Will the change last? That's the question.

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***Abstract*—Will the change last? In higher education, many of us put considerable efforts into program, curriculum, and educational reforms that lead to reasonable improvement. With each reform comes the challenge of sustaining the change. How do we assess how, or even if, to make the change last? To the authors' best knowledge, no validated model to guide such assessment exists. The authors propose one. Based on systemic study of our current and previous work on educational reform and the literature, we present a framework that assesses the sustainability of a program, curricular, or pedagogical change. In this special session, we will not only present this framework and demonstrate its usability in two different cases, but we also will guide attendees in applying this framework to assess the sustainability of their own changes. We will involve attendees in the design process of testing and further improving the framework to determine, "Will the change last?"**

Keywords—Sustainability, curriculum, change, engineering education

I. Introduction

The Mechanical Engineering Department at Seattle University was awarded the United States' National Science Foundation (NSF) Revolutionizing Engineering and Computer Science Departments (RED) grant in July 2017 to support the development of a program that fosters students' engineering identities in a culture of doing engineering with industry engineers. To organize the actions and changes needed for this new culture, the department follows the best practices recommended by Henderson et al. [1]. From an extensive review of articles on facilitating change in STEM education, Henderson et al. indicated four areas of change: *shared vision, reflective faculty, relevant curriculum and pedagogy, and supportive policies*. In references [2] - [6], we summarize actions we have taken in these four areas to promote changes and cultivate this new culture. As we approach the end of our five-year grant, we wonder how to make our change last. Looking back across previous educational reforms made at our institution and others, we developed a framework to help us examine the sustainability of any program, curricular, or pedagogical change.

II. Goals

Many educators and researchers put tremendous time and effort into designing and implementing program, curricular, and pedagogical reforms. NSF and other institutions spend considerable funds on these efforts expecting them to be sustained. Frequently, as evidenced in the literature, these reforms lead to significant improvement, but do these improvements last? In this special session, we take on the question of sustainability.

Over our many years in education, we have noted that remarkable innovations in our own and other educational programs often fall away. When we did not find an existing model, we were inspired to develop a framework that can guide the assessment of change sustainability. In this special session, we will present this framework and demonstrate its applicability in two case studies drawn from our own experience, one from RED and another from a previously funded NSF project. We will show attendees how to apply the framework to their own efforts that they have made or plan to make.

This special session is not for dissemination of our educational reforms. Rather, it is to confront the question of sustainability together. We share and demonstrate a framework to gauge sustainability. We guide attendees in applying the framework and invite them into a co-design process to improve and adapt the framework. Finally, we initiate an ongoing conversation about change sustainability. Thus, the special session is less an advocacy for this particular iteration of our sustainability assessment framework than it is an opportunity to engage in dialogue about the important issue of sustainability.

III. Description

Sustainability is a feature of most funding proposals and change efforts. Yet, such proposals and change efforts rarely specify how their sustainability is evaluated. Indeed, missing are comprehensive, applicable theoretical frameworks to assess the sustainability of a program, curricular, or pedagogical change. We conducted a search through NSF proposals, ASEE Peer, scholar.google.com and the subscription research databases Academic Search Complete to find an extant approach. Although we did not find a comprehensive model, we did find support for several of the seven perspectives in our framework:

1. Financial sustainability - Can we afford what we are doing? What will be the impact on our finances? In the future, the cost of instruction might increase because of increased material or labor costs or decreased course enrollment. With the rising cost of higher education in general [7], maintaining the sustainability of an educational innovation may require efforts to creatively stretch funds [8].

2. Educator sustainability - Do we consistently have the needed educators? What will be the impact on our educational team? Educational innovation usually means

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some change for the educator and an educator may not have the skills, knowledge, patience, willingness, or time to adapt. When an appropriate educator in a stable position is available, that faculty must perceive the innovation as supporting and not hindering what they need to do for tenure and promotion [9]. However, in today's educational landscape, an appropriate educator is often not in a stable position [10], [11]. When contingent faculty and/or graduate students are involved, sustaining a change becomes difficult.

3. Infrastructural sustainability - Do we have the right spaces? What will be the impact on infrastructure? While not every educational innovation necessitates a particular kind of space, many do (e.g., lab spaces, active learning spaces, studio spaces, maker spaces, and project spaces). Historically, limited lab space has meant limited growth for engineering programs [12]. Sustaining an educational change may require building adaptation [12] or adaptation to virtual spaces (e.g., [13]). When the right kind of space is missing or access to it is unreliable, a change becomes unsustainable.

4. Social/community sustainability - Do we have sufficient people connections? What will be the impact on the community? Many educational innovations involve people beyond the program. For example, connecting student projects with the community is pedagogically valuable [14], [15], but hard [16], sensitive [17] work. Engineering education, in particular, relies on innovative project-based approaches that uses projects from real-world practice. Getting access to projects, project sponsors, and professional mentors requires tremendous effort [18] and the relationship between the program and the professional community is affected, for better or for ill.

5. Educational experience sustainability - Can we ensure a good educational experience? What will be the impact on the educational experience? A successful educational experience is often judged by its outcomes but may be more about its process. Educators know that a good educational experience has the "right" balance of challenge and progress, of fun and struggle, of individual and team work, etc. A critical variable in sustaining a student experience may be in what students are able to contribute. With US higher education courses framed in terms of "credit hours" [19] and students working while in school [20], an educational experience may require more from students than they can reliably provide. Sometimes a particular student experience emerges from interactions among those involved in an educational innovation [21]. That emergence may not be predictable enough to be sustainable.

6. Advising sustainability - Will we be able to sustain advising impacts? What will be the impact on advising? Our educational innovations may have impacts on students' schedules or future plans that affect advising. Change can also place greater demand on advising resources because an experience creates interest and growth in the program, because a change prompts challenge and growth with which students need support, or because an innovation results in unusual grades or unpleasant experiences that lead students to seek guidance [22], [23].

7. Extended sustainability - Will this have impact on some other part of the educational system? Are those impacts permissible? It is essential to appreciate any change within the context of the entire system [24]. Educational innovations do not happen in isolation; what students experience in one course affects the surrounding courses and educators. Furthermore, it is unlikely that only one change in an educational system is occurring at a given time and those innovations may be at odds. Without supportive institutional and department culture and policy, change is hard to sustain [24].

Utilizing this framework, we examine two cases, one funded by our previous NSF grant and another one related to the current RED project.

A. Case 1- AEPCL

The first and the second authors were awarded an NSF TUES (Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics) grant in late 2013. The new pedagogy, Authentic Engineering Problem Centered Learning (AEPCL), utilized an inverted classroom (IC) and authentic engineering problems (AEPs) in Heat Transfer [25]. The flipped format allowed time for practical, authentic, ill-defined, and non-linear problems provided by industrial partners [26].

For this two-year project, the first author taught the class in the spring of 2014 using the traditional format to collect the control group data for various outcomes related to students' problem solving and design thinking skills. In the spring of 2015, the class was offered in AEPCL format. The first author built an IC repository for all the lectures (25 total) with slides, videos, and quizzes. The first author also worked with industrial partners to develop five AEPs that involved different concepts of heat transfer. In AEPCL, students watched IC lectures on their own time and worked on AEPs during class time because the lecture time was freed up by the IC approach. Within a two-week span, each AEP was presented with an industrial partner during the first lecture, and the first author would facilitate students' discussion to develop their solutions in a three-person team during the following three to four class periods. The industrial partner came back to evaluate students' solution presentations at the end of the second week.

Results showed that students in AEPCL class were found to have better problem solving [27] and design thinking skills [28] without any sacrifice to fundamental knowledge. However, the AEPCL model did not continue in Heat Transfer and the model did not propagate to other classes in the Mechanical Engineering (ME) curriculum. We assessed the AEPCL model with our proposed sustainability framework. Below we provide our evaluation and reasons why AEPCL was not sustained.

1. Financial sustainability – AEPCL relied heavily on the involvement of industry partners. During the process, each partner spent significant time formulating problems,

working with the instructor, interacting with students, and evaluating results. It would not be reasonable to expect industry partners to do this work without compensation. After the NSF funding ended, the department lacked funds to pay industry partners and the instructor struggled to find practicing engineers who could devote this time on a volunteer basis. Hence, AEPCL was not sustainable financially.

2. Educator sustainability – Another important issue that led to the end of AEPCL was the educator. At the time AEPCL was implemented, the first author was at the beginning of her tenure evaluation. When the Heat Transfer course was taught traditionally, students praised the instructor for her effective teaching and rated her effectiveness and the course highly on the end-of-quarter evaluation. Although the instructor brought the same high-quality teaching (if not better) to her recorded lectures and in-class support during AEPCL, students did not sufficiently appreciate her efforts; her course evaluation ratings were lower than desired for tenure and promotion. The juxtaposition of the extensive instructor effort AEPCL required, and the lower teaching evaluations caused the instructor to be reluctant to continue AEPCL. The first author did not have the opportunity to reconsider or adapt AEPCL because she was needed to teach other classes and the new educator did not take up AEPCL; educator change is another reason changes are not sustained.

3. Infrastructure sustainability – AEPCL emphasized active team problem-solving during class meetings. An appropriate collaborative space with lots of whiteboards and minimal furniture rearrangement for each class was needed. The instructor had to put in a special request for an assigned classroom that met these requirements, and such a space could not be guaranteed. The uncertainty of having a suitable teaching space added to concern about continuing AEPCL. Another infrastructure issue was the teaching schedule. Faculty have different strengths and staffing changes in one area of a program can necessitate changes in others.

4. Social/community sustainability – The connection to industry was a highlight of AEPCL and one of the more time-consuming aspects of setting up the course. The instructor recognized the infeasibility of continuing several unique industry relationships for one class in the context of her six-course workload. As the program lacked graduate teaching assistants or staff to manage course administration, the author turned to an available campus support for help, the University Center for Community Engagement (CCE). Together, they worked to secure an industry partner for a community service project for another Heat Transfer offering. However, this approach still required tremendous instructor effort to initiate and sustain the ongoing work, work that the CCE could not do. Although the project may have contributed to the community, this approach did not increase the sustainability of AEPCL. In addition, the combination of the instructor work required and the uncertain student response did not entice anyone else to consider adopting an AEPCL approach, despite evidence of enriched learning, better problem solving, and improved design skills.

5. Educational experience sustainability – Students' experience of AEPCL varied according to a project's difficulty and the industry partner's personality and classroom approach. Although an AEPCL goal was to encounter problems as one would in the workplace, the disparate nature of the problems and people involved made sustaining a uniformly good educational experience inherently difficult. While the AEPCL course unfolded, students felt burdened by the time they needed to put into the IC content and the AEPs. Some students relayed their unwillingness to put in the necessary effort during the course and conveyed their displeasure with the work expectations on course evaluations.

6. Advising sustainability – Heat Transfer is a required course in the ME curriculum and is only offered during the spring quarter of the third year. Because all students take Heat Transfer the same term, the new AEPCL pedagogy did not impact educational planning. However, it did impact career advising. AEPCL made students more accustomed to open-ended questions and team problem-solving ambiguity. They were more comfortable with and better prepared for challenges in senior design and in their future careers. Some students included AEPs in their resumes and portfolios.

7. Extended sustainability – Although the AEPCL project was supported by the department, there were comments from other faculty on how students spent more time on the AEPCL Heat Transfer than other classes they took concurrently, and it caused unexpected tension among faculty members in the department.

Although this project was disseminated through various workshops and generated interest from the attendees, there was no evidence that AEPCL was implemented in other Heat Transfer classes elsewhere. We celebrate the strengths of AEPCL, but assessing it with the sustainability framework, we also see the weaknesses and understand why it did not continue. Moreover, the analysis helps to distinguish the sustainable aspects from the unsustainable.

B. Case 2- DAQ course sequence in the New RED Curriculum

As the department considered updating the curriculum at the beginning of the RED project, they surveyed all stakeholders (faculty, students, industry partners, etc.). One thing that stood out was the disconnect between the required electrical engineering (EE) fundamental course and the rest of the mechanical engineering curriculum. Students found EE difficult and unrelated, while industry partners emphasized the importance of mechanical engineers who work and communicate effectively with electrical and computer engineers [3]. The result in the new ME curriculum is an integrated two-quarter sequence that combines the EE concepts with the follow-up data acquisition (DAQ) course.

The newly designed integrated EE/DAQ course sequence [29] is taken during the winter and spring quarters of the third year of the ME program. EE/DAQ I and EE/DAQ II are designed with two lecture/lab combinations every week, one for EE and one for DAQ. EE content is discussed in a 50-minute lecture followed by a 100-minute lab early in the week, and a 50-minute DAQ lecture and subsequent 100-minute lab occurs later in the week. The EE and DAQ content is coordinated so that content discussed in the EE lecture and lab are used in the DAQ lecture and lab. Both labs emphasize hands-on learning with team lab exercises connected to in-lecture examples focusing on doing engineering. The lab exercises also are connected to other ME courses that students take concurrently such as Machine Design, Fluid Mechanics, and Heat Transfer. Thus, the labs have the potential to strengthen connections across the curriculum and further help students connect and synthesize their knowledge from different ME courses and EE. For the first two offerings, the DAQ course sequence was co-taught by two ME faculty; one led the EE portion and the other guided the DAQ portion. During the latest offering, the sequence was taught by only one faculty (the first author) due to personnel changes in the department. Although there is no immediate plan to change how the DAQ sequence will be taught, this pedagogical innovation gives us another opportunity to apply our change sustainability framework.

1. Financial sustainability – The RED funding was used to purchase capital equipment needed for the first offering and the equipment has an expected lifetime of more than a decade. Because the new DAQ sequence has a dedicated lab portion, lab fees are charged to students' tuition. The lab exercises are designed to require only the lab supplies that the fees allow. Thus, there is no immediate financial stress for the new sequence to continue the next few years.

2. Educator sustainability – The collaboratively designed co-teaching model laid a good foundation for the course. This strong foundation is the principal reason the first author took over the full sequence with little difficulty and only some extra effort. What prompted the change to solo teaching was the retirement of the other instructor and the absence of any other current faculty able to take on the course. Additionally, with the sequence now accounting for a larger portion of her teaching load, the instructor is not available to meet other program needs. These faculty pressures call into question the sustainability of continuing to offer the sequence long-term.

3. Infrastructural sustainability –The college went through a recent renovation and the DAQ sequence is now housed in a new lab space that holds more students per lab session and provides a more welcoming environment. Having a reliable space contributes to the sustainability of the change.

4. Social/community sustainability – In creating the sequence, the ME Department brought EE instruction under its purview and removed it from the EE Department with their support. The ME Department may lack sufficient faculty with EE expertise to sustain the EE/DAQ sequence. A course needed by multiple departments always is better supported. Although some lab exercises were designed using real-life applications, they do not require interaction beyond the lab setting or the course community. Thus, this pedagogical innovation may not have sufficient social and community support to endure.

5. Educational experience sustainability – The COVID-19 pandemic moved the sequence online during the last week of the first DAQ I offering [30]. Although the instructors quickly modified all lab exercises to make them doable remotely, it took more time and effort to help students trouble-shoot in this format. It certainly frustrated students and their learning. Despite the format change, many students conveyed an appreciation for the integration in their reflections and in the end-of-quarter teaching evaluations. Some, however, expressed concerns about how EE and DAQ connected when two instructors co-taught the sequence. The latest offering had a single instructor for both the EE and DAQ sessions. Student reflections and course evaluations revealed no evidence of an EE-DAQ disconnect. They further suggested that students had a better educational experience than the originally designed co-teaching model.

6. Advising sustainability – This two-course sequence is offered only once a year. If a student has to miss either of the two quarters, they must be advised to complete the sequence their senior year. Thus far, several students have had to take DAQ II during their last term. In general, however, the change does not cause advising issues. It does contribute to career advising. Many students include skills and projects from EE/DAQ on their resumes.

7. Extended sustainability – The EE/DAQ sequence is a part of the larger ME curriculum and department culture change that involved the entire program and its people. All were in support. Many lab exercises were designed to meet department, college, university, and ABET learning outcomes. The college and university curriculum committees approved this change, and as mentioned, the EE Department was supportive. Allotting faculty resources to the sequence necessarily drew resources from elsewhere. With 8 full-time faculty, the ME Department may not be able to continue the sequence if the Department is expected to meet additional or different learning goals.

In applying the framework to these two case studies, we demonstrated how the framework can be used to reveal what changes are sustainable and why. The assessment also surfaced issues that impede sustainability. Finally, it elucidated what adaptations may be needed to sustain an innovation.

During the special session, we briefly will present these two cases and then guide attendees though examining their own changes through the framework's lens. We will evaluate the framework itself; how did it work for each of our changes? We invite attendees to co-design with us – to suggest improvements and adaptations to the framework making it even more applicable across different change situations. Additionally, we invite attendees to discuss how funding agencies and our institutions can continue to support the change they initially fund.

IV. Justification

NSF and other funding agencies have been supporting curricular and pedagogical reforms for years. Naturally, agencies expect resulting successes to be disseminated and sustained. Yet, after more than three decades of funding, adoption of practices developed through these funded projects is still rare [9, 31]. Even among those who have adopted new approaches, sustainability can be an issue [24]. Indeed, the very institution that developed a change may not have been able to maintain it as our case studies demonstrate.

As researchers wishing to evaluate our change efforts systematically, we turned to the literature. While the literature confirmed the difficulty of sustainability [9], [24], [31] and its importance [24], it did not provide us with an assessment model. However, it did provide us with the seeds to develop our own. How can we know a priori whether a change is sustainable? When we have made a change, how can we assess whether that change is sustainable, what impedes its sustainability, and what is needed to sustain the change? To address these questions, we developed a framework to screen and evaluate the sustainability of program, curricular, and pedagogical change. The framework will help educators, researchers, and funding agencies answer the question, “Will the change last?”

V. Session Agenda

The special session will last 80 minutes with the proposed agenda below.

1. Presenting the basic elements of the framework- 10 minutes.
2. Case study 1: Using authentic engineering problems in a Heat Transfer class. Background of the case and sustainability audit using the framework- 5 minutes.
3. Case study 2: Integrating Electrical Engineering Fundamentals with Mechanical Engineering Data Acquisition. Background of the case and sustainability audit using the framework- 5 minutes.
4. Group work- Attendees will team up and discuss how they will apply the framework to one of their own current or proposed cases. Sticky points, points of ease, and questions will be recorded on Google slides. Presenters will facilitate- 20 minutes.
5. Report out- Attendees will utilize their google slides to share. Other attendees can suggest options to increase the sustainability of a team’s proposed change. In addition, attendees will report their experience of using the framework and may suggest modifications for attendees’ consideration- 25 minutes.
6. Closing- Attendees will discuss proposed changes to the sustainability framework in a co-design process- 15 minutes.

VI. Expected Outcomes

Attendees will see how we apply the sustainability framework in two cases and will experience applying this framework to their own planned or past changes. Through activity and discussion, attendees will ascertain what is needed to make their change sustainable. Attendees will be encouraged to be a part of the design process and suggest improvements and adaptations to the framework. We will initiate discussion about how our institutions and funding agencies can support innovation. Google slides from this session will be distributed to continue the conversation. At the end, attendees will be better able to answer the question, “Will it last?”

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BIOGRAPHIES

Yen-Lin Han is Associate Professor of Mechanical Engineering and **Kathleen Cook** is Professor and Chair of Psychology at Seattle University. Yen-Lin Han is experienced at adopting innovative pedagogies and conducting engineering education research. Kathleen Cook's research interests include identity and effective educational approaches in STEM/engineering. Currently, they are Co-PI's for an NSF RED grant awarded to the Mechanical Engineering department at Seattle University. Both facilitators worked closely with **Jennifer Turns**, Professor of Human Centered Design and Engineering at the University of Washington and Co-PI on the RED project, on developing the framework and workshop materials presented. Dr. Turn's research interests include innovation in engineering education, reflection, design education, and research through design. Together, they have presented their work at ASEE, FIE, and ASME conferences and co-hosted multiple workshops for other engineering educators and RED PI's.