Fostering sustainable improvements in science education: An analysis through four frames

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There is a pressing need to improve the sustainability of educational improvement efforts, but sustainability remains undertheorized in science education. In this article, we draw upon frameworks from organizational culture and sustainability to characterize change within a single undergraduate science department. This in-depth longitudinal case study over 15 years provides careful documentation of the types of changes that are required to make improvements over time. In particular, we argue that cultural shifts are an important aspect of sustainable improvements. As we show, even a department that was considered an educational improvement "success story" was unable to sustain the improvements made through its initial effort. Nonetheless, we do argue that the initial effort resulted in shifts to multiple aspects of the department's culture (e.g., ways of thinking, the status of education in the department), that we characterize with Bolman and Deal's four frames. These cultural shifts provided the groundwork for a later effort, to ultimately create sustainable structures in the department resulting in sustained improvement. To conclude, we provide recommendations for how to improve the sustainability of change efforts and describe important methodological considerations for future studies of sustainability.

Keywords: Culture; Departmental Change; Sustainability; Undergraduate Education

Introduction

What is required to make sustainable improvements to science education? Even though hundreds of recent STEM educational improvement efforts have been documented, their lasting impact on science teaching has been relatively modest, in part because these efforts have been driven by overly simplistic models of change (Borrego & Henderson, 2014; Henderson, Beach, & Finkelstein, 2011). Research shows that these typical "documentation and dissemination" approaches to improving science teaching are unlikely to have the widespread impact that our community would hope for (Austin, 2011; Fairweather, 2008; Kezar, 2011). In addition, even when instructors do adopt new, disseminated approaches, they may discontinue their use

(Henderson, Dancy, & Niewiadomska-Bugaj, 2012). Thus, impacting science teaching at scale in sustainable ways remains a challenge.

To address this challenge, researchers are paying increasing attention to the contexts within which science educational improvement efforts are embedded. As a result, university departments are being considered as a key unit of focus for sustainable change, especially at larger institutions (AAAS, 2011; AACU, 2014). Departments tend to be fairly uniform along a variety of dimensions, including: teaching loads, service expectations, and overarching disciplinary identities, which makes them a logical unit to consider when trying to impact certain policies that may relate directly to the educational mission of a department (see Reinholz, Matz, Cole, & Apkarian, forthcoming). Given these common features of a department, they can be considered as relatively coherent yet manageably-sized units of culture, from which we infer that if meaningful changes can be established in a department, educational practices are less likely to return to the status quo (cf. Schein, 2010). But what does it take to create such lasting changes?

To answer this question, this paper provides a longitudinal case study of one science department over fifteen years (called the "Runes" department, to protect its identity). To analyze the department's change efforts, we use the *four frames* framework from organizational change (Bolman & Deal, 2008; Reinholz & Apkarian, 2018), which allows us to characterize the department's culture and its evolution over time. By focusing on a single, longitudinal case study, we attend to the culture of a department in sufficient depth to illuminate how cultural and contextual factors are crucial to supporting sustainable improvements to teaching in a university science department. We are guided by two research questions: (1) What factors contribute to whether or not an educational improvement is sustained within a science department? (2) How

might faculty views on sustainability shift as a result of participating in targeted efforts to sustainably improve education?

Significance

Organizational and cultural features of departments have been shown to impact teaching and learning across multiple settings including K12 and at the university level (e.g. Garmston & Wellman, 2016; Horn, 2008; Kezar, 2014). This study makes an important contribution to science education by more deeply theorizing the relationships between culture and the sustainability of educational improvement efforts within a university context. Although this study does not focus principally on teaching and learning, we argue that a focus on organizational considerations and systemic change is critical to improving the teaching and learning of science at any level. As others have argued before us in *Science Education*, if we ignore the organizational characteristics of schools, it will impede our field's ability to translate theory to practice. For instance, activities such as teacher professional development do not happen in a vacuum, so they must account for the complex contexts within which professional development occurs (Carlone & Webb, 2006), such as access to resources or technology that support implementation of new practices. Otherwise learned strategies may be short-lived. Similarly, organizational factors in schools contribute significantly to student outcomes (Smetana, Wenner, Settlage, & McCoach, 2016) and the uptake of new policies (Marco-Bujosa & Levy, 2016), so they provide an important complement to studies focused on classroom teaching and learning. Thus, attending to organizational factors and culture is important, as it sets the stage for changes in instructional practices to be sustained. In addition, theories of organizational learning can still provide insight into these more local phenomena, for instance by

shedding light on interpersonal interactions in the study of teams (Sohr, Gupta, & Elby, 2018).

For all of these reasons, there is great value in applying organizational learning theories to realm of science education.

Theoretical Framing

Sustainable change in education has been conceptualized in a variety of ways. At the most simplistic level, sustainability is defined as instructors continuing to use a new practice that they have adopted (Wieman, Deslauriers, & Gilley, 2013). From this perspective, a practice would be considered institutionalized after instructors and administrators become committed to its use over time (Miles, 1983). In contrast, a lack of sustainability would mean instructors quit using the technique, or use of a technique is intermittent but not consistent (Henderson et al., 2012). But use of a technique is not enough; it must be used with fidelity (O'Donnell, 2008). Otherwise, a lethal mutation—a variant of a practice that is inconsistent with the goal of the original practice (Seymour & Osana, 2003)—could threaten the sustainability of a change. Consider the use of random calling techniques to facilitate classroom discussions. If the envisioned purpose of the technique was to promote equitable participation amongst students, but instead it was used as a way to "cold call" students and put them on the spot, that could actually threaten equity (cf. Reinholz & Shah, 2018). To help ensure that a practice is used with fidelity, an innovation configuration map can be used to define accurate use of the practice along multiple dimensions (Hall, Hord, Aguilera, Zepeda, & von Frank, 2011).

Although fidelity of use matters, teaching techniques cannot simply be transferred from one environment to another; they must be adapted to the local context, and even the context itself changes over time (Kezar, 2011). Thus, sustainability can be conceptualized as a process of

continuously adapting practices to fit within evolving contexts (Hargreaves, 2002; Hargreaves & Goodson, 2006). Consider the use of technology. While at one time the use of an overhead projector was a technological advancement, the *continued use* of an overhead projector would now be seen as anachronistic. From this perspective, a sustainable change is not an event, but a process that requires ongoing changes to a system. For this reason, other terms such as *continuous improvement* (Fullan, 2005; Sackmann, Eggenhofer-Rehart, & Friesl, 2009; Temponi, 2005), *usability* (Fishman & Krajcik, 2003), and *adaptability* (Garmston & Wellman, 2016) are sometimes used in favor of sustainability. When an organization embodies principles of continuous improvement, it is called a *learning organization* (Garvin, 1993).

We draw from Hargreaves' (2002) conceptualization of sustainability, which posits that a sustainable educational change has five key features: (1) it endures over time, (2) it relies on existing or available resources, not just temporary funding, (3) it does not negatively impact other initiatives, (4) it builds capacity within the local environment, (5) it is flexible and can be adapted to support meaningful learning in complex, historical and evolving contexts. In addition, an educational change should be to some end, which means that a change is most effective when it is guided by a shared vision (Cooperrider, Whitney, & Stavros, 2008). We summarize these five characteristics more succinctly in the following definition:

> A *sustainable change* builds capacity by allocating available resources to create adaptable mechanisms that support improvements to endure over time.

When we say *available* resources, we recognize that a change may be catalyzed through a temporary infusion of external funds. Ultimately, this should create an *internal* mechanism so that the change can endure over time. In contrast, if an initiative requires ongoing external funding, it would not be considered sustainable. In an academic setting, a corollary is that

sustainable efforts do not negatively impact other initiatives, because they are not hoarding ongoing external resources.

We use the terms *capacity, mechanism,* and *adaptable* to signal that a one-time event rarely makes sustainable changes to a system. For instance, even if a professional development workshop results in enduring changes to faculty teaching practices, it is unlikely to have a lasting impact on a department, due to faculty turnover in the department. To be sustained, the workshops would need to draw from available funding—rather than external grants—so that they could continue in perpetuity (Richmond & Manokore, 2011), which would allow *all* new faculty members to attend. But what would be required for a department to make such a change? How would it reorganize its resources, ways of thinking, and formal roles to support ongoing workshops and meaningful participation from new faculty members?

The answer to the above questions is that *sustainable change requires cultural change.* Organizational culture describes the structures, policies, and procedures that allow a system to function (Schein, 2010). It follows that if a particular system is to function in new ways (i.e. change sustainably), these underlying organizational structures must change as well. For this reason, organizational learning theories now focus on culture as a key factor to making lasting change (e.g., Kezar, 2014). In this paper, we draw from the *four frames* framework (Bolman & Deal, 2008), to define organizational culture as follows (Reinholz & Apkarian, 2018):

> Culture is a historical and evolving set of *structures* and *symbols* and the resulting *power* relationships between *people*.

These four components of culture – structures, symbols, power, and people – describe four aspects of departmental culture. This culture is historical and evolving: change is inevitable, and to some extent, the direction of changes is rooted in the past (Cole, 1998). Nevertheless, intentional actions, such as with the Science Education Initiative (Chasteen, Perkins, Code, &

Wieman, 2016) and Departmental Action Teams (Reinholz, Corbo, Dancy, & Finkelstein, 2017) described later in this paper, can impact these trajectories of change.

Structures are formal roles, responsibilities, practices, and routines. The purpose of structures is to help organize interactions, by providing mechanisms for individuals to work together. Structures also provide opportunities for individuals in a department to specialize, taking on separate aspects of a department's larger mission to collectively contribute to the department's overall goal. When organized effectively, structures help a department fulfill its collective goals while still attending to individual differences.

Symbols focus on beliefs and meaning making. To make meaning, individuals draw on cultural symbols, artifacts, language, myths, values, etc. In this way, sensemaking within a department is mediated by the presence (or lack of) cultural symbols. Symbols play an important role in understanding how particular structures are taken up. Following the example of random calling methods, this singular practice may be used to multiple different ends, and the way in which it is taken up depends on the individual instructor's beliefs. Rituals, stories, and key events in the history of a department may play an important role on how the present and future are understood. We describe below how the prior event of the Science Education Initiative played an important role in a future change effort in the Runes department.

The people frame highlights that departments ultimately consist of individuals with their own goals, agency, needs, and identities. A productive department is one that helps people fulfill these individual goals while simultaneously pursuing its collective mission. In contrast, a department where many people have goals that are at odds with the overall mission will be less functional. Because this frame is about individual people, it also draws attention to how different department members may experience its culture in unique ways.

Finally, power mediates interactions through status, positioning, and political coalitions. Power relates to an individual's relative capacity to influence the circumstances of others (Keltner, Gruenfeld, & Anderson, 2003). Certain members of a department may have relatively higher status than others (e.g., due to status associated with rank, job category, and research productivity), which gives them additional say in decision making. At the same time, multiple department members may band together to form a coalition which increases their decision-making power. In some sense, all social interactions are inherently political, and this frame draws attention to that.

Using the four frames, we are able to describe shifts in cultural practices at the level of a department. Nonetheless, we recognize that a department is made up of individuals, and a department-level focus will not capture all changes at the individual level, such as tracking the fidelity of use of a given teaching practice. However, this work is complementary to existing studies that do examine individual uptake and fidelity of implementation of evidence-based classroom practices (e.g. Stains & Vickrey, 2017; Turpen & Finkelstein, 2009), as study of department-level culture is likely to add explanatory power about why individuals' practices change (or do not). Given that a department's culture can positively support (or inhibit) meaningful instruction, there is a strong theoretical argument that the cultural shifts we document would support new teaching practices. In the results section, we draw attention to some of the structures that were implemented as a part of the change initiative that are likely to have a direct impact on instruction in the department.

We use the four frames as a tool to describe underlying shifts in a department that can support or inhibit sustainability. From the perspective that sustainable change requires cultural change (Schein, 2010), we would expect that a sustainable change would require shifts along

multiple dimensions of the four frames. In addition, the change process cannot be static, but should adapt to the needs of the department on an ongoing basis. A goal of this paper is to further elaborate this connection between cultural change and sustainability. Although organizational learning theory posits that changes at a cultural level are more likely to be sustained (Schein, 2010), this hasn't been explored extensively in higher education contexts. In addition, there are few conceptions of sustainability published in Discipline-Based Education Research (DBER), and because our case study takes place over a very long span of time (15 years), it has the potential to contribution to such a conceptualization in a meaningful way.

To make these theoretical contributions, this paper focuses on the case of a single science department that was widely considered an example of success for the Science Education Initiative on its campus (SEI; Chasteen et al., 2016). Despite this success, sustainability of the department's efforts remained an ongoing issue. Given that the SEI model is in widespread use and is considered a leading model for departmental change on university campuses, the fact that this very successful department still struggled with sustainability means it is an important case that deserves attention. An understanding of this department has the potential to greatly enhance future implementations of the SEI approach and also speak to what is required to make lasting change more generally.

Our findings indicate that the SEI effort did result in lasting changes to the department's symbols, people, and possibly power relations. At the same time, the effort had little to no impact on departmental *structures*, which meant that there was no way to sustain the intensity of the SEI approach over time. It was evident to department members that the SEI approach was not being sustained, but a course of action was unclear. As an analytic tool, the four frames allow us to identify the problem of missing structures, and it suggests possible solutions. This helps us

understand how insufficient changes to the department's culture resulted in an effort that was not sustained.

To attend to this problem, the department participated in a second change effort, organized around the Departmental Action Team (DAT) Model (Reinholz et al., 2017). Because the DAT process focuses explicitly on building sustainable structures within a department, it helped the former SEI participants better understand what was missing from the original effort, and ultimately supported them to create internal mechanisms to support an SEI-like approach in perpetuity. In addition, we identified changes in how particular members of the department reasoned about sustainability in different ways as a result of their participation in these efforts.

To reiterate, this case makes a number of important contributions. First, it demonstrates how frameworks of organizational culture can provide deep insight into the sustainability of educational change efforts. In particular, it suggests that change efforts benefit when they attend to multiple aspects of culture (i.e. multiple frames) and also that even when a change effort is seen as not sustained by its participants, it may still have lasting impacts on *some* aspects of departmental culture that can set the stage for future efforts. Second, it illustrates how the DAT approach, with its explicit focus on building sustainable structures, can be a useful tool for educational improvement. Third, these findings suggest ways that the SEI model can be modified in the future to increase the likelihood that it has a sustainable impact.

Method

Context

The Runes Department was created in the early 2000s, as a merger between parts of two other departments that were also restructured. Since that time, it has attracted a large

undergraduate enrollment (approximately 340 undergraduate degrees awarded and 1800 total majors enrolled in 2015) and as a consequence has a comparatively high teaching load with respect to other STEM departments on its campus. To handle this load, the department employs a large number of non-tenure track, full time instructors who teach 8 courses each year (tenure-track faculty teach only 2-3 courses each year).

The course requirements for Runes majors have changed since the department's creation, but they currently include 12 courses taught by Runes faculty. Runes majors take their introductory (first-year) courses from other departments. In their second year, they take their first Runes course sequence (A and A-Lab) as well as a major-specific math course (M). They then take a second Runes course sequence (B1, B2, and B-Lab) in their third year. Finally, they choose 3 out of 6 upper division core courses (C1-C6) to take in their final year. Collectively, we will refer to these 12 courses (A, A-Lab, M, B1, B2, B-Lab, and C1-C6) as the Runes "required courses." These courses have been the main focus of the educational reform efforts that we discuss in this paper.

The first of these efforts is the *Science Education Initiative (SEI)*. The SEI has been described extensively in the literature (e.g., Wieman, 2017), and given the value of the SEI approach, it has been widely replicated at a number of institutions (see Chasteen & Code, 2018). Here we provided a brief description of the SEI as it related to the present study.

The SEI was a university-funded program at the University of Colorado and the University of British Columbia that supported improved undergraduate education in science departments through three main mechanisms: (1) focusing on the transformation of individual courses, (2) providing expertise and time to help faculty improve their teaching, and (3) working directly at the department level (Chasteen et al., 2016). To receive support from SEI,

departments developed grant proposals requesting funding from SEI Central, the coordinating body of the SEI; participating departments typically received approximately $650,000 over the course of five years. This money was used primarily to hire science teaching fellows (STFs), postdocs with PhDs in a STEM (science, technology, engineering, and math) discipline who received training in education research and development from SEI Central. STFs served as educational experts, directly embedded in the departments, who could help faculty in their course transformation efforts; thus, departments had some agency in determining how they wished to use their STFs. Nevertheless, the main job of an STF was to help faculty to design learning goals and assessments for their courses and to implement active learning techniques in their classrooms. Each department also identified a "departmental director," a faculty member who could serve as a liaison with SEI Central and as the immediate supervisor of and advocate for the STFs. None of the authors of this paper were directly involved with the SEI.

The second mechanism for educational reform in Runes was a *Departmental Action Team (DAT),* which is one component of a larger cross-STEM educational reform project at the University of Colorado (Corbo, Reinholz, Dancy, Deetz, & Finkelstein, 2016; Reinholz et al., 2017). DATs are working groups of faculty (and often students and staff) within a single department that focus on addressing broad-scale educational issues, with the goal of creating mechanisms for addressing the issue in a sustained, ongoing fashion. DATs are participant-driven: the participants determine the focus of the DAT, how frequently it will meet, and what types of "homework" activities they will do between meetings. Like the SEI model, the DAT model provides support through postdoctoral researchers. In the case of the DATs, the postdocs serve as a facilitator for the team; they provide logistical support, expertise in education research and organizational change, and a focus on the components highlighted in our change model. In

contrast to the SEI, the DAT facilitators are not hired by the department, but are instead external to it. Authors Reinholz and Corbo were the co-facilitators for the Runes DAT.

The DAT met for two years before it dissolved. After the dissolution of the DAT, members of the Runes department continued their improvement effort through the creation of three *Agents of Change in Education (ACE)* positions. These were three positions that came out of the Runes DAT's work and are sanctioned by the department. The overall goal of these specialists was to continue the original work of the SEI program that was no longer funded, and to expand its original reach by fostering greater coordination amongst faculty members teaching the required Runes courses to ensure coherence in learning goals and student experiences across them.

Participants

In our analysis, we focus on five Runes faculty members: Anne, Bart, Elly, Karen, and Sophia (four women and one man; all names are pseudonyms). One of these faculty members is a tenured full professor and four are non-tenure track instructors (one of whom recently retired). All five were members of the Runes DAT (although one started attending meetings in the DAT's second semester), several were heavily involved with the SEI (one as an STF and one as a departmental director), and three of them are currently the Runes departmental educations specialists; see Table 1 for a summary of who played what role. Initially, there was another tenured faculty member on the DAT, but the DAT started during his sabbatical year, and he was unable to continue his participation due to travel and other conflicting priorities.

<INSERT TABLE 1>

Data Collection

Data sources related to the SEI used in our analysis include: literature published on the SEI (Chasteen et al., 2015), public SEI departmental reports, and personal interactions with Runes faculty and core SEI project members. Additionally, the SEI collected data on the number of course transformation elements initiated in particular courses and by particular faculty members (i.e., using learning goals, implementation of personal response systems, etc.), which allowed them to compute an "impact score" that has a maximum of 14 points for courses and 9 points for faculty members. These maximum scores represent the total number of available changes that *could* be adopted by a faculty member or in a course (e.g., creating learning goals, adopting new assessments). Based on this score, courses and faculty members are categorized as having experienced a "large" impact (score greater than 4) or a "modest" impact (score of 3 or 4, or 2 if changes include learning goals or assessment). We make use of these categories in our analysis below, and we add a "negligible" category to describe impacts that were non-zero but which did not count as "modest." To enable the reader to refer to prior work published by the SEI, we note that Runes was referred to by them as "Department D" (Chasteen et al., 2015).

Data related to the DAT and ACEs came from a variety of sources. Before the DAT's formation, our project team interviewed nine Runes faculty members to better understand the department and to determine if there was interest in forming a DAT. The DAT began meeting in September 2014; we conducted a survey of DAT participants at the beginning of the following spring semester (2 out of 5 response rate), and we conducted interviews with the DAT participants at the end of the spring 2015 semester (5 out of 5 response rate). At the end of the spring 2016 semester, a focus group was conducted with all 5 DAT members. Two years later, during summer 2018 follow-up interviews were conducted with all 5 former DAT members. Finally, one of the facilitators kept detailed notes of each DAT meeting, with close paraphrases

of DAT-member contributions (a total of 35 meetings over two years, with a total of 135 pages of notes), and all artifacts (e.g., diagrams, presentations, surveys) generated by the DAT were collected. There is also extensive documentation of all other informal meetings we had with department members. We draw on all of these data to build our descriptions. Often, the data elicited through our process of creating and documenting the DAT in Runes provided insight into the prior SEI efforts in Runes as DAT participants naturally brought up the SEI as salient to their work.

Analytic Methods

This paper uses a case study approach, which is appropriate to understand a "contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2009, p. 18). We focus on a single case study with a longitudinal design so that we can follow this single case in sufficient depth to support theory building. Our work is guided by the research questions: What factors contribute to whether or not an educational improvement is sustained within a science department? And, how can faculty views on sustainability be shifted as a result of participating in targeted efforts to sustainably improve education? Our proposition is that cultural shifts are required for sustainability, and such shifts can be documented using the four frames model. We also argue that faculty views on sustainability can be further developed through their participation in the DAT effort, which focuses specifically on sustainability. In the case that follows, we link multiple sources of data to support this proposition, while simultaneously addressing rival explanations.

We used Lincoln and Guba's (1985) *trustworthiness* framework—consisting of credibility, transferability, dependability, and confirmability—to guide our construction of the case. Through a process of pattern matching and discussion within our team, we aim to build a *credible* case. We have confidence in this case, given that we have had prolonged interactions with the participants over multiple years, triangulated our data sources, and performed member checking. To support *transferability*, we provide thick descriptions of the focal department so that it can be compared to other departments. Because this department is representative of other research-focused science departments, and change models such as the SEI and DATs are now being utilized across the national landscape, similar phenomena would likely play out in similar contexts, but our goal here is not to claim representativeness across departments. Nevertheless, the experiences are especially valuable to report, because this department was considered an SEI success, and it still struggled with sustainability. Thus, our findings are broadly relevant to other change efforts.

We achieve *dependability* through careful documentation of our process and triangulation of data sources. By having multiple team members engage with this particular case, we have checked for consistencies with our deep understanding of DATs and departmental change in general. Finally, *confirmability* focuses on neutrality and avoiding researcher bias. By checking the results of the case both within our team and through member checking with DAT participants, we have attempted to mitigate bias from within our team. The draft manuscript was sent out to all five members of the DAT, and one of them provided feedback that was incorporated.

Our unit of analysis for the sustainability of these change efforts is the department as a whole. When we consider the department as our unit, we are concerned with aspects of

department culture that permeate the department, either because many department members are aware of them, or because they have had a large impact on the department. The five focal faculty members provide us great insight into change in the department more broadly, because they have been centrally involved in the department's major change efforts. Still, given the complexities and lack of coherence of culture, we expect all department members to see the department culture differently, because they occupy different roles within the department.

For our study of faculty views of sustainability, our unit of analysis is the core group of five participants involved in the DAT process. While these department members were not equally involved in all departmental education efforts, they were central enough to ongoing efforts in the department that they can be understood as the "usual suspects" when it comes to pushing forward educational efforts. Thus, our focus on their views on sustainability provides insight into how other faculty motivated to create change might come to reconceptualize sustainability over time.

To understand their thinking, our analytic process involved searching for the term "sustain" across all interviews with DAT members. The term came up 66 times, which meant it was either used explicitly in the question asked by the interviewer, or in the response by the interviewee. These statements were analyzed through an iterative process of qualitative thematic analysis (Boyatzis, 1998) and constant comparison (Krathwohl, 1998) to find patterns in how faculty members described sustainability and how the patterns changed over time.

Results

Our results are organized into two subsections, each addressing one of the two research questions. The first subsection tracks changes to the department's culture across three individual

change efforts, and connects these shifts in culture to the sustainability of the efforts. The second

subsection focuses on how DAT participant views of sustainability evolved over time.

Change Efforts, Cultural Shifts, and Sustainability

This section tracks cultural changes in the department across three initiatives: The

Science Education Initiative, Department Action Team, and Agents of Change in Education. It

closes with a discussion of the connection between cultural shifts and sustainability.

The Science Education Initiative

Shortly after the Runes department was created, it applied for and received five years of

SEI funding totaling over $700,000, a relatively high amount among SEI departments. The

department's application provides insight into how the department as a whole initially thought

about education, because the proposal was approved through faculty vote. While not all faculty

members necessarily embraced the views of the proposal, there were no objections deep enough

to stop the proposal from being submitted, and ultimately being funded. In its application for SEI

funding, the Runes department described its issues as follows,

> In our lower-division courses, far too many of our students view their science education
> only as a means of obtaining grades and, ultimately, a degree. Too many of our students
> do not appreciate undergraduate science education as an opportunity to develop (a)
> knowledge that will serve them well in their future education and careers, and (b)
> thinking skills that are essential for success in school and the working world. We deeply
> desire to change this aspect of the culture of science education in our Department, and
> our impression is that participation in the Science Education Initiative will enable us to
> do so.

The department clearly states a desire to change its culture in a way that supports deeper student

thinking. Further, the department expresses a belief that their teaching is at least in part

responsible for this challenge,

Despite our presenting fundamental [Runes] knowledge in our lower-division courses, far too many of our students reach the upper division either without having retained the knowledge or having slipped backwards to naïve notions about key concepts in [Runes]. We recognize that this problem stems, in large part, from how we are teaching the lower-division courses. We appreciate that the Science Education Initiative will help us develop teaching methods that promote a deeper understanding of concepts in [Runes], so that students retain knowledge, or at least so that they are able to reconstruct the knowledge accurately when they need it.

In the closing statement of the application, the department recognized the "considerable amount of work" that would be required by "most of the faculty," but nonetheless was "enthusiastic" about participating in the SEI. As we outline below, this commitment to change contributed to the Runes department being one of the most successful departments involved with the SEI.

During the five years of SEI intervention, the department hired four STFs total, with two or three employed simultaneously at any given time. Additionally, two Runes faculty members served sequentially as departmental directors for the Runes SEI initiative. At the completion of their funding cycle, the SEI characterized Runes' efforts as follows (Chasteen et al., 2015):

In [Runes], STFs worked in several introductory courses, impacting a large number of students, and partnered successfully with a broad range of faculty…Faculty in the department were deeply engaged with the SEI, with tangible support and involvement from the chair, who explicitly expected that faculty would use SEI-created materials. This department has continued to be involved in educational transformation, engaging in a national initiative, and hiring one of the STFs as a permanent instructor.

According to a poster summarizing the impacts of the SEI in Runes, "[t]he original charge of the [Runes] SEI program was three-fold: [to] change the culture of science education in [Runes], [to] help develop teaching methods that promote a deeper understanding of concepts in [Runes] so that students retain knowledge, [and to] promote critical thinking, problem solving, and communication skills in science." To achieve these goals, the Runes STFs engaged in a number of activities primarily targeting the required courses:

1. Working with faculty to develop course-specific learning goals that "establish what students *should* know upon completion of a course, and include everything from basic concepts and vocabulary to more advanced critical thinking and data interpretation skills." Ten of the 12 required courses had draft, individual, or consensus learning goals developed.

2. Measuring what students were actually learning by "gathered data on students' problem-solving skills, conceptual understanding, attitudes, and skills in the areas where faculty members have identified learning goals." Eight out of 12 required courses were assessed in some fashion, through classroom observation, surveying and interviewing students and alumni, and/or developing pre/post conceptual assessments.

3. Working with faculty to help them improve their instructional materials and pedagogical strategies, including adding clicker questions and improving clicker pedagogy, developing homework and pre-class preparation assignments, improving recitation and lab instruction, and adding homework help sessions and class projects. Ten out of 12 required courses experienced some improvement in materials and/or pedagogy, as well as three non-required Runes courses.

4. Facilitating faculty working groups associated with the required courses as "a mechanism by which faculty who teach similar courses can meet to decide on learning goals and assessments, and have a community to discuss the happenings of their course." The goal of the working groups was to instill a sense of collective ownership and expertise over educational change. Nine out of 12 required courses had associated working groups, which involved 19 Runes faculty members in total.

Based on impact score, the SEI had a large impact on 7 out of 12 required courses, a modest impact on 2 out of 12, and a negligible impact on 3 out of 12. Additionally, the SEI identified 25 Runes faculty members who regularly taught undergraduate courses during the department's participation with SEI. Of these, SEI had a large impact on 12 out of 25, a modest impact on 5 out of 25, a negligible impact on 3 out of 25, and zero impact on 5 out of 25. Thus, SEI had a considerable impact in Runes in an absolute sense in terms of the number of required courses transformed, the number of faculty who learned about and improved their teaching, and the broad scope of the activities led by the STFs.

The Runes department is generally considered an SEI success in a comparative sense as well. Table 2 compares six SEI departments along four metrics related to faculty and courses impacted in the departments. Runes has the highest percent of courses that experienced any impact, is essentially tied for first in the percent of courses that experienced a large impact, and comes in second in both the percent of faculty who experienced any impact and a large impact. Thus, there is considerable support for the claim that Runes was one of the more successful SEI transformations that took place on its campus.

<INSERT TABLE 2>

Despite this success, Runes faculty perceived backsliding in progress after the end of SEI funding in 2011. Three of five DAT members talked about this explicitly in their spring 2015 interviews, in response to the interviewer asking them to describe the history of their DAT. The interview did not explicitly cue a question about sustainability, but it came up spontaneously in three of the interviews. The previous SEI director explicitly brought up sustainability and reasons why he thought it was difficult to achieve,

> I think [Runes] did some really good things, but I think sustainability became a problem…We had new faculty come on board, we had new classes that were being

taught, and carrying over the learning goals - who does that? Who helps those new faculty to understand all that was done by the SEI in terms of the learning goals and how to use clickers in the classroom, those types of things? If no one's there to do it, it doesn't happen as easily or as readily. (Bart, 2015)

What Bart describes here is the turnover of faculty and the lack of a person to help faculty members learn to do SEI "types of things." Karen also highlighted the issue of "new people teaching courses" in the department, with no "mechanism" to sustain this approach. Sophia described a lack of the "SEI presence," which had some courses "slip back" to an old way of teaching. She continued that without ongoing support from STFs, "especially for the busy tenure track [faculty], there's been some loss of the efforts that had been facilitated by the SEI." The way that these faculty members describe a lack of sustainability of the SEI as a key impetus for the DAT work is consistent with our impressions developed after our extensive work with the department, and the issue of SEI backsliding also came up repeatedly in later interviews.

In sum, these three faculty members perceived the SEI as critical to the educational progress made by Runes, and also that the end of SEI funding led to perceived stagnation and erosion of progress. But what exactly was lost? (We consider what was not lost below.) The quotes above describe the SEI approach being lost due to faculty turnover, and new faculty not adopting learning goals or innovative teaching practices. The loss of the STF presence in the department meant that there were no *people* who were directly responsible for providing professional development to faculty members. In addition, SEI *structures* such as course-based working groups and yearly cross-department meetings ended with the end of SEI funding. While the faculty members recognized a lack of mechanisms for onboarding new faculty, they did not yet frame this understanding in term of the lack of departmental *structures*. This idea only emerged much later, in interviews after they had worked with the DAT for a year.

Despite this perceived lack of sustainability, the SEI did make lasting changes to the department's culture. From the perspective of *structures*, there were still many instructors who were using new practices (e.g., clickers) in their courses. In addition, new ideas (i.e. *symbols*) were now prevalent in the department: backwards design, learning goals, active learning, STFs, and even the SEI itself. These symbols could contribute to shifting the way the department thinks about education, and even what is possible to achieve. In terms of *people*, the department did hire Elly, a former STF, into the department, but there were no formal mechanisms for her to support faculty members as a part of her job; she had to provide support entirely on a volunteer basis (i.e. a person had the expertise, but there was no formal structure for the department to leverage that expertise). Finally, in terms of *power*, the relative success of the SEI could contribute to the possibility of future change efforts. As we describe below, it is evident that the SEI set the stage for the success of future change efforts.

Departmental Action Team

The Runes DAT consisted of the five department faculty members mentioned above and two postdoctoral researchers who acted as external facilitators. During the academic year, the DAT met approximately every other week, for an hour at a time. The Runes DAT commenced for two years before it disbanded, to be replaced by a *structure* for organizing Agents of Change in Education (ACEs). Given our extensive experience facilitating DATs in over 10 departments, we consider the case of Runes to be a success story, just as it was with the SEI.

Many of the faculty members described joining the DAT as a way to *sustain* improvements that resulted from the SEI. For instance, Elly described how the DAT would "step up from where the SEI left off," and Bart described the DAT "as an opportunity" for "developing

sustainability" for an SEI-like approach. Throughout our interactions with DAT members, and ultimately in the outcome of the DAT, we found continued evidence that the purpose of the DAT was to continue where the SEI left off. Still, it is likely that different DAT participants had different visions of exactly where the SEI left off and where to go next.

The initial meetings of the DAT focused on building a shared vision to guide the DAT's work. After a collective brainstorming exercise related to the group's goals for students, it came up with a list of learning outcomes for students that focused on communication, critical thinking, content knowledge integration across courses, scientific practices, and independent research and learning. To help students achieve these goals, DAT members began to plan a course of action. In these conversations, they noted that while the SEI had helped the department to create learning goals for many of their courses, the goals were mostly limited to content, with less focus on skills and practices. This was despite the overall SEI goal to foster deeper learning, such as conceptual understanding and problem-solving skills. It could be that the SEI effort ran out of time to achieve this larger goal, or that other barriers within the department (e.g., resistant faculty members) inhibited some progress.

The DAT participants also discussed how all of their courses would benefit if they could rely on students entering upper division courses having certain skills that they could build on, rather than re-teaching basic skills. They also identified the lack of a mechanism for communicating learning goals to new faculty members as a significant impediment to sustaining course reforms. Through these conversations, the participants settled on the coherence of the department's curriculum, sustaining SEI innovations, and infusing the curriculum with critical thinking, communication, and bigger-picture science skills (beyond content understanding) as their areas of focus. The mechanisms with which the group would achieve these goals shifted

during the course of the first year of the DAT's meeting. Throughout its first year, the DAT met with key stakeholders, collected and analyzed data, and made a case for departmental support for ongoing improvements.

As a result of the DAT's work, the Runes department sanctioned three *Agents of Change in Education* (ACE) positions (ACE is a pseudonym added to protect the identity of the department). These positions were intended to initially be filled by members of the DAT, each receiving a one-course teaching release each semester. Each ACE would be responsible for a subset of the major courses: (1) A and A-Lab; (2) B1, B2, B-Lab, and M; (3) and C1-C6. ACEs would meet with the faculty associated with their set of courses at least once each semester (e.g., the B-coordinator will meet together with the faculty teaching B1, B2, B-Lab, and M). Related to their courses, each ACE would: (1) update and maintain course learning goals, (2) meet with new faculty teaching courses related to these goals, (3) perform classroom observations as desired, and (4) collect student data. Collectively, the ACEs would collaborate to support coherence across the curriculum and provide instructional support more generally. The overarching goal of the ACEs is to provide a *sustainable* mechanism for communication across courses to support a coherent Runes curriculum; ACEs will not dictate how courses are taught. By building capacity for a change that can endure over time using internal mechanisms, the ACE model is well-aligned with our definition of sustainability.

For one year after these positions were approved, the original DAT members continued to meet to better outline the goals for the positions. It also developed and administered a survey to the department, which was intended to provide a baseline for the work of the coordinators over time. The finalized survey focused on the following areas: (A) use of active learning techniques, (B) use of learning goals (in individual courses and across courses), and (C) the three goals for

Runes majors previously developed by the group (domain knowledge, critical thinking, and professional skills). There was a high faculty response rate to the survey (27 of 33 faculty, or 82%), with all 10 instructors in the department responding to the survey. This indicated that the faculty in Runes had some interest in the work of the ACEs.

It is clear that the SEI made shifts in departmental culture that provided the foundation for the work of the DAT in this department. DAT members frequently referred to SEI ideas (i.e. *symbols*), such as learning goals, clickers, backwards design, STFs, and the SEI itself, as they engaged in their work. In addition, the *structure* of having external postdocs supporting faculty was already familiar, because that was a primary mechanism through which the SEI enacted change. Moreover, the support that the SEI had in the department (i.e. *power*), most likely impacted that department's continued willingness to support the educational effort of the DAT. With the DAT, there was ultimately no introduction of new *people* into the department. While the department did attempt to hire a Discipline-Based Education Research (DBER) specialist in the department, it was a failed search and the position was never filled. Thus, rather than adding new people, the goal of the DAT was to create the *structure* for ACEs, which would operate as a structure to continue SEI-like work indefinitely.

Since the ACE positions were adopted by the department, the department chair has changed twice but the positions still remain. This is relatively strong evidence that the positions may be sustained over time. In this way, the DAT helped address what was missing from the original SEI effort, a *structural* component of the department that would sustain improvement over time. In her 2018 interview, Elly described how the ACE positions "empowered" her to help as many people as possible, which she previously "didn't have time for," because the work was done entirely on a volunteer basis.

In sum, there is strong evidence that the SEI provided the basis for productive DAT work in this department, and that the DAT augmented the original effort in important ways. In particular, it added a focus on sustainability in terms of creating new *structures* in the department. As we will describe in the next section, we also found evidence that it added new *symbols* in terms of sustainability, as the DAT participants learned new ways of interacting with other faculty members that were grounded in principles of organizational change. We see these principles at play in how the ACE positions have been enacted, with their focus on building sustainable structural supports to build community and enhance collective teaching efforts.

Agents of Change in Education

In their two years of existence, the ACEs have become actively involved in a variety of aspects of the department's educational mission. (All quotes and information for this section are drawn from the interviews with all five DAT members that took place in spring 2018.) One of the group's first activities was revisiting the department's learning goals. This involved getting together faculty members who were teaching in different course sequences and it was a mechanism to include new faculty who were not a part of the SEI. In addition, these groups began to create learning goals for some of the upper division courses that never previously had learning goals.

Despite some progress, this process has not been uniformly positive. For example, Anne described a "particular faculty member who brings in a lot of grant money" being unwilling to follow the established learning goals for the course he teaches. As a result, certain Runes content is taught twice in subsequent courses, while other topics are not covered at all. In the Runes department, there is no formal mechanism for enforcing that this particular faculty member

teaches certain content in that course, and to date the department administration has not reassigned him to another course.

In addition to helping faculty align learning goals, the ACEs have provided support through a variety of activities such as workshops and individual consultations. For example, when the campus adopted a new learning management system, the ACEs provided targeted support to other members of their department. The ACEs also provide ongoing consultations for course transformations. For example, Karen described a "distinguished professor" in the department who makes "no secret about his opinions," who "worked very closely" with the ACEs to revise one of the courses he teaches. What Karen is describing is an instance of a powerful faculty member in the department who was previously resistant to change, and who was ultimately willing to receive support from the ACEs.

In addition to providing services similar to the original SEI, the ACEs have been actively involved in creating new *structures* in the department. For instance, the ACEs created a new seminar for all undergraduate teaching assistants (UGTAs) to improve their teaching. Elly described this as follows,

> [W]e've now started doing UGTA training…anywhere from eight to sixteen undergraduates will sign up for this one credit seminar, then we'll just give them the quick and dirty this is science education, these are the things you can be doing in the classroom to help your faculty member, and then they'll do a project at the end of the semester. (Elly, 2018)

This structure has the potential for impact in many ways. On one hand, UGTA training is now "a thing that embodies reformed teaching in the department" (i.e. *symbol*), and it could become a *structure* that exists over time. In addition, UGTAs are being exposed to new teaching methods that may ultimately influence the teaching practices of the faculty that they are paired with.

The ACEs also started a faculty coffee hour, as Sophia described,

[I]n the past year or two we've started a coffee hour. We meet once a week for an hour over coffee, and that actually has been very good for us. Again, it's a community building opportunity. But we often have a lot of conversations centering around our teaching, and a lot of times we bring up difficulties we're having and we ask other people how do you deal with this. That actually is becoming an important mechanism for change amongst the instructor teaching faculty. (Sophia, 2018)

Although it was unclear whether this coffee hour was mostly limited to instructors or if tenure-track faculty members participate, this is another ongoing *structure* to increase the focus on teaching in the department. Sophia described these initiatives as a larger goal to find "more mechanisms to pull faculty in" and to get them talking about teaching. Sophia went on to describe how the ACEs were brainstorming about "journal clubs" as "another mechanism to get people gathering, talking about teaching." As we describe in the following section, these types of activities represent a shift in thinking for the ACEs, to a place where they are explicitly thinking about sustainability through the creation of new structures.

In addition to building sustainable structures, the positive work of the ACEs has shifted *power* relations in the department, by elevating the status of instructors. This was noted by Sophia, Karen, and Anne, all who have been instructors in the department for many years. Karen described her perception that having an "assigned role" for "non-tenure track instructors" has "elevated the position of instructors in the departmental in general." Similarly, Anne described this situation as "a very positive thing" because "instructors in general feel like what we're doing is valued," and that as a result of these new positions they can have "more voice" that they "thought they had." Sophia described her feeling "that the role that instructors play is valued more and appreciated more." She continued on to describe how she feels empowered by the new positions,

Also because of the role as a [ACE], it kind of makes me feel more empowered…rather than just sitting back and waiting for someone to contact me and say would you like to

work on this. Feeling that I should be seeking out opportunities and I should be trying to have more of a voice as regards change or discussions about undergraduate education. (Sophia, 2018)

What Sophia describes is department sanction and validation of her educational improvement efforts. With the creation of the ACE positions, she has a charge and the legitimacy to do the work that she previously felt less empowered to do. Because we did not interview other instructors in the department we cannot say how widespread the perception of this shift in power is. Nonetheless, it is clear from the above statements that these focal instructors did perceive a shift in power, and it has empowered them to engage in ongoing improvement efforts.

These descriptions highlight how the ACEs have shifted the department in terms of *structures* and *power* relations. Was this enough to fulfill the DAT's original goal, to sustain the SEI by onboarding new faculty members? We found some evidence that the answer to this question is yes. For instance, Sophia described how the ACEs mentored new faculty members,

> Seeing some of the new junior faculty coming in and how they're being mentored as they're taking over certain courses, they're learning about clickers and they're learning about active learning and how to foster not just memorization but problem solving in students. So we are having more of those discussions. And that's why we wanted to create these positions, to make sure that what we gained through the Science Education Initiative kept moving forward, that as new faculty come in that they are receiving the training and the support that they need to be successful. Because, you know, most faculty are trained to be research scientists, they're not trained to teach. (Sophia, 2018)

Here Sophia describes a shift in how new faculty members come into the department. Rather than not being given support and SEI techniques not being taken up (as before), there is an active effort to teach new faculty to use new methods. Elly also remarked that because of the "support structure" of the ACEs the department seemed more "willing to let new faculty try new things." Thus, what we find here is some evidence that the ACE positions may have shifted other ways of

thinking the department (i.e. *symbols*), because new faculty members were permitted to experiment more with their teaching.

Given the evidence we have collected it appears that the ACE positions were largely successful in meeting their originally stated goals. Above we documented shifts in terms of *structures, power,* and *symbols* in the department, which indicates that the ACEs have had a large impact in shifting the culture of the department to make educational improvement more sustainable. While the ACEs described some very compelling instances of change in the department, we do not have further data on how widespread these shifts are. In addition, whether or not these shifts endure is an empirical question. In the next section, we connect shifts in department culture and how they related to the sustainability of change efforts.

Connecting Culture and Sustainability

The description of change efforts within Runes highlights the importance of shifting culture to achieve sustainability. Table 3 summarizes the cultural shifts made in the department and connects them to our five criteria for sustainability.

While the original SEI effort did shift *symbols, people,* and *power,* it built no *structures* that could sustain the SEI-like approach. In this way, we see that insufficient changes to culture may inhibit the sustainability of the effort. In particular, the SEI had insufficient *capacity building* and there was no creation of *adaptable* mechanisms for the change to *endure* once external funding was removed. While we found no evidence of *negative impact on other efforts*, it was also true that the SEI effort had no way to *use existing resources* to sustain the changes once external funding was removed. Thus, what we see is that even though the SEI did not satisfy most of the criteria for sustainability, it still made important cultural shifts that laid groundwork for future sustainability of efforts.

<INSERT TABLE 3>

In contrast, the DAT was a temporary model that the department used to create new *structures* to sustain its efforts. The DAT also supported shifts in *symbols*, as it provided further education for the participants about sustainable change. This allowed the DAT model to build on the prior cultural shifts that had already begun with the SEI. In terms of sustainability, the DAT *built capacity* by creating ACE positions, and the DAT itself as an *adaptable* mechanism that the department later used as a part of another effort (see below). The DAT did not use *existing resources* nor did it *negatively impact other efforts*, but it used a modest temporary infusion of external funds (an order of magnitude less than the SEI) to create *enduring* changes through the ACE positions.

Finally, the ACE positions have built upon ideas learned from the DAT, and continue to create new *structures* and elevate the *power* of instructors in the department. The ACEs *build capacity* by creating new structures, and these structures are *adaptable*, as they can be made to fit the current needs of the department. The ACEs do not appear to *negatively impact other efforts*, and in fact they are funded entirely by *available resources* within the department. Preliminary evidence indicates that the impact of the positions will *endure*, but further follow-up study will be needed to confirm this.

Faculty Views on Sustainability

This section describes how faculty views on sustainability changed over time. Tracking these changes is important, because it allows us to see how beliefs about change (i.e. *symbols*) ultimately impacted the approach to change that faculty in the department used, which has implications for sustainability of their efforts. In particular, by shifting their focus to build

capacity and create adaptability mechanisms (i.e. *structures)*, faculty members were able to attend to sustainability in new ways that were not inherent in the original SEI effort.

Although we do not have pre-interviews with faculty members, we found compelling evidence from multiple participants that their thinking shifted as a result of the DAT process. These statements came from the 2018 interviews, two years after the ACE positions were formed. For example, Sophia described her shift in thinking as follows,

> It's surprising it took us so long to identify it...what we identified as the issue and wanted to try to solve was to maintain that momentum, build on it, and to try to come up with some mechanism for sustainability of those efforts. (Sophia, 2018)

Sophia had been actively involved in educational improvement efforts for many years, but it was her participation in the DAT that finally made her realize the importance of developing a sustainability mechanism (i.e. a *structure)*. She later described the importance of this "embedded resource" to make sure the department's curriculum "stays aligned." Karen's response was remarkably similar,

> You know, it's funny, in retrospect I think the SEI accomplished a lot, the staffing went away and the accomplishments started to slide from natural attrition, so the solution is more staffing, permanent staffing…(laughs) But it took us a year to get to such a simple conclusion, in a way…having those permanent assignments means someone's always paying attention to this, is assigned to spend time on this kind of thing. And that's what it takes. Otherwise, everybody's busy. (Karen, 2018)

Here Karen makes the point that unless someone has the job to sustain efforts, it will not happen. Even though it seems obvious now, she remarked on how long it took to reach that conclusion.

Elly described that "what [she] learned" was that "you have to have someone who a carved-out part of their job responsibility is to do this." She went on to describe she was "killing herself" in her attempts to play the STF role in her formal position as an instructor, and that she was "dying" because she hated to say no to other faculty members. This contrasts Elly's

perspective of now feeling "empowered" with the ACE positions in place. Anne similarly described that "to make it sustainable" there must "someone whose role" is designated to support faculty members.

What the DAT participants describe here is that there needs to be a formal role (i.e. *structure*) within the department, so that someone can designate part of their job to helping other faculty members learn to teach better. Otherwise it will not happen. In addition, such a structure can change *power* relations in the department, by formally validating the work of the ACEs. What was surprising to the DAT participants is that this conclusion that now seemed obvious to them was not something that they had recognized during their prior engagement with the SEI. We hypothesize that is was the case because building sustainable structures was not a focus of the original SEI initiative.

Even though the ACEs have had a large impact to date and have widespread support, they may not be impervious to future changes. For example, Sophia discusses possible threats to sustainability,

> For the moment we've had a lot of support, and I think what we're trying to focus on is finding a way to make ourselves more visible and more indispensable so that hopefully if somebody tried to pull those roles back there might be an outcry of like, wait, we can't exist without this support. We're trying to find ways to really be visible, to make ourselves valuable to faculty so that faculty recognize they need this assistance, recognize that this is a valuable resource for the department, and it's to the benefit of the department to maintain this. We're still in the infancy stages. We're trying to find a way to sustain the sustainability mechanism. (Sophia, 2018)

Here Sophia talks explicitly about strategies used in the DATs (e.g., externalizing progress, building structures) and the need for them to engage in this work to sustain the ACE positions. Sophia continued on to describe her team as "DAT addicts," because they "found the DATs just to be a really effective mechanism for getting faculty involved in discussions of change within the department." When Sophia refers to DATs in the plural, she is describing a second DAT that

was formed as a part of another campus initiative to improve the assessment of teaching on campus. Notably, Elly was also a part of that DAT, but it was not a focus of our interviews. In addition, Sophia mentioned the possibility of a third DAT "to pull in graduate students and undergraduates more."

Anne also recognized the transformative potential of a DAT-like process in guiding her work,

> What's truly unique about the DAT is that oftentimes it's identifying a problem that the department doesn't know it has. (Anne, 2018)

Still, Anne noted that if you mentioned a DAT to many people in the department, they would not "know what they are." Thus, Anne would "love to see more DATs" to get more department members involved. This draws attention to the importance of getting more *people* in the department involved in the change effort. Implicit in these statements is the valuing of a particular way of thinking that attends to building sustainable solutions to ongoing issues in the department.

Although it was clear that the DAT process influenced the ACE positions, the DAT's impact was not uniform. For instance, while Elly described the DAT process as useful, she also did not indicate that she learned much new beyond her prior training through the SEI. This is consistent with Elly's optimism that change would remain without continued sustainability mechanisms. Her perception was that the shift in Runes culture was so great that it would be self-sustaining, which is a perception consistent with the original SEI model of change,

> I think we've already changed the culture so much that even I think if we had a chair, let's say, that wasn't supportive, we would still keep moving forward. It would be a little bit harder, because I know in order to participate in the DAT you kind of need chair support. But we've been so lucky in this department. (Elly, 2018)

Elly continued to note that before the SEI reforms all courses in the department "were just taught as a traditional lecture." Elly's perception was that this type of teaching as no longer acceptable in the department, so much that it's an "unspoken requirement" that faculty members will have learning goals and activities. What Elly describes here is her perception department that has undergone some radical shifts in educational practices and beliefs over 15 years. What began as a department that had little use of innovative teaching techniques has now normalized the use of innovative practices, and in her view, sustainability of this effort is no longer in great danger.

In sum, we found evidence that the DAT process with its focus on sustainability impacted how faculty members in the DAT thought about sustainability, which in turn impacted their work with the ACE positions. In particular, the former DAT members focused on creating explicit mechanisms to sustain their ongoing work. Still, this impact did not appear to be uniform across participants, with some shifting their beliefs more than others.

Limitations to Generalizability

The Runes department is a telling case because even though it achieved a high level of success in the SEI it still faced threats to sustainability. In this way, the lessons learned here are of potential value broadly, but one must first acknowledge unique aspects of the department. We do not claim that this department was representative of all other departments, but rather that it provides insight into *phenomena* that could play out in any department. Here we outline some unique departmental aspects. First of all, this department was able to achieve what it did due to a high-level of focus on education and administrative support. As Karen notes,

> I've always been pretty impressed that our faculty in this department has cared about undergraduate education from the very beginning when I first started twenty-four years ago…it helps that we weren't swimming upstream. (Karen, 2018)

Karen went on to describe a "bell curve" of faculty with some caring about education more than others, but still a general focus on education. Karen also describes the role of "supportive chairs" who made this entire change process possible. In addition, Karen described how the creation of ACEs serendipitously coincided with another administrative change in how time was assigned for instructors,

> Yes. It's a budgetary issue as well as an issue related to the teaching classes. Here's another external circumstance that actually ended up being important: in 2014, the definition of fulltime instructor and faculty changed on our campus from teaching three courses a semester to teaching four courses a semester…Suddenly we went from a situation where we had trouble having enough person power to assign to all the sections of all the classes that needed to be taught to having an excess. So questions about, well, what are we going to do with folks? So there was an opening. (Karen, 2018)

As the above description makes clear, this particular series of change efforts was bolstered by administrative support, relatively willing faculty, and also important administrative changes. The lack of any of these circumstances, related to *power*, could have been a major impediment. At the same time, it is unlikely that these circumstances alone would have been enough to create change without the presence of the DAT. As described above, the DAT members reflected on how obvious it now seemed to them to need to create new *structures* for sustainability, but also that it took them nearly a year meeting as a group to reach that conclusion.

Another limitation of this case is that we have not interviewed faculty members outside of this focal group. On one hand, the given effort may have benefited from a small number of faculty who had built positive relationships with each other and knowledge of change through sustained engagement. As the same time, there is a danger of localizing the efforts and their impact to a small subset of the department. Because we do not have interviews outside of the focal faculty group, we cannot speak directly to the changes in beliefs of other faculty members. Nonetheless, we do have extensive evidence through artifacts and prior SEI studies that in fact

practices within the department have shifted considerably. We also have some reports from our focal faculty members that address broader departmental perceptions. In addition, as part of a larger DAT project, we are working on longitudinal data collection on departmental culture around teaching and change from non-DAT members.

Finally, there is a question as to the relation between the SEI and the DAT in this department. We argue that the DAT was needed to sustain what the SEI began, but we hypothesize that the DAT still could have made lasting changes without the prior SEI effort. This is based on our extensive work implementing DATs in ten other departments (Reinholz et al., 2018). Still, as Bart points out, the nature and scope of the changes in this department were certainly greatly enhanced by the prior presence of the SEI. In this way, the DAT and ACE positions benefited from the prior SEI effort.

Discussion

Research on sustainable change shows that there are many different ways to conceptualize change. These conceptualizations range from the relatively limited idea of simply sustaining practices, to deeper notions of shifting culture and continuous improvement. We found some evidence for this range of perspectives amongst our focal faculty members, and we found that their participation in an effort explicitly focused on sustainable change shifted their perspectives in ways that had lasting impacts on their future educational improvement work.

With this manuscript we also aim to problematize what it means for something to be sustained. In our early interviews with DAT members, they described the SEI as not being sustained, because there was no way for onboarding new faculty members into the use of innovative practices. While this certainly demonstrates that some aspects of the SEI were not

sustained, we also found evidence that the cultural changes that were made (e.g., beliefs about teaching, a former STF being hired into the department) played an important role in subsequent change efforts. In this way, whether or not something is sustained is a nuanced question that requires us to look at multiple aspects of cultural shifts. We found the four frames to be a productive model for doing this, but it is certainly not the only one.

This finding has a number of important methodological implications for future research on sustainability. First, we note that truly understanding sustainability requires very longitudinal analyses. Even after tracking this department for 15 years, a follow-up study will be required to truly determine the sustainability of the ACE positions. In addition, the study draws attention to the important role that prior efforts may play in the success of any given initiative. Thus, when evaluating the quality of a given initiative, it is important to give sufficient attention to prior efforts and how they may have served as preparation for future sustainability. Rather than trying to claim the success of a single initiative, it may be more productive to consider a series of improvement efforts and their ability to adapt over time. Finally, this work highlights how many aspects of sustainability might not be visible until many years down the road. Even though the department members initially felt that the SEI was not sustained, our analysis shows that the SEI did lay crucial groundwork for future efforts, but the importance of the groundwork could only be captured by a study that happened many years after the SEI, which is not typical in our field.

To return to another one of the original goals of this manuscript, we discuss ways that the original SEI effort in this department may have been modified. The SEI brought a considerable sum of money to the department, much more than the DAT project, but nearly all of this funding was used to provide external support. To make the SEI process more sustainable, these types of support needed to be internalized. The Runes department took a huge step forward by hiring one

of the STFs as a full-time instructor, but it still lacked the mechanisms to support the department to leverage this individual's expertise.

The ACE positions provide a great example of how to internalize SEI-like support into a department on an ongoing basis. In addition, through their initial projects in the department, the ACEs have been building new structures—professional development for UGTAs, coffee meetings, and possibly a journal club—which could help elevate the status of educational efforts in the department further. One of the key ideas that the DAT members learned as participants in the DAT was the need to internalize mechanisms for sustainable improvement, rather than relying solely on external support. An SEI 2.0 could easily include these new features, by focusing on building structures and also by explicitly teaching participants about sustainable change.

Beyond the SEI and DAT model, this paper provides insight into how to sustain improvement, and also how difficult it can be. This is a department that is ideal in most ways—a high level of faculty interest, a high level of administrative support, and a lot of external funding—but sustainability still has not come automatically. It is something that the faculty members have worked tirelessly for, and they continue to address future threats to the sustainability of their efforts. This highlights just how unrealistic it is to consider sustainability as an "add on" to an improvement effort. For change to be sustained, sustainability should be intentionally included as a part of the process from the offset.

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Appendix A: Runes DAT Exit Interview Protocol

Guiding Research Questions

1. How did the DAT members perceive themselves as change agents within the department?
2. Which specific aspects of DAT structure and facilitation were most crucial?
3. How/why/why not did the DATs potentially have an impact on the culture, structures within the overall department?

Trajectory of the DAT

1. Tell me about the DAT.
2. How did the DAT get started, and how did you personally end up joining it?
3. Describe what the DAT has been doing for the last year. How did the DAT decide to do those things.
   a. How difficult was it to come to agreement on these activities?
4. What is the plan for the DAT moving forward? Is it still meeting? How is its work going to be sustained?
5. Do you think there were any important factors in your department "being ready" for the DAT and the changes it is proposing? Or could this be done in any department at any institution?

Personal Experience with the DAT
6. Describe your personal experiences with the DAT.
   a. Did you feel excited about joining the DAT, or were you thinking "Not another committee!"?
   b. What helped you decide to join the DAT?
   c. Is the DAT a valuable use of your time? An enjoyable use of your time?
   d. Are your experiences in the DAT matching your expectations, or are they different from your expectations? Explain.
7. What about the DAT surprised you?
8. Is there anything you think about or understand differently now, as a result of the DAT?
9. Would you like to continue to be a part of this DAT, or another DAT, in the future? Why or why not?

DATs as Change Agents
10. What impact, if any, has the DAT had on your department so far (e.g., structural changes, conversations)?
    a. What impact might it have in the future?
    b. Have any faculty beyond those participating in the DAT been impacted?
11. Does the department buy-in to and support the DAT and the changes it is trying to make, or not really?
    a. How do other faculty perceive the DAT?
    b. Is the department ready for the changes being proposed by the DAT?
    c. Do you anticipate resistance to the changes the DAT is trying to make?

12. What is your understanding of how departments change? Or do you feel like departments remain the same over time?
    a. What causes them to change?
    b. What process do they use to change? Is it planned? Orderly? Chaotic?
    c. Is change good or bad?
    d. Who determines what the department changes into?
13. What is the departmental culture around teaching? Is the DAT likely to be able to change this culture for the better?
    a. For example: how it is valued for T&P? Is teaching a common topic of conversation in formal and informal settings?
    b. Has this culture already changed over time? How did that happen?
14. What do you see as crucial to sustaining a change in the long term?
15. As a result of engaging with the DAT, in what way, if at all, are you thinking differently about how change happens? About your ability to make change in the department?

DAT Facilitation
16. How well did your DAT function? What went well and what went poorly?
    a. Do you have any feedback or suggestions that can help us enhance what went well or improve what went poorly?
17. Were there any features of the DAT that you found to be particularly beneficial or problematic?
    a. Examples: frequency of meetings, homework between meetings, pace of progress
18. Compare and contrast your DAT with other faculty groups or committees that you have been a part of (if helpful, think of a particularly good or a particularly bad committee you have been on).
    a. Was the DAT particularly better or worse than these committees? How do you account for this?
19. Describe your interactions with other DAT members. What worked well and not so well?
    a. Did you have a history of working with people in the DAT before the DAT?
    b. Did people's participation seem equitable, or were there power imbalances?
    c. Have your interactions with other DAT participants changed outside of the context of the DAT?
20. What have [the facilitator's] roles been in the DAT?
    a. How essential was their facilitation?
    b. Were there any particular things that they did that you found helpful?
    c. What else should they be doing?
    d. What do you think will happen to the DAT once funding for facilitators ends?
21. To what extent was it important (or not) that the facilitators were external to the department?

Wrapping Up
22. Is there anything else along these lines that I haven't asked but I should have?

Appendix B: Runes DAT Focus Group Protocol

Guiding Research Questions

1. Which specific aspects of DAT structure and facilitation were most crucial?
2. How did the DAT members perceive themselves as able to influence the department?
3. How/why/why not did the DATs potentially have an impact on the culture, structures within the overall department?

Framing: The DAT members are not just participants, but our partners. ***We want to share with others*** what works and not, and also to know if these goals make sense. What is important for us to do to facilitate DATs for other people? ***Please provide examples whenever possible.***

Introduction / General Information

1. Overall, what was your experience with the DAT?

Group Process / Facilitation

2. What structures and facilitation were most productive in the DAT process? If we were to share with another institution how do this, what should we be sure to articulate?

3. What might be avoided in the future?

Impact

4. To what extent do you think the DAT has or will lead to changes that will be sustained in your department? (note to self: push them for details about what the change was, how was it different, to be specific, concrete difference, was it culture, structure, etc.)

Change Agents-Agency

5. A goal of the project was for DAT participants to feel more knowledgeable and empowered to make change. Is this a worthy goal?

6. How well was this goal reached?

7. Closing Question: Is there anything else that you would like to share to help us better facilitate DATs in the future and to help others to facilitate DATs?

Table 1 A summary of the roles of the 5 Runes faculty members that we focus on in this paper, in terms of their faculty ranks and their participation in the SEI, DAT, and ACEs. The ACE column indicated which courses the faculty member is primarily responsible for coordinating. The SEI "impact score" is defined below.

		Role		
	Faculty Rank	**SEI**	**DAT**	**ACE**
Anne	Senior Instructor	Impact score: 7/9	Participated throughout	A and A-Lab
Bart	Associate professor	Departmental Director Impact score: 7/9	Participated throughout	
Elly	Senior Instructor	STF	Joined 2nd semester	C1-C6 and M
Karen	Senior Instructor Emeritus	Impact score: 0/9	Participated throughout	
Sophia	Senior Instructor	Impact score: 8/9	Participated throughout	B1, B2, and B-Lab

Table 2 A comparison of 6 SEI departments in terms of percent of faculty impacted by SEI in any way, percent of faculty who experienced a large impact, percent of courses impacted by SEI in any way, percent of courses that experienced a large impact. The largest value in each column is bolded.

Department	Faculty		Courses	
	% Any Impact	% Large Impact	% Any Impact	% Large Impact
Herbs	**91**	**59**	48	**28**
Runes	80	48	**58**	27
Charms	60	33	37	21
Gems	60	21	38	19
Elixirs	59	22	27	18
Potions	29	15	24	21

Table 3. Cultural changes and sustainability of efforts

	Cultural Changes	**Sustainability**
SEI	Structures: Use of new practices (e.g., learning goals, clickers)	Enduring: Perceived backsliding by faculty members
	Symbols: Ideas like backwards design, learning goals, active learning, STFs	Using Existing Resources: Required external funding.
	People: Former STF Elly hired into the department	Negatively impacting other efforts: N/A.
	Power: Elevated status of education in the department	Capacity Building: No mechanisms created to sustain the effort.
		Adaptable: No mechanisms for onboarding new faculty
DAT	Structures: Created ACE positions.	Enduring: ACE positions still exist after 3 changes in department chair
	Symbols: Focus on sustainability and being a change agent	Using Existing Resources: Used temporary external funding
	People: No changes made	Negatively impacting other efforts: N/A.
	Power: Possibly elevated status of education in the department	Capacity Building: ACE mechanism created to sustain the effort.
		Adaptable: DAT mechanism used again in department for other issues (see below)
ACE	Structures: UGTA training, coffee hour, possible journal club	Enduring: Mechanisms currently remain, but further study is required
	Symbols: No evidence of new symbols	Using Existing Resources: Uses internal department funding
	People: No changes made	Negatively impacting other efforts: N/A.
	Power: Elevated status of instructors in the department	Capacity Building: New structures created and momentum built
		Adaptable: New mechanisms are being created to support continuous improvement