to other systems*, such as other colleges on the UGA campus, the University System of Georgia (USG), and the American Society for Engineering Education (ASEE; fifth aspect discussed above). We likewise seek to forge productive relationships with members of these systems and to capitalise on the opportunities these relationships offer. Finally, considering the sixth point, we recognise that the low adoption rate of evidence-based STEM teaching and learning approaches is a *consequence of academic systems 'functioning as designed'* (Vanasupa and Schlemer 2016, 6). Put another way, we acknowledge that aspects of our academic and organisational cultures, such as the privileging of research and individual excellence over instruction, and perceived hierarchies between tenured/tenure-track faculty and non-tenure-track faculty and staff, can work against efforts to develop community around scholarly approaches to teaching and learning. Our institutional change model challenges these, and other, often unquestioned features of academic settings.

4. Practical implementation

Our discussion of three of the above six core definitional aspects of complex systems provides some insight into how our institutional change model is grounded in complex systems theory. Below, we introduce a set of ecological design principles, developed in the context of permaculture, that we have found to be particularly helpful in informing the day-to-day operations of our Institute. We were

Table 1. Example ecological design principles and their translation to our institutional model.

Ecological design principle	Translation to our model
1. *Observe*. Use protracted and thoughtful observation rather than prolonged and thoughtless action. Observe the site for its elements in all seasons. Design for specific sites, clients, and cultures.	A. *Observe*. Observe and become familiar with existing cultures, values, interests, and structures. Adopt a strengths perspective, and think about how site specific aspects will impact the 'fit' (Froyd et al. 2017) of subsequent initiatives. See also Donella Meadows' first two of 14 ways to *Dance with Systems*: 'get the beat' and 'listen to the wisdom of the system' (Meadows 2019a).
2. *Connect*. Use relative location, that is, place the elements of your design in ways that create useful relationships and time-saving connections among all parts. The number of connections among elements creates a healthy, diverse ecosystem, not the number of elements.	B. *Connect*. Develop a diverse range of activities that connect people in as many different ways as possible. Make it easy for people to participate when they have the time and inclination – ensure that invitations are as open and inclusive as possible. Leverage existing activities, such as mealtimes, and programmes (such as CTL-managed FLCs) to facilitate 'time-saving' connections and prevent commitment overload.
3. *Catch and store energy and materials*. Identify, collect, and hold useful flows. Every cycle is an opportunity for yield, every gradient (in slope, charge, temperature, and the like) can produce energy. Reinvesting resources builds capacity to capture yet more resources.	C. *Identify, collect, and share useful information*. Differences (i.e., gradients) in engineering education (ENED) expertise (research or practice) are opportunities for all to learn. Build capacity by capturing and making knowledge (e.g., how to search ENED literature; how to write an ENED conference abstract) easily accessible and widely available. 'Reinvest' insights and lessons-learned by collecting, documenting, celebrating, and sharing them with others. See also 'stay humble, stay a learner' and 'honor and protect information' in (Meadows 2019a).
4. *Make the least change for the greatest effect*. Understand the system you are working with well enough to find its 'leverage points' and intervene there, where the least work accomplishes the most change.	D. *Make the least change for the greatest effect*. Work first with faculty members who are already interested in improving teaching and learning. Leverage that interest to introduce evidence-based practices that align with existing interests. Identify and share innovative teaching and learning efforts across the college to 'seed' further interest, e.g., through teaching and learning showcases.

(*Continued*)

Table 1. (Continued).

Ecological design principle	Translation to our model
5. *Get a yield*. Design for both immediate and long-term returns from your efforts: 'You can't work on an empty stomach.' Set up positive feedback loops to build the system and repay your investment.	E. *Get a yield*. Find ways to generate immediate and long-term rewards for participation in Institute activities, e.g., through connecting participation in Institute activities to annual review processes and setting up internal award programmes. Support intra- and extramural funding efforts. Share insights at ENED conferences and in journals. Share the rewards (oftentimes, credit shared is credit multiplied). See also 'go for the good of the whole' in (Meadows 2019a).
6. *Turn problems into solutions*. Constraints can inspire creative design, and most problems usually carry not just the seeds of their own solution within them but also the inspiration for simultaneously solving other problems.	F. *Turn problems into solutions*. Find ways to work with rather than fight against the constraints of academic systems – find the niches that exist between different stakeholder groups and focus on commonalities rather than differences. Be creative and look for opportunities to solve multiple problems at the same time.
7. *The biggest limit to abundance is creativity*. The designer's imagination and skill usually limit productivity and diversity before any physical limits are reached.	G. *The biggest limit to abundance is creativity*. Endeavour to shift away from the individualistic focus of academia to creatively identify win-win-win scenarios of abundance. See also 'expose your mental models to the open air' in (Meadows 2019a).

initially attracted to these principles because they offer actionable ways to put complex systems theory directly into practice (see Table 1).

4.1. Ecological design principles - making connections

Permaculture is an approach to the design of sustainable human settlements (i.e., systems with social, ecological, and economic aspects) that is founded and expands on the core definitional aspects of complex systems theory outlined above. Originally developed by two Australians in the 1990s, Bill Mollison and David Holmgren, permaculture was inspired by observing the natural Australian landscape. As described by Hemenway (2009):

> Inspired and awed by the life-giving abundance and rich interconnectedness of this ecosystem [Tasmanian rainforests], he [Mollison] jotted in his diary, "I believe that we could build systems that would function as well as this one does." (p. 5)

Some people mistake permaculture for a set of tools or techniques, such as organic gardening, recycling, or natural building. Permaculture, however, is better described as a design approach, or set of principles, which helps one consider when and how to use and connect different strategies and techniques. As further explained by Hemenway:

> . . . permaculture practitioners . . . focus less on the objects themselves than on the careful design of relationships among them—interconnections—that will create a healthy, sustainable whole. These relationships are what turn a collection of unrelated parts into a functioning system, whether it's a backyard, community, or an ecosystem. (p. 5)

Permaculture's focus on relationships is in alignment with the first and overarching definitional aspect of complex systems thinking discussed above – 'Complex systems theory focuses on the relationships between different elements in a system.' This focus also aligns with our emphasis on building relationships between different people within and outside of our Institute, rather than focusing on 'the objects themselves,' that is, particular courses or pedagogical techniques. In our institutional model, outcomes emerge from these relationships, rather than been prescribed or mandated.

In Hemenway's book, 'Gaia's Garden: A Guide to Home-Scale Permaculture,' he outlines 14 core, ecological design principles. In Table 1, we adapt six of these principles to the context of our institutional change model. These examples are intended to provide readers with insight into how we envisioned operationalising the ecological design principles to cultivate a culture of innovative and scholarly teaching and learning in our college of engineering. The two examples we share in Section 6 show what these principles look like in practice.

5. Methodology/methods

We used ethnographic methods (LeCompte, Goetz, and Tesch 1993), specifically prolonged participant observation, to develop practice examples that demonstrate how the operationalisation of the above-described theoretical frameworks is influencing faculty, staff, and graduate student experiences in our college. Data for these practice examples were collected in the form of ethnographic fieldnotes (Emerson, Fretz, and Shaw 1995) by the first and second authors across all aspects of the Institute's programming (see description of EETI activities in Section 2) over a three year period from August 2016 to July 2019. These observation notes focused on instances and developments relevant to the three goals of the Institute, which were also

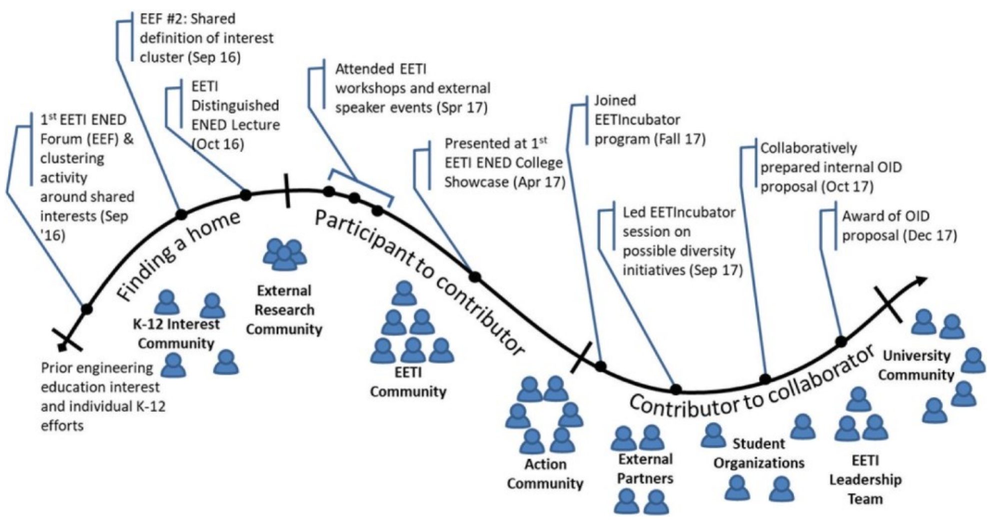

Figure 1. Visual representation of Dr. Powell's participation in EETI activities from Fall 2016 to Fall 2017. Various configurations of people under the line illustrate the different communities Dr. Powell engaged with during this time.

outlined in Section 2. For instance, the first practice example we describe below relates the first goal, 'Build capacity in engineering education by developing and nurturing a college-wide community of engineering personnel engaged in educational innovation, research, and outreach.' For this practice example, Sochacka and Walther observed an instructor's increasing involvement in the Institute's programming in parallel to the development of a sub-group of faculty and students who shared a common interest in local high school outreach efforts.

The ethnographic fieldnotes were iteratively and collaboratively analysed using a thinking with theory approach (Jackson and Mazzei 2012). Analysis was typically conducted in a team setting with different configurations of the authors. The visual trajectory presented in Figure 1 below was one outcome of such a session, as was the description of the three tensions described in the second practice example presented below. Given the nature of the participant observation approach, participants were not actively recruited for this study *per se*, i.e., participants were observed in natural settings. Instead, as cases began to take shape, we reached out to participants involved in the practice examples to ask for their perspective on our sense-making process and if they wished to join our study as co-researchers.

In this paper, we share two practice examples from this ongoing ethnographic investigation. Both examples describe the impact of our Institute on the lived experiences of instructors in our college. The developmental trajectories of these two instructors were selected for this paper because their stories illustrate some of the opportunities and challenges associated with our approach to systemic institutional change.

We note that this research was approved by UGA's Institutional Review Board (IRB) under protocol ID PROJECT00002390.

6. Results

The first practice example shows how EETI programming enabled an instructor to make connections with other faculty members, a student club, and a unit on campus (specifically the Office of Institutional Diversity) in ways that supported and enhanced his existing interests in outreach to a local, high school. The second practice example demonstrates focuses how the theoretical frameworks that informed the initial design and day-to-day operations of the Institute were also helpful in navigating tensions that arose in a collaborative educational research project.

6.1. *From lone wolf to collaborator*

The first practice example describes the gradual integration of a lecturer (i.e., a teaching-focused faculty member) into the EETI community. Dr. Powell (pseudonym), completed both his undergraduate and graduate degrees in engineering at UGA. During his time as a graduate student, he taught multiple sections of a freshman design course. In parallel to working on his dissertation and teaching undergraduate courses, Dr. Powell became involved in several after-school STEM programs with students in a neighbouring, resource-constrained county. After completing his dissertation, he was hired as a full-time lecturer in engineering and continued his outreach work.

Sochacka and Walther first learned of Dr. Powell's passion for working with high school students during the first EETI monthly forum, which was held in Fall 2016. This forum, which was one of a series of four forums over that semester, was designed to develop a shared understanding of existing strengths, assets, and interests that our faculty, staff, and graduate students had in our college in relation to engineering education research, teaching, and service activities. This beginning of Dr. Powell's engagement with EETI activities is illustrated on the left hand side of the trajectory in Figure 1.

After participating in the first Engineering Education Forum (EEF), which was held in September 2016, Dr. Powell found a community of faculty members who shared an interest in K-12 outreach activities. Based on this existing shared interest, or strength, Dr. Powell, continued to participate in EETI activities – he attended workshops, external invited speaker events, shared his passion for K-12 outreach through a presentation at the first EETI internal, teaching and learning showcase (a forum event), and joined the Institute's research incubator program in Fall 2017. Dr. Powell's involvement in the incubator led to the writing of a collaborative proposal in partnership with the local chapter of the National Society of Black Engineers (NSBE; ~10 K). This proposal was submitted to UGA's Office of Institutional Diversity in response to their annual solicitation for diversity and inclusion projects. The project was designed to support and further enhance Dr. Powell's existing STEM outreach activities.

Dr. Powell's trajectory provides an example of how cultivating the conditions for engagement with scholarly teaching and learning can lead to emergent institutional change. In this practice example, a series of EETI events, and the relationships that were developed at those events, enabled a faculty member to share his interest in K-12 outreach with other interested colleagues and work together to secure funding to further enhance his efforts. This funding, in turn, provided direct benefits to resource-constrained teachers and students at a local high school and a mechanism to integrate student mentors (members of NSBE) into the project.

6.1.1. Understanding this practice example through the lens of the ecological design principles

Hemingway's (2009) ecological design principles provide a language to explore and identify the conditions that enabled Dr. Powell to enhance his existing outreach efforts. The first forum provided an opportunity for EETI members, including Dr. Powell to 'become familiar with existing cultures, values, interests, and structures' (Principle 1; Hemingway et al., 2009). The later forums, particularly the teaching and learning showcase, provided further opporunities for faculty members to connect over these existing and shared interests (Principle 2). The incubator program then provided a setting for faculty to share relevant information, in this case, the call for diversity and inclusion proposals from the UGA Office of Institutional Diversity, as well as skills; in this case, an experienced proposal writer in engineering education research (not one of the authors) worked with Dr. Powell to prepare the submission (Principle 3). When the incubator participants initially considered which ideas to put forward for this funding opportunity, they explicitly focused on 'making the least change for the greatest effect' or, put another way, leveraging and enhancing an existing effort (Principle 4). Dr. Powell's connection with the local school was one of two ideas that met this criterion. This project also aligned with NSBE's commitment to serve the community through outreach efforts. It was the experienced proposal writer, who at the time was also the faculty advisor to NSBE, who facilitated the connection between NSBE and Dr. Powell and, in doing so, provided Dr. Powell with much needed student mentors for the high school STEM activities. Finally, we might consider the awarded grant as a 'yield,' which directly benefited the high school students and teachers who were the primary recipients of the funds (Principle 5). The Office of Institutional Diversity grant also provided an opportunity for NSBE students to be compensated for their service through monetary support that was used to finance their attendance at their national annual conference. The end result was a win- win-win for all involved, for Dr. Powell, for EETI, for NSBE, and for the local high school (Principle 7).

6.2. Navigating perceptions of scarcity

The second practice example describes a series of tensions that emerged in the context of an extramurally funded engineering education research project that involved a collaboration between a lecturer (i.e., a teaching-focused non-tenure-track faculty member; Dr. Stevens; pseudonym) and a tenure-track assistant professor in engineering education. Dr. Stevens' trajectory shares many similar features to that presented in Figure 1. Dr. Stevens also attended monthly forums, presented at one of the teaching and learning showcases, participated in the incubator program, and built relationships with other EETI members. Two years after first getting involved in EETI, Dr. Stevens and two other colleagues were awarded an extramural grant from the National Science Foundation – the first such award in the history of the college to include a lecturer as the Principle Investigator of the project. What we focus on here, however, is a series of tensions that emerged as the co-investigators on this project navigated the different goals, constraints, and epistemological beliefs of the research team. In the following paragraphs, we describe these tensions and how they stemmed from beyond the particulars of the faculty involved in this initiative to touch on broader cultural considerations that must be taken into consideration when implementing an institutional change effort such as the one we describe in this paper. We then describe how we used complex systems theory and ecological design principles to navigate these tensions.

6.2.1. Differences in knowledge and perceived levels of power

One tension that arose in this collaboration stemmed from perceptions of power and control over the project. In the United States, there is a perceived hierarchy between tenure-track and non-tenure-track faculty, with the former holding the more esteemed position. Part of this perceived hierarchy is connected to the activities performed by tenure-track and non-tenure-track faculty. At UGA, tenure-track faculty have combined research and teaching appointments, while the majority of non-tenure-track faculty have primarily teaching appointments. In this National Science Foundation educational research project, however, a non-tenure track faculty member was the Principle Investigator. This decision was made for two reasons. First, the idea for the project emerged from Dr. Stevens' teaching practice and, second, the National Science Foundation programme that funded the project is designed to expand the community of scholars who conduct research in engineering education, i.e., while tenure-track faculty members in engineering education are encouraged to serve as mentors, they cannot lead projects in this programme. This perceived hierarchy made it challenging for Dr. Stevens to fully assume his Principle Investigator leadership position in the project, which at times left a leadership vacuum. This hesitation on Dr. Stevens' part was further compounded by real differences in knowledge and experience in engineering education research methods – it was difficult to be both a leader and a learner. On the other hand, when the tenure-track faculty member filled the leadership vacuum, they were similarly placed in an awkward position, in this case of feeling obligated to lead a project in which they were designated as a mentor.

6.2.2. Conflicting goals of instructional and research faculty: what's good for students vs. what's good for research

Another tension that surfaced in the early stages of the project concerned different priorities and understandings around producing 'rigorous research' and making a positive impact on students. Dr. Stevens is a passionate instructor who is wholeheartedly committed to improving the experiences of his students. In addition to generating fundamental knowledge, he wanted to use the research project as a vehicle to directly improve student learning in his classes. The tenure-track faculty member involved in the project is also a dedicated teacher, although their success will be primarily judged based on research dollars awarded through grants and publications. This tension was further compounded by the different time scales that are associated with these two goals. Students move through classes on a semesterly basis, while a research paper in engineering education may require several semesters of data and years to analyse these data, write up, and publish. This meant that, after collecting data from students, Dr. Stevens was motivated to conduct speedy, preliminary data analyses that would provide students who took part in the study with the opportunity to reflect on their responses compared to their classmates. In contrast, the tenure-track faculty member on the project prioritised ensuring that the data analysis was sufficiently rigorous and in alignment with the original research plan, questions, and gaps in the literature. At times, this expectation for rigour clashed with Dr. Stevens' desire produce research-based insights that students could immediately benefit from.

6.2.3. Different time commitments and constraints

Finally, a third tension that impacted the team dynamics concerned the different time commitments and constraints of the research team. Dr. Stevens teaches full time during the semester and, therefore, has a concentrated block of time in the summer to work on research activities. The tenure-track faculty member and third member of the research team both have more flexibility to work on research projects during the academic year. These differences further accentuated perceived levels of urgency that any challenges that arose in the project had 'to be worked out' by the end of the summer.

6.2.4. Application of complex systems theory and ecological design principles

These tensions presented the EETI leadership team with an opportunity to experiment with applying complex systems theory and the ecological design principles to solve a nested problem, i.e., a project nested within a broader academic system. The first step in this process was to recognise that, beyond the individuals involved, the challenges the team faced stemmed from the system within which they operated (see points 5 and 6 under Complex systems theory: 'Complex systems are always open and connected to, or nested within, other systems;' and 'apparent problems . . . are outcomes of a system functioning as designed rather than something "going wrong."'). Next, the EETI leadership team sought to impress upon the project team three further principles of systems thinking and ecological design, namely, i) to prioritise relationships over outcomes (see point 1: 'Complex systems theory focuses on the relationships between different elements in a system'); ii) to acknowledge the value and importance of diversity (e.g., diversity of perspective and experience; see Principle 2 in Table 1); and iii) to adopt an attitude of abundance rather than scarcity (see Principle 7).

The focus on relationships over outcomes changed the nature of the conversations that ensued after the tensions emerged. Rather than focusing on 'getting the project done,' the project and EETI leadership team focused on (re)building the relationship between the lecturer (i.e., the non-tenure-track faculty member) and tenure-track faculty member. An important part of this process was to acknowledge the value of the different perspectives and experiences that each faculty member brought to the project. The question was not 'which perspective is right,' or 'more important,' but 'how can these perspectives complement each other and strengthen the project?' Finally, a focus on the relationship and on valuing diversity opened up a space to question the often assumed zero-sum nature of academic reward structures. Instead, the project team sought to leverage their differences to identify win-win opportunities where research and teaching goals could complement each other to lead to stronger outcomes in both areas. More specifically, looking for win-win opportunities opened up a discussion around how research could (and should) both generate fundamental knowledge around student learning and directly benefit the students who provide data for a particular study.

7. Discussion and conclusions

These two practice examples provide insight into how theoretical perspectives can inform the design and day-to-day operations of an institutional change model in engineering education. An orientation towards propagation and the strengths that reside in a system enabled change agents to capitalise on the potential that already existed in the system. In both practice examples, EETI leadership and programming sought to 'engage with adopters early and often to understand their instructional systems and interactively develop a strong product adaptable to specific contexts' (Froyd et al. 2017, 35). In the first practice example, one might argue that the Office of Institutional Diversity grant was the innovation that was propagated, i.e., adapted to fit into the context of Dr. Powell's existing outreach efforts. In the second practice example, the very act of conducting engineering education research was propagated to Dr. Stevens through the mechanism of the National Science Foundation programme, which is designed to expand the community of engineering education researchers. Here again, however, the 'product' (i.e., engineering education research) had to be adapted to fit with the instructional goals of a teaching-focused faculty member, which resulted in an emphasis being placed on the quick turn-around of data analyses so that students could directly benefit from the study. Finally, in both examples the ecological design principles helped to create the conditions to support the building of relationships and emergence of activities that flowed on from those relationships, while both ecological design principles and complex systems theory guided the teams when tensions arose. While not all EETI participants generate stories so directly illustrative of our philosophy and its application, it is important to note that neither of the two practice examples here would have materialised without intentionally designing our day-to-day activities around a coherent set of theoretical underpinnings.

We offer the theoretical constructs described in this paper as building blocks of an institutional change model that, we believe, is appropriate and particularly timely for transforming systems of engineering education – that is, for facilitating change in an environment that is already full of experts, not to mention strong characters who see little reason to bend to the will of others. We offer the two practice examples we shared as illustrations of some of the opportunities and challenges that may be encountered when embarking on this approach to institutional change. We welcome the prospect of engaging with others who are similarly committed to or curious about how to create change in engineering education in ways that honour the strengths that already reside in our workplaces.

Notes

1. For example, published works presented at the American Society for Engineering Education (ASEE) increased threefold between 1999 and 2019 from 729 to 2,211 (ASEE, 2020).
2. In the United States, 'tenure' grants a professor permanent employment at their university and protects them from being dismissed without adequate cause.
3. This gap is not to be confused with perceived inconsistencies between engineering education and engineering practice (Brunhaver et al. 2017; Jesiek, Borrego, and Beddoes 2010; Trevelyan 2010).
4. In the United States, 'staff' refers to administrative personnel, such as business managers, academic advisors, and IT specialists. Faculty refers to personnel who have research and/or teaching responsibilities.
5. The School of Electrical and Computer Engineering (ECE); the School of Chemical, Materials, and Biological Engineering (CMB); and the School of Environmental, Civil, Agricultural, and Mechanical Engineering (ECAM).
6. In the College of Engineering at UGA, tenured faculty include associate and full professors. Assistant professors are guaranteed consideration for eventual tenure, typically after a 5–6 year probation period. Non-tenure -track faculty include lecturers and senior lecturers (i.e., teaching-focused faculty), assistant, associate, and full professors of practice, and research scientists.

Acknowledgments

We would like to acknowledge the College of Engineering at UGA for their support of the Engineering Education Transformations Institute. We would also like to acknowledge the faculty, staff, and students who participate in and contribute to the Institute's activities. We are grateful to Linda Vanasupa who provided constructive feedback on earlier drafts of the list of core definitional aspects of complex systems. This article builds on a conference paper, entitled "Cultivating a culture of scholarly teaching and learning: An ecological approach to institutional change in engineering education," which was presented at the 2019 Australasian Association of Engineering Education (AAEE) Annual Conference (Sochacka et al. 2019).

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

Part of this material is based on work supported by the National Science Foundation under grant 1927341. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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