

Impacts, supports, and constraints on sustained departmental change catalyzed by Departmental Action Teams

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We investigated sustained departmental change catalyzed by three Departmental Action Teams (DATs) that worked on change projects independently following an initial period of external facilitation. Using qualitative analysis of interview data, we documented four main categories of change catalyzed by DATs, three categories of supports for change, and four categories of constraints on change. DATs accomplished a wide variety of sustained changes, and DAT members frequently leveraged their individual learning to benefit the work in departmental groups outside of their DAT. Change was documented at the levels of the individual, the group, and the organization (i.e., department or university), suggesting that the DAT model is capable of supporting organizational learning at all of these levels. Additionally, DATs successfully used levers of project prioritization and positional power to generate sustained change. DATs did not rely heavily on support outside of their departments to accomplish sustained change. This study provides insight into the mechanisms by which departmentally based change teams accomplish change in departmental cultures, practices, and processes influencing science, technology, engineering, and mathematics education.

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I. INTRODUCTION AND BACKGROUND

As the nickname “ivory tower” is often used to imply, change in higher education can be difficult to achieve through external and internal initiatives alike [1–4]. Ideally, change in higher education would be sustained rather than ephemeral, and planned rather than reactive, but ephemeral, reactive change is more common. When planning for sustained change in higher education, it is important to attend to both observable and concrete desired changes (e.g., policies, job descriptions, rates of admission, student retention, course curricula, instructional practices, and use of physical spaces) and hidden, often unarticulated desired changes (e.g., values, norms, attitudes, and beliefs), using strategic methods for supporting these changes [5,6]. Well-planned initiatives resulting in observable change outcomes can help catalyze related hidden outcomes, and vice versa. Together, changes at these different levels can drive overall change in culture.

A. Landscape of change efforts in higher education

To date, there have been many large-scale initiatives to catalyze change in higher education. The American

Association of Colleges and Universities’ Project Kaleidoscope [7], the Student Experience Project [8], and the Association of American Universities Undergraduate STEM Education Initiative [9] are examples of nationwide projects that have been launched with the intention of improving undergraduate education at a broad institutional level. Other change efforts have focused on change at the department level, including projects such as the Effective Practices for Physics Programs Initiative (EP3) [10], the DeLTA Project [11], and the American Physical Society Inclusion, Diversity, and Equity Alliance [12]. These efforts have focused on affecting change related to goals such as improving educational climate, fostering a sense of belonging, or adopting evidence-based teaching practices across the curriculum. Finally, many other initiatives have focused on the teaching practices of individual instructors or on individual course transformation, such as the Science Education Initiative [13], the Physics and Astronomy Faculty Teaching Institute [14], and the Learning Assistant Alliance [15].

One important area of study for higher education change efforts is their impact and sustainability over time. While the projects highlighted above have been largely successful in driving positive change for their participating individuals, departments, and institutions, there are many other change initiatives that have not achieved or sustained their desired outcomes. There are often multiple institutional or cultural barriers that contribute to this. For example, structural barriers such as reward or promotion structures and slow decision-making policies may inhibit change

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from taking place [16,17]. Researchers have noted that institutional approaches to leadership and communication can also be a barrier to change, especially when units tend to be siloed [16,18]. Additionally, many change initiatives fail to actively plan for sustainability, which can lead to backsliding and erosion of success over time [19]. In general, the long-term, sustained impacts of change projects—what these impacts are and what brings them about—have received less attention in the organizational change literature. Instead, most studies document impacts that arise during or shortly after the time frame of a project.

B. Defining organizational culture

Team-based, facilitated departmental change initiatives hold promise for enabling planned, sustained, and synergistic change. Change efforts at this scale have an advantage over change efforts at higher levels because they are better able to situate their efforts within the existing departmental culture. Departments (and other types of units) within colleges and universities tend to have coherent cultures and established practices of furthering their missions using small teams (e.g., committees) [20]. Research on change efforts in higher education has found that the efforts experience resistance if they do not attend to the existing organizational context and culture [1,2,21].

In our work on departmental change, we use the definition of organizational culture as put forth by Schein:

Organizational culture is the pattern of basic assumptions that a given group has invented, discovered, or developed in learning to cope with its problems of external adaptation and internal integration, and that have worked well enough to be considered valid, and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems [22] (p. 3).

Key to this definition is that *culture is a feature of groups*, and therefore, we may reasonably expect that different groups will exhibit different cultures. In the context of higher education, we can distinguish among the cultures of disciplines, universities, departments, and groups within departments (e.g., committees and research groups). While the cultures of these different groups will influence each other, they are also distinct—the culture of a particular physics department may be an amalgam of cultural features of physics as a discipline, of the department’s institution type (e.g., small liberal arts college vs research-focused university), and of other idiosyncratic factors. In this study, we focus on the cultures of particular departmental change teams and the departments in which they are embedded.

Additionally, Schein defines three “levels” of organizational culture [22] that we apply in our conceptualization of cultural analysis:

1. *Visible artifacts*: the physical organization of space; manner of dress, language, and other behaviors; use of technologies; public documents like charters or internal policy documents; methods for onboarding new members; and so on. This level is relatively easy to observe, but not to interpret, because it focuses on *what* the organization does but not on *why* it does so.
2. *Espoused values*: the reasons that organization members would give for why the visible artifacts are the way they are when asked. While these values provide some explanatory power, they may be incomplete or even contradict some organizational behaviors (as in an organization that “talks the talk” but does not “walk the walk” in some aspect of its functioning). However, since these values can be articulated by organizational insiders, they can be explicitly analyzed, debated, and modified within the organization.
3. *Basic assumptions*: the deeper, typically invisible reasons that *actually* guide how the organization behaves, which may or may not be aligned with the espoused values. These assumptions are so taken-for-granted and nondebateable that organizational insiders would typically dismiss any questioning of them by outsiders.

In sum, signals of organizational culture can be found in nearly everything that emerges from an organization and its members, and Schein’s three levels help to organize the types of evidence that a researcher can glean from observation, document analysis, or analysis of statements from organizational insiders. In this study, we identify and analyze examples of both artifacts and espoused values from the cultures of three science, technology, engineering, and mathematics (STEM) departments. Identifying cultural features at the basic assumptions level would have required more extensive anthropological inquiry that was beyond the scope of this study.

C. Departmental Action Team (DAT) model and research

The Departmental Action Team (DAT) model [23,24] was developed to guide team-based departmental change initiatives [25]. This model has two overarching goals: (i) to create sustainable change around a broad-scale issue related to undergraduate education in the department by shifting departmental structures and culture and (ii) to help DAT participants become change agents through developing facilitation and leadership skills. To date, the DAT Project has supported 17 DATs across 2 institutions. The DAT project team provided external facilitation to departmental teams composed of students, staff, and faculty. They worked with most teams over an average period of two years. The DATs engaged in activities like visioning, collecting and analyzing data, discussing and implementing group processes, and developing products related to their

TABLE I. Summary of 4I OLF processes, including each process's related organizational level, definition, and an illustrative example.

Process	Organizational level	Definition	Example
Intuiting	Individual	An individual's subconscious processes of perceiving and absorbing information	Reading about inclusive teaching concepts
Interpreting	Individual and group	An individual's conscious processes as they interact with new information and engage in initial sensemaking within groups	Thinking about how inclusive teaching concepts might impact one's teaching and discussing questions about it with a colleague
Integrating	Group	Social learning in pairs or groups, as they work to make collective sense of the implications of their learning for the context in which they work	Discussing ways to implement inclusive teaching into a co-taught class with one's colleague
Institutionalizing	Department	Processes whereby groups of individuals codify learning into the policies and culture of an organization, often through group decision making	Working with a department to implement inclusive teaching practices in all classes

overall goals around improving undergraduate education. DATs typically met for 1 to 2 hours every other week during the academic year. Some DATs took on internal facilitation roles once the support from the DAT project team had ended.

Many features of the DAT model have been investigated and disseminated. Products that externalize the model include a guidebook to DAT facilitation [23], research on key components of the DAT model including its theory of change and core principles [19,26–28], examples of initial changes catalyzed by DATs [29], and departmental change research instruments [30,31].

While the DAT model and the short-term impacts of DATs have been externalized, the long-term impacts of DATs have not been systematically analyzed. During the time DATs worked with external facilitators, many DATs made changes or produced resources that had the potential to positively impact the undergraduate student experience in their departments beyond the duration of their meetings. Furthermore, most DATs continued to meet and carry out their change projects even after support from the DAT project's external facilitators ended [32]. As the first DATs were formed nearly a decade ago, we now have an opportunity to address this gap in the literature by examining examples where DAT departments sustained change over a number of years.

D. Organizational Learning Framework

Since the development of the DAT model, we have continued to seek out change theories to understand the implementation of DAT model practices and resulting outcomes. More recently, we have started to explore how organizations learn and how knowledge is passed

within an institution. The 4I Organizational Learning Framework (4I OLF) proposed by Crossan and colleagues [33] is widely recognized and has been used to understand change in many different contexts [34]. The 4I OLF articulates four learning processes (the 4I's: intuiting, interpreting, integrating, and institutionalizing) that facilitate learning between an organization's three levels (individual, group, and organization). The processes of the 4I OLF, with illustrative examples, are described in Table I.

Crossan and colleagues postulate that organizational learning is dynamic and that learning processes are typically happening simultaneously across levels, with learning moving both from the individual level to the organizational level and vice versa [33]. Subsequent updates to the original framework have focused largely on the role individuals play in facilitating organizational learning. For example, researchers have focused on cognitive barriers that might influence the flow of learning [35] and the types of leadership characteristics that enable or prevent learning from occurring [36].

The 4I OLF has been applied to understand organizational learning in several contexts, including government [37], public health [38], and leadership development [39]. However, the 4I OLF has been used to investigate change efforts in higher education in only a few cases [40–43]. For example, the 4I OLF was used to better understand the boundary-spanning behaviors of change agents working to translate learning from a national network supportive of the scholarship of teaching and learning to groups within their own universities [42]. Nevertheless, we found the delineation of the four learning processes and three organizational levels useful for exploring how and why the DATs' change efforts made lasting impacts.

In this study, we use the 4I OLF as a supplementary, *post hoc* analytical lens, and we hope that the insights we gained from its application can be used by others to inspire future studies and change efforts.

E. Research questions

In this paper, we investigate the long-term impacts of the changes catalyzed by three DATs from four to six years after external facilitation ended. We also address the organizational levels at which change occurred and the processes and change levers that aided the change initiatives in making sustained impacts. Our primary data source is interviews with DAT members who were part of their teams during the initial period of their DAT's external facilitation. Our study was guided by the following research questions:

- Which planned, sustained DAT impacts occurred at the levels of the individual, group, and department?
- What factors supported DATs in making sustained impacts?
- What factors constrained DATs in making sustained impacts?

II. METHODS

We set out to study the mechanisms by which Departmental Action Teams (DATs) achieve planned and sustained change in their departments. We also wanted to explore whether DATs catalyze change beyond their original goals. To this end, we chose 3 DATs to focus on, out of 17 DATs that were convened and guided by external facilitators from our project between 2014 and 2020 at two R1 universities in the western United States. These DATs were assigned the pseudonyms of Crystals, Pyromancy, and Apparition. Information about how DATs are formed and facilitated can be found at the DAT Project website [24] and in our facilitation guidebook [23].

A. Department selection, recruitment, and data collection

The selection criteria for DATs included this study were that (a) each DAT had accomplished change(s) aligned with their original goals during their initial period of external facilitation, (b) each DAT (or their department) had sustained those changes, and (c) each DAT, or their department, had engaged in new change initiatives that were related to the original work of the DAT for at least a year following external facilitation. We identified 8 of our project's original 17 DATs (47%) that met these criteria; due to resource limitations, we were not able to examine all DATs exhibiting these types of sustained changes for this study. Instead, we chose three that represented both institutions in our study, as well as a diversity of STEM disciplines, change project foci, and engagement with the DAT team after the end of external facilitation. Of these

three, two were from physical science departments and one was from a biological science department. Furthermore, one was from one of the R1 universities where we had run the project, and the other two were from the other university.

Using email, we invited all past DAT members to take part in the study, regardless of how long they had served on their DAT or whether they had shifted departments or universities since serving. We invited a total of 37 DAT members across the 3 DATs. We interviewed all DAT members who consented to participate; 6 members each responded from Crystals and Pyromancy and 5 members responded from Apparition, for a total of 17 interviews. The interviewee pool from each DAT included at least one tenure-track faculty member, one departmental staff member or advisor, and one graduate student. In addition, one undergraduate student from Apparition was interviewed. In this article, we maintain confidentiality of interviewees by only referencing the general role they played in their department (faculty, staff, graduate student, or undergraduate student). Note that these are the roles that these individuals held at the time of their participation in the relevant DATs, but not necessarily at the time of the interviews. In particular, the individuals we label as students had graduated by the time of their interviews.

All three authors conducted interviews using a semi-structured protocol consisting of 14 questions (see Supplemental Material [44]), assigning interviewees such that interviewers did not have prior direct experience with any DAT member they interviewed. During the interview, participants were asked to describe their department briefly and any change initiatives that occurred in the department historically, then describe their DAT and any changes they perceived their DAT to have made within their department. At the conclusion of the interview, we asked DAT members to review the six DAT core principles [27] and asked them to reflect on the extent to which their department aligned with these principles and whether any alignment could be attributed to the work of their DAT. Interviews were conducted and recorded using Zoom and audio files were converted to text by a human transcriber.

B. Inductive coding and analysis

Interview transcripts were first collaboratively analyzed using constant comparison methods [45] and inductive analysis [46], with at least two authors assessing each transcript at each analytic step. The first step of analysis involved all three authors marking and briefly paraphrasing meaningful and coherent excerpts within each transcript. Each excerpt consisted of a single coherent idea, which may have been expressed in a phrase, a sentence, or across multiple sentences. To encourage independent discovery of potential qualitative codes among the identified excerpts, two authors (C. N. and S. W.) each developed a set of codes to describe the excerpts found in three transcripts from a

single DAT. A total of six transcripts were examined at this initial stage of coding. These two authors then compared the two sets of proposed codes and merged and revised them as necessary to create a single codebook containing a total of 76 fine-grained codes. This codebook was applied to all 17 transcripts, with these two authors engaging in regular iterative discussion, revision, and recoding as needed. Each transcript's coding was checked by both authors.

Following this stage, two authors (C.N. and S.W.) proposed, discussed, revised, and agreed upon a consolidated set of 14 higher level code categories, which comprise the numbered categories reported in this paper. Each of these higher level code categories comprises between 3 and 13 fine-grained coding categories. Each transcript was then coded with respect to the higher level code categories, within qualitative analysis software. All three authors then proposed, discussed, revised, and agreed upon a set of 3 clusters to describe the set of 14 code categories. Broadly speaking, the clusters relate to DAT impacts (cluster 1), features that supported the DATs (cluster 2), and features that constrained the DATs (cluster 3). These clusters were also assigned to the data within Dedoose. Dedoose was used to calculate code frequencies by transcript and by DAT, and produce excerpt files tagged by participant, DAT, and code category.

C. Analysis of the “post” code

As we engaged in this coding process, we noticed that interviewees sometimes explicitly referenced DAT impacts that occurred after a DAT transitioned to internal facilitation. During these periods, DAT external facilitators were only available to DATs for consultation; Pyromancy and Crystals engaged occasionally in such consultation, but Apparition did not. Excerpts related to such impacts ($n = 129$) were given an additional code of “post.”

The three clusters were identified after the “post” codes were assigned. We found that the vast majority of the “post” codes are associated with cluster 1. We believe this to be the case because DAT impacts can typically be associated with particular times in the history of the DATs. However, there were only a few excerpts that were coded “post” that fell into clusters 2 and 3, since supports and constraints were features of department members, DAT members, administrators, or the university as a whole that were not typically associated with a particular time. Therefore, in the Results and Discussion sections, we discuss the “post” codes only with respect to cluster 1, and not clusters 2 and 3.

D. Application of the 4I OLF

Following these analytical steps, we reexamined our data through the lens of the 4I OLF. In applying the 4I OLF, we first examined excerpts from each category within cluster 1 for evidence of each process of organizational learning. After finding initial evidence, we considered cases in which

the processes of the 4I OLF seemed to apply, and not to apply, to excerpts from each category in clusters 2 and 3.

E. Member checking

After drafting this manuscript, we performed a general check for validity by requesting feedback from all former members of the Apparition, Pyromancy, and Crystals DATs. Every DAT member for whom contact information could be obtained was emailed a copy of the manuscript and Supplemental Material [44]. DAT members were asked to provide feedback on the overall conclusions of the paper and to flag any descriptions or quotes about their DAT that they felt were mischaracterized or too sensitive to include. Three Crystals, one Apparition, and one Pyromancy member provided feedback; none requested that material be excluded from the manuscript or Supplemental Material [44].

III. RESULTS

A. Overview of focal DATs and coding clusters

In this section, we introduce our three focal DATs, with brief descriptions of departmental context, the work the DAT accomplished while supported by their external facilitator(s), and work that occurred after the external facilitator(s) exited the DAT. Table II provides a comparative summary across the three focal DATs in this study, with brief descriptions of the facilitation, departmental roles, department chair involvement, goals, and major changes achieved by each DAT.

1. Apparition

The Apparition department offers 4 different undergraduate STEM majors and employs about 30 faculty members and 7 staff members. Before the DAT formed, a major faculty turnover occurred, which led to a shift in departmental culture characterized by greater collegiality and collaboration.

The Apparition DAT worked together for two years with two external DAT facilitators and then continued their work for at least one year with two internal facilitators. The work of this group eventually transitioned from regular facilitated meetings to “as needed” effort on the project. The focus of the DAT was determined in advance by an upcoming external accreditation review of one of the department's majors, which required an assessment plan around program-level learning outcomes (LOs).

The Apparition DAT's total membership over the externally facilitated time period included three faculty members (one of whom was the department chair), three staff members, one graduate student, and two undergraduate students, with some turnover of faculty members and undergraduate students. Meetings were typically attended by six to eight members. The DAT initially began work to create an assessment plan for the current set of LOs, but

TABLE II. Major characteristics of focal DATs. UG, undergraduate; G, graduate; NTT, non-tenure-track; and TT, tenure-track.

	Apparition	Crystals	Pyromancy
Facilitation	Externally facilitated from 2017 to 2019, internally facilitated thereafter	Externally facilitated from 2014 to 2016; internally facilitated thereafter as a permanent departmental committee	Externally facilitated from 2018 to 2020; formed and internally facilitated a new group thereafter
Member roles	UG and G students, advisors, TT faculty	UG and G students, advisors, postdocs, departmental staff, NTT and TT faculty	UG and G students, science outreach staff, NTT and TT faculty members
Goals	Support upcoming accreditation	Support equity-related awareness and projects	Strengthen departmental communication
Sustained changes	Revised program-level learning outcomes; created assessment plan; similar groups repeated the process for other majors	Annual departmental welcome event; weekly seminar series; changed introductory course for majors	Established a new equity-focused DAT; DAT norms of collaboration were adopted by other departmental groups

quickly determined that this set was not coherent enough and required revision. During the time supported by the DAT facilitator, the group worked primarily to revise the LOs. The chair provided regular updates to departmental faculty about the progress of the DAT, and the DAT formally presented their LOs to departmental faculty when nearly complete. One of the DAT facilitators worked with two staff members over one semester to coach them as they began to internally facilitate the group. After that time, the two internal facilitators supported the group in developing an assessment plan, which was approved by the faculty body. The internal facilitators also led the department in preparing for the accreditation review.

In parallel, groups affiliated with additional majors in the department formed and began to replicate this process to revise the LOs for their majors. These groups included former DAT members, and these members helped the groups learn the DAT process of approaching their change projects.

2. Crystals

The Crystals department is large, with over 100 faculty and instructors and about 30 staff. This department offers two undergraduate majors and serves many students outside its STEM major with its introductory courses. The Crystals DAT worked together for two years with two DAT facilitators, then continued their work for at least eight years as a departmental committee. Their membership over the facilitated time period included two undergraduate students, three graduate students, one postdoc, two departmental staff members, and five tenure-track faculty members. The group occasionally gave presentations at faculty

meetings. The DAT focused on making equity-related change through a wide variety of projects.

In their first year, the group examined institutional data related to patterns of major enrollment and persistence. They compiled a report with recommendations from this work, which showed a trend that women were leaving the major. After this project, the department faculty voted to make the DAT a permanent departmental committee that would include undergraduate students, graduate students, departmental staff, and faculty in its membership. The group went on to enact various recommendations in the report, including creating gender-neutral bathrooms, supporting recruitment by calling admitted students from minoritized groups, creating a welcome event for incoming students, revamping the department's recruitment materials, and establishing an equity-focused monthly seminar series. Departmental staff member time and funds were allocated by the chair in support of these activities.

Others in the department also took the lead on enacting some of the DAT's recommendations, including shifting an "honors" introductory course to a major's required course, with the aim of increasing cohesion and belonging among majors. Eventually, other departmental groups or department staff members took over responsibility for running the welcome event and the equity-focused monthly seminar, while the DAT engaged in new projects. After working together for about six years, the DAT's work was honored with an institutional service award. During most of the group's existence, the chair was informed of and supported the group's work but did not guide it. In recent years, a new chair engaged in directing the membership and work of the group to a greater degree; several DAT members reported

that the new chair's involvement both complicated and obstructed the work of the group.

3. *Pyromancy*

The Pyromancy department employs about 30 faculty and instructors and about 5 staff. The Pyromancy DAT worked with two DAT facilitators over a two-year period. The membership over the facilitated time period included five undergraduate students, five graduate students, two departmental staff members (from an affiliated public outreach unit), two tenure-track faculty members, and two non-tenure-track faculty members. The department chair occasionally sat in on DAT meetings as an observer, occasionally met with DAT facilitators to learn more about how the model and facilitation work, and frequently discussed DAT work with DAT members in informal settings. The group identified their main priorities as improving communication and building community in the department, partly in response to tension that had arisen between graduate students and faculty members in the department, and also to improve the experience of undergraduate majors. Their first project was hosting an interactive departmental forum in which information was presented about opportunities for undergraduate and graduate students to be involved in the department, outside of their classes and research. Small groups were then formed to discuss the opportunities available and desired in the department, and participants completed exit tickets providing feedback. In parallel to the DAT's work, the department chair introduced DAT collaborative norms to the department's faculty meetings, and a DAT graduate student member produced a guide to support departmental committees in incorporating these norms.

The Pyromancy DAT used the departmental forum feedback to guide its later work. In addition to hosting a second departmental forum, the group established project-based subgroups in their second year; these projects focused on clarifying and streamlining web information provided to undergraduates about how the department works. In the last three months of this time, the work of these groups shifted online due to the COVID-19 pandemic. After the DAT facilitators exited, DAT members continued to lead their project subgroups, but some of the projects did not get completed. Eventually, the department formed a new group focused on equity-related projects that replicated most of the elements of the DAT model; the chair and some original DAT members participated in this new group.

4. *Coding clusters and categories capturing DAT impacts, supports, and constraints*

Development of the coding system (see Sec. II) revealed three major clusters, each containing several categories (Table III). Cluster 1 describes changes and impacts generated and influenced by DATs; these were highly

varied. Cluster 2 describes ways in which a variety of supports operating at the individual, group, department, and university levels together made possible the impacts described in cluster 1. Cluster 3 describes internal and external factors that constrained cluster 1 impacts. Two categories appeared in all transcripts in the dataset (1.1 and 2.1); other categories were observed in a majority of transcripts (1.2–1.4, 2.3, 3.1–3.3). Two categories were observed in less than half of the transcripts (2.2, 3.4), and both of these relate to entities external to the DATs. The highest variation between DATs was observed for categories related to constraints that affected DAT work (cluster 3). The remaining subsections of the Results explore the evidence for each of these coding clusters and categories.

B. *The work of DATs had impacts on multiple levels of their departments (cluster 1)*

We found that the work of DATs impacted their departments at multiple levels: individual, group, and department. Specifically, we found evidence of positive impact on individual attitudes and skills, DAT team culture, departmental structures, and change projects undertaken by additional groups in the department. We include representative quotes for each of the four cluster 1 categories in this manuscript and in Supplemental Material [44].

1. *DAT member skills and attitudes were changed through DAT participation and modeling (category 1.1)*

Every interviewee described one or more ways in which DAT participation led them to change their individual attitudes or acquire skills. Evidence of such changes is explored in this section, while evidence related to the application of these changes is explored in Sec. III B 2.

One key area of skill growth was related to running effective team meetings. DAT members from Pyromancy highlighted that attending DAT meetings led them to realize the importance of high-quality meeting documentation through “the power of a well-crafted document with lots of questions and to-do items on it” (*Pyromancy faculty member*). More abstractly, attending meetings “gave me different ways to think about...conflict resolution and how to break down a problem that I hadn't learned about before” (*Pyromancy graduate student*).

Another DAT member related an attitudinal shift, specifically one related to effectively advocating for change:

I learned how to present something in a way that shows other people that it needs to change rather than ... “I don't like this, I wish it was different” ... Just having that mentality really reconstructs the way that you would offer the information to someone. (*Pyromancy graduate student*)

Multiple Pyromancy DAT members recognized that they had developed skills and attitudes related to gathering

TABLE III. Frequency with which coding clusters and categories appeared across transcripts. E is the total number of excerpts coded with a particular category across all 17 transcripts, T is the total number of transcripts coded with a particular category, A is the total number of Apparition transcripts coded with a particular category, C is the total number of Crystals transcripts coded with a particular category, and P is the total number of Pyromancy transcripts coded with a particular category (thus, $T = A + C + P$). Note that we conducted interviews with six members of each of the Crystals and Pyromancy DATs, while we conducted interviews with five members of the Apparitions DAT.

Cluster	Category	E	T	A	C	P
1. The work of DATs had impacts on multiple levels of their departments	1.1 DAT member skills and attitudes were changed through DAT participation and modeling	53	17	5	6	6
	1.2 The DAT spurred perception, attitude, and behavior changes in departmental members	71	15	5	5	5
	1.3 DAT work influenced structural departmental changes that were sustained	74	15	5	5	5
	1.4 DAT work catalyzed or informed other change work	55	16	4	6	6
2. Supports at the individual, group, and organization levels helped DATs make impacts	2.1 Ways the DAT worked supported DAT impacts	150	17	5	6	6
	2.2 DAT work was valued by some stakeholders	49	14	4	5	5
	2.3 Some departmental and university features supported DAT work	13	7	3	2	2
3. DATs faced varied internal and external constraints in conducting their work	3.1 DAT members were sometimes frustrated with aspects of the DAT model	21	10	2	3	5
	3.2 Limited time constrained DAT members in engaging with the DAT's work	20	9	3	1	5
	3.3 A lack of support limited some DATs' impacts	68	13	2	5	6
	3.4 Factors external to the department constrained some DATs' impacts	14	7	3	2	2

community input. One member related that “getting input from our community is really necessary” (*Pyromancy faculty member*), and another shared that “the DAT principles...helped me stay grounded...being firm that we can't just take action without convening groups and doing deep listening” (*Pyromancy faculty member*).

In the transcripts of other DATs, we found excerpts that described the development of leadership skills. Example excerpts related to these skills are found in Supplemental Material [44].

Across these category 1.1 excerpts, we find evidence that DATs supported their members in engaging in the first two processes of organizational learning: intuiting and interpreting. Both of these processes relate to learning at the individual level. Quotes above relating to DAT members' ways of thinking about conflict resolution and feeling “grounded” and “firm” can be seen as evidence of the process of intuiting, which can include subconscious activity. Evidence for the conscious process of interpreting is seen in quotes relating to valuing meeting documentation, understanding new ways to break down problems and present the need for change to colleagues, and the value of gaining input from departmental members. In these quotes,

individuals indicate they have made sense of specific DAT experiences and have interpreted those experiences as potentially valuable in other contexts.

2. The DAT spurred perception, attitude, and behavior changes in departmental members (category 1.2)

In defining this category, we considered changes that were described by DAT members as influencing attitudes, practices, or other behaviors among members of their department who were not a part of the DAT. Interview transcripts frequently featured the description of an initial change at the individual level (category 1.1) and continued on to describe how the DAT member later applied that skill in a new departmental context, and how department member attitudes or behaviors were altered as a result (category 1.2). In addition to the quotes selected here from Crystals interviewees, additional evidence for this category can be found in Supplemental Material [44].

Nearly every interviewee ($n = 15$) described applying at least one DAT-related skill in a new context, including committee meetings at departmental and college levels, meetings of research groups, meetings of groups outside

the department (e.g., when a staff member took a job in a new department), and meetings of groups outside the university (e.g., when a student took a job in industry).

A number of category 1.2 excerpts concerned applying meeting processes that had been modeled by DAT facilitators to groups outside the DAT. For example, one Crystals DAT member, who was a departmental staff member, became a vocal advocate for and user of DAT meeting processes, including after she shifted to working in a different department on campus:

[O]ne of the biggest things that I have taken away and continue to use to this day. I run [a] committee, it's myself and...a faculty member, and [we apply] a lot of the [DAT] principles of organization. We read norms at the beginning of the semester for the meetings, we keep running meeting notes. It's just so normalized to me now. I'm like "of course, how would you do it any other way?" (*Crystals staff member*)

This staff member explicitly referred back to the experience and knowledge developed by the Crystals DAT in discussions with colleagues:

I cannot tell you the number of people that I reference back to [the Crystals DAT] ... I'm like "hey, yo, learn from these people ... This committee has... a lot of experience not just with sustaining a group like this but with the process, the hardships, the things to look out for." (*Crystals staff member*)

In this category, we also noticed descriptions of changes that stemmed from the DAT sharing information about its work with department members. For example, the Crystals DAT expended considerable effort in its first year compiling and analyzing enrollment and retention data to understand how students from different demographic groups were progressing through Crystals courses. A Crystals DAT faculty member explained how the production of a report compiling this analysis enrollment and retention data across student demographic groups raised awareness among department members about the fact that women were not being retained at the same rates as men:

I thought that was a positive set of data in the sense that it was pretty unambiguous that we were losing women. I think it was hard to say whether we were losing other underrepresented groups because there were so few of them at the beginning. (*Crystals faculty member*)

I think that the DAT presentation in front of the faculty ... where we were able to present some data about how different populations were

experiencing our courses, at least in the sense of did they bother to continue taking them, informed a bunch of folk that what they sort of had imagined might be true, was. (*Crystals faculty member*)

Finally, DAT members described several examples of ideas and behaviors that were advocated for by the DAT and subsequently became more prevalent across the DAT's department. For instance, one Crystals DAT faculty member related that they sometimes felt that their efforts on the DAT were not making much difference around the valuation of diverse student representation and retention. However, they recalled that other department members perceived change in their department over time and encouraged them to continue their work:

[W]ith friends ... they're like ... "you're making more changes than you think because there are people who are hearing you, it's just that they're not the loud voices, they're all being quiet, and slowly over time things are changing." (*Crystals faculty member*)

Across these category 1.2 excerpts, we find evidence for how DATs supported organizational learning at a new level: integration. Integration is an organizational learning process that occurs only at the group level and involves individuals engaging in explanatory or modeling activities that influence the collective understanding or behavior of multiple people. One quote from the Crystals staff member indicates that she had a major influence in helping a new group adopt DAT-related meeting processes and that she was explicitly directing members of other groups to "hey, yo, learn from" the Crystals DAT's experiences. Similarly, quotes from the Crystals faculty member indicate that the presentation of a report to Crystals faculty made that group collectively more aware of a retention disparity between men and women undergraduates.

The final quote presented, in which a Crystals faculty member recalls being reassured that department members are "slowly changing," provides evidence that department members outside the DAT noticed a quiet shift among multiple colleagues, in which they increased the alignment of some of their values with the Crystals DAT's focus on equity. Depending on how widespread this shift was, this quote could be evidence of organizational learning involving either the process of interpreting (DAT members influencing the thinking and awareness of other department members around equity) or the process of integrating (the department undergoing a collective shift around its understanding of equity).

3. DAT work influenced structural departmental changes that were sustained (category 1.3)

As described in Sec. III B 2, the work of the Crystals DAT led to a number of sustained structural changes in their

department. With the term “structural,” we are referring to changes to policies or other organizational features of the department. For Crystals, this encompasses the work they did to create a permanent departmental committee from the original DAT, create gender-neutral bathrooms (primarily by gaining departmental permission to add signage to existing single-occupancy bathrooms), revamp the department’s recruitment materials, and establish two student-friendly events (a fall welcome and a monthly equity seminar) that have persisted in the department.

Several DAT members expressed the opinion that the establishment of a permanent departmental committee that included student membership was perhaps the most important and influential structural change that Crystals achieved:

[T]he creation of [committee name] was huge. That’s [been] a standing committee for quite some time, that I think has also been a campus leader in a lot of ways. (*Crystals staff member*)

Another graduate student DAT member described how the annual student Welcome Event, initiated by the DAT, became sustained:

I do think that the fall welcome definitely caught on quite a bit, and I feel like in the few years that I was there when we did it, it did get bigger and I think it became more of an expected event. (*Crystals graduate student*)

The department’s enactment of the Crystals DAT recommendations to change the designation of an “honors” introductory course to one required of incoming majors is a further example of a sustained structural change influenced by the DAT. One faculty member described the DAT-proposed changes to majors’ engagement in the introductory course, and the impact that course has had on students’ sense of belonging:

[T]he DAT proposed that we pull [our] majors out of the intro ... classes so that they had a better sense of community, because [a] sense of community is so important for belonging, and belonging is important for long-term persistence in [our field] ... Now we do have a separate class for [our] majors, and I think [the sense of] belonging [among our majors] has gone up. (*Crystals faculty member*)

These quotes provide evidence that Crystals DAT members initiated structural changes that have been sustained in the department through ongoing effort that includes departmental members who were not a part of the DAT. Across our dataset, DAT members described many other types of structural changes that their DATs accomplished. Additional quotes describing some of the changes that

Pyromancy and Apparition DATs accomplished can be found in Supplemental Material [44].

The structural changes cataloged across category 1.3 excerpts provide evidence that these DATs were able to engage their departments in the final process of organizational learning: institutionalizing. Institutionalizing is recognized as the only 4I OLF process to involve a whole organization. In the context of this study, departments that hosted DATs are organizations. Changes to organizational structures (e.g., the Crystals’ permanent committee), to physical structures (e.g., gender-neutral bathrooms), and to recurring departmental events (e.g., a fall welcome and a monthly equity seminar) are evidence of institutionalizing. Within the 4I OLF, such structural changes are considered changes to the culture of an organization because they have the potential to be perpetuated even as individuals and small groups within the organization come and go.

4. DAT work catalyzed or informed other change work (category 1.4)

We previously documented that 65% of the 17 DATs initiated through this project continued to engage in change work after the point when DAT facilitators exited the groups [32]. In many cases, DATs continued to meet and work on their existing change projects. In other cases, the work of groups outside the DAT was influenced by DATs. Finally, in some cases, new DAT-like groups began new change projects. The excerpts in category 1.4 document these types of ongoing DAT influence.

For example, a number of Apparition DAT members described how a presentation to the faculty of program learning goals developed by the DAT generated conversations that eventually led to the establishment of new “mini-DATs.” DAT members were included in or led these new groups, which resulted in the groups replicating many aspects of the Apparition DAT’s processes. These included processes related to working as a team, creating learning goals, and creating an assessment plan. DAT members explained that the first impact of the DAT’s presentation was that it spurred faculty conversations about other parts of their undergraduate and graduate curricula:

[W]hen we were wrapping up some of our assessment plan and presenting the [learning outcomes] from the first [major] it certainly started stimulating side conversations of people who weren’t involved in the DAT ... reflecting on the components of the curriculum ... faculty [from other majors] wound up getting together and building their own subgroup to really optimize ... the curriculum and streamline some redundancies within it. (*Apparition faculty member*)

[We pulled] some of our learning outcomes from our undergraduate program to graduate because it

was a pretty easy crossover. So yeah, definitely spillover with some of the groundwork already done for that particular project. (*Apparition staff member*)

Additional Apparition excerpts provide insight into how the original DAT continued to meet alongside the new mini-DATs and what the mini-DATs discussed:

I would call these other curricular teams mini-DATs. The original [DAT] group does meet around the [first major’s] piece, and identifies, “okay, what do we need to be doing this semester, what are the changes?” (*Apparition faculty member*)

[I]n my time here we’ve had more focused curricular conversations ... since we did the DAT ... We’ve had conversations exploring four plus one curriculums for masters and two plus twos with community college curriculums, so being more creative and flexible in how we approach getting students through our program. (*Apparition faculty member*)

The department chair also noticed that as these new groups formed, leadership capacity increased in the department as DAT members became internal facilitators of the mini-DATs and applied the facilitation skills they saw modeled by their external DAT facilitators:

Now I can kind of lean on the faculty to lead those things ... because they see a good model for how to lead a team through that type of an exercise ... I think the DAT helped bring some of those facilitation skills around curriculum to the department. (*Apparition faculty member*)

The set of Apparition excerpts coded into category 1.4 reveals that the Apparition department’s new “mini-DATs” benefited from their internal facilitators’ application of DAT structures and facilitation skills. The work of these groups catalyzed new change projects by extending the DAT’s original change work around defining and assessing program-level learning outcomes to serve at least two other

majors in the department. As the new “mini-DATs” represented new structures within the Apparition department, they can be seen as further evidence of the 4I OLF process of institutionalizing. Many other instances of institutionalizing, in the form of new change efforts that were catalyzed and informed by the work of DATs, were documented across the transcripts and can be found in Supplemental Material [44].

5. DAT impacts were sustained after external facilitation

Table IV summarizes the frequency with which cluster 1 excerpts were coded with the “post” code, as defined in Sec. II C. Out of all 253 excerpts with a cluster 1 code, 51% were co-coded with the “post” code. Overall, this pattern indicates that while DATs all began their work with the guidance of external facilitators, many impacts of this work emerged only during a sustained period of change that lasted beyond the period of external facilitation.

We notice that while 75% of reported impacts to individual DAT members (category 1.1) occurred during periods in which DAT external facilitators were active, more than 50% of all other cluster 1 codes occurred after the end of external facilitation. Looking at these data through the lens of the 4I OLF helps to clarify this pattern. The learning processes that occur at the individual level of the 4I OLF are intuiting (at a subconscious level) and interpreting (at a conscious level). It makes sense that with a new program like a DAT, early individual learning would be necessary to support later group-level learning processes. As many individual skill and attitude changes were attributed to the experiences that occurred during externally facilitated DAT meetings, it makes sense that a large proportion of category 1.1 impacts happened during the DATs’ initial externally facilitated periods.

On the other hand, the 4I OLF process of integration involves the application of individual knowledge and skill in ways that influence the perception, attitudes, and behavior of other individuals in a group, for which we noted evidence within category 1.2 excerpts. Finally, the process of institutionalization in the 4I OLF can be applied to understand both the codification of group decisions into departmental structural changes (category 1.3) and the ways in which DAT work influenced subsequent change initiatives by groups of departmental members (category

TABLE IV. Numbers and percentages of cluster 1 codes that were co-coded as occurring after the end of external facilitation. E is the total number of excerpts for each category (this mirrors the E column of Table III), P is the number of the total excerpts co-coded with “post,” and %P is the percent of the total excerpts co-coded with “post.”

Cluster 1 category	E	P	%P (%)
1.1 DAT member skills and attitudes were changed through DAT participation and modeling	53	13	25
1.2 The DAT spurred perception, attitude, and behavior changes in departmental members	71	40	56
1.3 DAT work influenced structural departmental changes that were sustained	74	38	51
1.4 DAT work catalyzed or informed other change work	55	38	69

1.4). As organizational change involving institutionalization is known to be particularly slow, it makes sense that a large fraction of excerpts coded in category 1.4 occurred only after the end of the DATs' external facilitation.

C. Supports at the individual, group, and organization levels helped DATs make impacts (cluster 2)

Several factors supported DATs in achieving the impacts described in the cluster 1 categories. These factors included the ways in which the DATs themselves functioned, the value placed on the work of the DATs by external stakeholders, and other supportive features of the departments and institution. We include representative quotes for each of the three cluster 2 categories in this manuscript and in Supplemental Material [44]. We also note that, in contrast to cluster 1, we did not find evidence of 4I OLF processes in some of the cluster 2 categories. We discuss why we believe that to be the case in Secs. III C 4 and IV E.

1. Ways the DAT worked supported DAT impacts (category 2.1)

Interview transcripts contained a wide variety of evidence for how DAT cultural characteristics and procedural processes supported the DATs' ability to make impacts in their departments. Many of these characteristics and processes are areas that DAT facilitators emphasized [23].

For example, the first few meetings of each DAT focused on using a consensus-based process to develop a vision of the outcomes they would like to achieve, and from that vision the group set out shorter-range goals and timelines. DAT facilitators often reminded the group of their collectively chosen vision and goals, to support the DAT in working with focus. We found evidence in interview transcripts that this process was supportive. In the following quotes, Pyromancy DAT members describe their largest-scale goals (which align well with the overall goals of the DAT project), and how the group used a consensus process to choose goals:

I see two main focuses, two main goals of the DAT. One was to actually identify areas that need change and effect change ... then the second was to instruct or educate the DAT members about how to be sustainable change agents. We've taken really both of those goals and adopted those into our [new] DAT. (*Pyromancy staff member*)

The way that our DAT was facilitated was "let's brainstorm where we see areas of improvement in our department and come together as a team to agree on, okay, we have lots of different things, let's pick one." (*Pyromancy graduate student*)

We found that interviewees often mentioned certain structural features of DATs that supported their ability to effectively collaborate, including providing payment incentives for student members, running consensus-based meetings that provided time for reflection and inclusive discussion, sharing leadership, and working in subgroups, as illustrated in these Pyromancy quotes:

[T]he incentives, particularly for students and staff who otherwise would have no reason to do this besides the goodness of their heart, is a big thing. (*Pyromancy faculty member*)

I experienced ... a modeling of how to run a meeting where all voices are heard, how to model collaborative behaviors, how to reach consensus, how to have a positive and open discussion. I mean the two [external facilitators] just did a really good job with that. And also just slowing the conversation down so people have time to think, they have time to digest before they speak. (*Pyromancy staff member*)

[I]n the DAT it wasn't just paid staff or faculty members that were leading projects. The graduate students and undergraduate students were being brought in to lead those department-level projects. (*Pyromancy staff member*)

[A]t some point we split it up into groups and everyone had their focus group on a different project and I think that worked a lot better. (*Pyromancy, graduate student*)

Finally, DAT members emphasized that having diverse membership on the DATs was a key to their success, and that facilitators and DAT members worked together to make sure that diverse members' voices were heard, regardless of their role in the department or their personality types:

I did like that it was a mix of staff, faculty, grad students, undergrads, rather than just being one unit ... it was great to have faculty and undergrad perspectives to say what they thought was needed, because as a grad student I wouldn't understand their perspective. (*Pyromancy graduate student*)

[A]s a child I was scolded ... for being an introvert ... when we were having these conversations on the DAT ... there was so much space to think and make sure that we were hearing all voices. Just simple things like ... making sure that we had reached consensus before moving on. As women ... sometimes you just get ramrodded,

so it was really nice to have that structure and that space to have full discussions. (*Pyromancy staff member*)

These quotes reveal a number of structures that DAT members adopted to support their work and the inclusion of all voices in their work. Additional examples across all DATs can be found in Supplemental Material [44]. The structures featured in this section were introduced to DAT members by their external facilitators. Thus, within this category, we see further evidence of the 4I OLF group learning process of integrating. We also think that the presence of these supportive structures aided the integrating and institutionalizing processes that occurred as DATs began to make impacts on their departments, as described in the cluster 1 results.

2. DAT work was valued by some stakeholders (category 2.2)

Within category 2.2 excerpts, DAT members described feeling that their work was supported by individuals and organizations both within and outside their departments, including departmental chairs, departmental faculty members, departmental staff members, departmental committees, and institutional committees. Departmental chair support was present with variable intensity across the three DATs in this study, with the Apparition chair present at DAT meetings, the Pyromancy chair present at a handful of DAT meetings and in frequent communication with DAT members, and the Crystals chair providing support primarily through departmental committee meetings outside of the DAT.

The following quotes from the Crystals DAT illustrate several of these sources of stakeholder support for their work:

[The department chair] carved out funding, [and was] supportive of [the DAT] being voted on by all faculty to become a standing committee. (*Crystals staff member*)

I don't know if the department as a whole did, but I think there were individuals and certain professors that really valued it and saw it as a place to get something discussed or to consider what can we do for this situation ... there were professors who would still remain on the email list and still add to the conversation even though that wasn't their department assignment. Or ones that had previously been on the committee ... would still add their voice. (*Crystals graduate student*)

The faculty I think was damn near unanimous ... the [standing] committee and its founding reason

for existence was accepted more or less immediately. (*Crystals faculty member*)

Everyone I talked to thought it was important work and that we were doing things well ... There were some private comments made to me ... There was interest. The piece that I was most involved in was the study of diversity in the undergraduate student population in the classes and flows of students. People were interested in that because they asked me for the results, basically, and asked me about them. (*Crystals faculty member*)

[The DAT] won the [university system's] Presidential Diversity Award. I think that group has become an example. (*Crystals staff member*)

These quotes provide evidence that the DATs' work was valued, and in the case of Crystals, even perceived as exceptional on their wider campus. The tone of the quotes also conveys that DAT members were encouraged by and proud to have the support of their departments.

3. Some departmental and university features supported DAT work (category 2.3)

Compared to the other supports that we have described, relatively few departmental or institutional features were described by DAT members as supporting their work, with only 13 relevant quotes catalogued across all interview transcripts. These quotes described resources provided by departments and department chairs, and the impetus to engage in change efforts stemming from accreditation processes. The latter was a particularly salient impetus for Apparition DAT members:

Our project was really focused on ... an outcomes assessment plan. This is part of our [major's] accreditation standards, and we are going up for reaccreditation. (*Apparition faculty member*)

[W]e were focused on specific learning outcomes for accredited majors. There's a lot. And since we're accredited by an outside body we have to crosswalk to what their expectations are, so it's a confusing and complicated exercise. I feel like we did a really great job of it for [that major], and it's put us in a good situation to go into reaccreditation. (*Apparition faculty member*)

I think that [reflecting on assessments] will be coming, as we prepare for our next accreditation in the program where we'll have to present and reflect on some of that material and talk about

what it's actually meaning for us. (*Apparition faculty member*)

These quotes illustrate how the accreditation process both influenced the Apparition DAT's goal of redeveloping student learning outcomes and developing a new assessment plan, as well as their plans to engage with upcoming assessment data for the next cycle of accreditation.

4. Patterns among DAT-supportive factors

Across cluster 2 categories, we notice that all DATs adopted patterns of working together and cultivated valuation of their work in ways that were modeled by DAT facilitators and were aligned with the DAT model [23]. The most frequently described supportive elements were the DATs' goal orientation, the application of efficient meeting structures, the development of a membership that was diverse with respect to departmental role and that actively supported the inclusion of all voices, and the presence of departmental chair support. We can infer that the presence of these elements supported the DATs in working effectively with their departments, resulting in valuation of their work by chairs and other departmental members. It would appear that these elements of the DAT model are particularly important for successful, sustained team-based change work.

We note that not all of these supportive factors were described by 4I OLF learning processes. For example, neither the various organizational structures that supported the DATs' work nor the positional power and encouragement deployed by supportive chairs seem to be directly related to organizational learning, although they may have indirectly supported 4I OLF processes. This finding suggests that there are factors that fall outside of the 4I OLF that are nevertheless important for sustained team-based departmental change.

D. DATs faced varied internal and external constraints in conducting their work (cluster 3)

In addition to factors that supported the work of the DATs, we also found several factors that constrained the ability of the DATs to effectively conduct their work. These factors included DAT member frustrations with parts of the DAT process, DAT member time constraints, a lack of external support for some of the DATs' activities, and other inhibiting factors external to the departments. We include representative quotes for each of the four cluster 3 categories in this manuscript and in Supplemental Material [44]. Similar to cluster 2, we did not find evidence of 4I OLF processes in all of the cluster 3 categories. We discuss why we believe that to be the case in Secs. III D 5 and IV E.

1. DAT members were sometimes frustrated with aspects of the DAT model (category 3.1)

Interviews revealed two sources of tension that DAT members experienced with the DAT model that may have

acted as constraining factors on DAT work. We noticed these tensions particularly within the Pyromancy and Crystals DATs. First, several interviewees mentioned a tension around the time allocated for relationship building or deliberative conversations vs action-oriented conversations:

One of the things that I liked and also didn't like about the DAT was at the very beginning there were ice breakers, and there was always an interesting question and conversation going on, and I thought that was really cool because it was a very intentional "let's get to know each other outside of academia," a chance to let us all talk together. That was really nice. But on the other hand sometimes I felt like it went on for too long ... There's never enough time to actually get to know your colleagues while trying to improve the department culture, which is a strange paradox or catch 22. (*Pyromancy graduate student*)

We had so many divergent conversations. And this is something that I still struggle with, that I want to make sure that every voice is heard, but at some point you have to say okay, we've heard that, but we're not going in that direction ... A couple people wanted to work on this topic and a couple of people wanted to work on that topic so we kind of ended up doing short shift to all of them. (*Pyromancy faculty member*)

The Pyromancy chair suggested that one solution to this tension could be to facilitate a faster transition into planning and execution conversations:

The big question that I still have about it is this balance between deliberation and action that I think that some of the grad students pointed to. You need both. It obviously isn't an either/or. But looking back it felt like we did a little bit more deliberation than acting in the DAT ... I think it meant that we didn't do as much as we could have if we had just kind of gotten maybe a little bit more quickly into a concrete cycle of trying a thing, making sure that we were collecting the data to figure out whether or not it was working, and then iterating on it. (*Pyromancy faculty member*)

One graduate student pointed out that some of this tension could have been generated by the fact that individuals generally have difficulty around tracking progress toward goals:

[T]here needs to be a metric for ... how much is getting done per meeting time or maybe per hour or something ... Because that was actually

something I heard a lot from other students on the committee, that they felt like nothing was getting done. And obviously things were [getting done] over time. If you look at semester beginning, semester end, projects were finished. I think if there was a guideline or maybe the facilitators checked in on that we could have handled some time ... issues a lot faster. (*Pyromancy graduate student*)

Across the excerpts related to this tension, DAT members typically expressed both valuing and feeling conflicted about time allocated to deliberation, recognizing that these types of conversation carry benefits for DAT member feelings of empowerment and efficacy and group cohesion, which are important for engagement in change projects [23].

The second tension we noticed was related to handling turnover of members and transitioning to internal facilitation. While each DAT successfully handled these two challenges, DAT members expressed that the DAT model could more strongly support and scaffold these processes:

I do think it's a struggle to keep educating new waves of students, in particular, as students graduate. (*Pyromancy faculty member*)

[A]nother hard thing has been going from externally facilitated to internally facilitated, like I mentioned earlier. As you know, the process and the culture of how the group functions really depends a lot on that facilitator. (*Pyromancy faculty member*)

Across the set of transcripts, DAT members tended to recognize that these sources of tensions were manageable and part of the DAT process. Identifying these as the primary tensions expressed by DAT members is valuable for the further development of the DAT model.

2. Limited time constrained DAT members in engaging with the DAT's work (category 3.2)

The most commonly reported constraint on the work of DATs was the limited time available to DAT members. To mitigate this constraint, DAT faculty and staff members typically negotiated for their DAT work to count toward their job performance expectations. The DAT project also paid DAT undergraduate and graduate students a stipend per semester of activity. Nevertheless, time constraints were pervasive, and the COVID-19 pandemic exacerbated them. Pyromancy DAT members described these limitations in the following ways:

We all are just so busy and so swamped. We all wear multiple hats. (*Pyromancy staff member*)

[F]ighting against our oversubscribed schedules and trying to find the time and the effort to put towards these things ... because of that it's going to be a ... slower process to actually see things be noticeably different from how they were before. (*Pyromancy graduate student*)

[W]ith the pandemic I felt like everyone was just not working as much on especially extracurriculars. We were all trying to figure out what to do for real work, regular work. (*Pyromancy faculty member*)

Within the Pyromancy DAT, one project that had originated with undergraduate students was not completed due to time limitations on faculty members who were needed to approve a final document that was to be included on the website. One faculty member explained:

I guess I had other things [of] higher priority to do ... I just didn't have enough hours ... This one just always ended up falling to the bottom of my list, like oh yeah I need to get to cleaning that document up and putting it on our website. So it really did kind of die with me. I do have big guilt about that, but at the same time it just wasn't ... something that needed to get done in the department at the time. (*Pyromancy faculty member*)

We interpret the phenomenon so frankly discussed by this Pyromancy DAT member as an example of how the process of organizational learning can get disrupted. It would seem that this project had been agreed upon by the DAT, which would indicate entering a stage of integration. However, the project management process left the end stage of the project up to an individual, and coincidentally during this phase of the project, the COVID-19 pandemic also disrupted regular group meetings and constrained the time of every DAT member. It seems logical that, under these circumstances, the organizational learning process became stalled and was not able to proceed through the institutionalization process as originally intended, specifically in making the project public on the department website.

3. A lack of support limited some DATs' impacts (category 3.3)

DAT members reported several ways in which a lack of support from department members affected the progression of their work, and this was the category that was by far the most frequently coded within cluster 3. These included apathetic responses to the initiatives they proposed, resistance to work that was suggested (which tended to be most commonly experienced when DATs were pursuing projects related to diversity, equity, and inclusion), and feeling that their work was siloed within the DAT and unable to gain

wider engagement. The following quotes from Crystals DAT members, who were working on diversity, equity, and inclusion projects, illustrate evidence for apathetic attitudes and siloing:

At one point there was a discussion of making a teaching best practices handout. But not much effort I think was put into that, because I think the professors on the [DAT] didn't think that other professors would be very receptive to it. (*Crystals graduate student*)

[The idea] that we as faculty are responsible for grad students who aren't in our groups is a massive black hole ... you know, something bad is happening to a grad student in somebody else's group, "that's not my fault, that's not my responsibility, I don't have anything to say about that" ... [You need buy in] ... if you're going to protect students. (*Crystals faculty member*)

... [T]here's also a sense that once we created [the standing committee] a fair number of the faculty members said "there, mission accomplished, let us know how well it works." "It's a hard job and I hope I don't have to do it" is sort of the attitude ... this is clearly a systemic deeply rooted issue, and that gives a lot of people free rein to just say "I'm running away from this one." (*Crystals faculty member*)

These quotes convey feelings of frustration that DAT members sometimes expressed regarding their department members' lack of engagement with their work, and indicate that at times, certain projects were not pursued due to a lack of support. Taken together with the evidence for the valuation of DAT work (category 2.2), we see that all the focal DATs experienced both validation and lack of engagement. While signals of support may have buoyed up their change projects, other interactions signaling lack of support sometimes constrained their efforts. While these phenomena are not directly aligned with 4I OLF processes, it is possible that these phenomena indirectly influenced DAT members in their processes of intuiting, interpreting, or integrating.

4. Factors external to the department constrained some DATs' impacts (category 3.4)

DAT members described a few factors external to their department as shaping or constraining their work, but these were much less prevalent than the factors internal to their department (support) and to DAT members (time), with only 14 relevant excerpts identified in this category. For example, within Apparition, only one external constraint was identified, which was that their project was related to the accreditation of their major:

Our ... program is accredited by the [professional s]ociety ... They have their own processes for setting the academic accreditation standards ... I wouldn't say it hindered our work, but it's an example of external forces that we can't control. (*Apparition faculty member*)

Since our program is externally accredited ... we certainly had to bring that into our conversations developing our student learning outcomes and ... assessment ... We have two programs that are externally accredited and two programs that aren't, and those programs that aren't externally accredited have been much more creative in how they've thought through that process ... instead of having to start from we need to check some boxes in an accreditation program. (*Apparition faculty member*)

In this case, accreditation impacted the way the DAT carried out its work in that it had to make decisions that were aligned with externally imposed standards, which made it more difficult to be as "creative" as they might have been with programs that were not externally accredited. However, given the relative rarity of these comments, we cannot draw conclusions about this category as a whole.

5. Patterns among DAT-constraining factors

We note that there is less alignment with the 4I OLF in the constraints categories (cluster 3) than the impacts categories (cluster 1) and even the supports categories (cluster 2). The most common constraining factor was the perceived lack of support from department members, and this factor seems to indirectly influence the DATs' engagement in organizational learning processes.

The other constraining factors seem even less related to organizational learning. We note that examples in categories 3.1 and 3.2 (DAT members feeling tension between deliberative and action-oriented conversations and DAT members being constrained for time) are both related to prioritization of work. In the case of time constraints, this relates to prioritization between DAT work and other duties, and in the case of tension with action-oriented conversation, this relates to prioritization of topics within DAT meetings. While prioritization is an important part of the change planning process, it seems to exist outside of the 4I OLF.

Finally, the least frequent constraint (category 3.4, factors external to the DAT) is also related to the application of positional or group power, as seen in the example of how the Apparition DAT's work was shaped by its accrediting body. This lever of power is yet another driver of change that is not directly aligned with a process of organizational learning.

IV. DISCUSSION

A. DATs produced a wide variety of sustained changes to departmental cultures

The illustrative quotes presented here and within Supplemental Material [44] establish that a wide variety of changes were wrought, catalyzed, informed, and sustained by the work of the Apparition, Crystals, and Pyromancy DATs. Additional sustained changes across the 17 DATs organized by this project are summarized in Ref. [32].

Sustained changes were documented within individual DAT members (category 1.1), within departmental groups and across departmental cultures (category 1.2), and within departmental structures (category 1.3); moreover, the work of DATs also shaped additional sustained departmental change efforts (category 1.4). Many changes were readily observable to department members. For example, interviewees described creating gender-neutral signage for bathrooms (Crystals DAT), creating a set of program-level learning outcomes (Apparition DAT), and hosting a departmental forum (Pyromancy DAT). Less observable changes included expanded department-wide emphasis on addressing issues of diversity, equity, and inclusion (Crystals DAT); a wider engagement of the department in conversations about program learning outcomes (Apparition DAT); and a new emphasis in establishing and adhering to community standards and norms in committee meetings (Pyromancy DAT). Together, these examples of changes are well aligned with the artifacts and espoused values levels of organizational culture (see Sec. IB).

Further, in some cases, we noticed that some observable departmental changes served to support the development of less observable change, or vice versa. For example, the Crystals DAT began its work by producing and presenting a report on underrepresented student retention in the department, which showed that more women than men were leaving the Crystals major and indicated that the same pattern may be occurring with students from underrepresented racial groups. The report represents a cultural artifact that led the department to focus discussion and prioritize further work around issues of diversity, equity, and inclusion by making the DAT a standing committee—an additional cultural artifact. The department-wide discussions provided opportunities for faculty members and students both inside and outside the DAT to engage with literature related to these issues, which led to their participation in another of the DAT's early projects, a seminar series on diversity, equity, and inclusion. Thus, the DAT's focus on DEI issues supported the spread of related knowledge across the department, and this in turn supported attitudinal changes, particularly among Crystals faculty members, at the level of espoused values. Over time, attitudinal changes supported by the DAT's ongoing work, and other concurrent equity-oriented work in the department, resulted in it being commonplace for students,

faculty members, and staff members across the department to consider, discuss, and address DEI issues.

While this sequence of cultural changes at the artifact and values levels did not proceed linearly, smoothly, or as completely as hoped for (see additional quotes from Crystals DAT members in Supplemental Material [44]), this and other examples from our focal DATs indicate that the DAT model did support the emergence of sustained changes at both of these levels of organizational culture. This is aligned with recommendations from organizational change researchers that change efforts should target change on multiple levels to increase impact and sustainability [1–3,6].

To summarize, the patterns that emerged from our analysis of DAT member interviews, and that are encoded by our emergent categories and clusters represent various ways in which (i) the cultures of the DATs were influenced by their facilitators, their departments, and other groups, and in turn, and (ii) the cultures of the DATs influenced the cultures of their departments. Because of the nature of our study, the cultural changes we identified exist at Schein's levels of artifacts and espoused values. Possible changes at the assumptions level would require further study to identify.

B. DAT impacts influenced the work of other groups

The impacts of the Apparition, Crystals, and Pyromancy DATs influenced other groups, both within the DATs' departments and in other department- and college-level groups. For example, in each DAT department studied, DAT-like groups either continued with internal facilitation or new DAT-like groups were formed to continue to spur change. In these groups, DAT members replicated some facilitation practices from their former DAT external facilitators, and their groups continued to enact and embody some DAT meeting practices and DAT model principles.

We posit that such influence, driven by the advocacy and modeling of DAT members, is a key mediator of sustained cultural change, both within departments and across campuses. We were surprised at how commonly these influences were documented, because DATs were not intentionally organized or facilitated to create such impacts.

We observe that several of our interviewees acted as outsized influencers in this regard, and note that the skills these interviewees repeatedly described using were readily learned through their DAT experience, as the work of these DATs occurred before the publication of written DAT resources [23,24]. Therefore, we assert that collectively driven, team-based change initiatives provide a natural learning progression for the development of influencers who can become important facilitators and mediators of ongoing and sustained change in higher education. However, it is possible that more efficient methods could be developed to support the development of such influencers. Further research is needed to develop and research programs aimed at scaling up the development of internal

facilitators for departmental, collective, team-based change, and other types of change catalysts in higher education.

Together, the observations both that cluster 1 impacts align with all processes of the 4I OLF and that the majority of DAT impacts occurred after the end of external facilitation for the three DATs in this study provide support for the idea that the DAT model provides comprehensive support for the kinds of organizational learning necessary to catalyze and sustain department-level change.

C. Departmental supports were critical for sustaining each DAT's work and could be bolstered in the DAT model

Each DAT described a range of factors that supported their work, including structures that facilitators taught DATs to use during meetings, cultural practices that ensured all voices on the DAT would be heard, and specific ways in which chair support furthered their work. Typically, we have been wary of convening DATs when signs exist that the department chair might oppose their work [23]; this finding supports the continuance of this practice. In contrast to this finding, there was relatively little evidence of institutional support for the DATs' work. This finding suggests that departments can catalyze and sustain change without major support, financial or otherwise, from higher administrators or from institutional offices. While this finding does not suggest that offices and administrators cannot provide useful support, it shows that institution-level support was experienced as the least influential of the types of support that DATs experienced.

Alongside this finding, lack of support from the wider department was the most common constraint cited among our interviews. For example, in Crystals, DAT members described feeling siloed, such that their group became the "go-to" for researching and resolving any DEI issues. We suspect that for all three of these DATs, perceived lack of support might have been ameliorated by greater communication with the wider department. In reviewing the elements of the DAT model [26], we notice that regular communication with the wider department is not emphasized. We conclude that building in regular departmental communication is an area in which the DAT model could be improved.

D. Constraints on DATs are idiosyncratic, but supports are universal

Looking across all constraining factors, we notice that they impacted our focal DATs more idiosyncratically than the factors that we identified as being supportive. In other words, the factors that we found to be supportive were described as supportive by interviewees from all DATs, whereas the factors that most constrained a DAT's work varied across the three DATs in the study. For example, DAT faculty members' lack of both support and time were most impactful for Pyromancy, whereas the siloing of DEI

to their team was most impactful for Crystals and external constraints (i.e., accreditation requirements) most impacted the work of the Apparition DAT. This pattern reminds us of a quote from Leo Tolstoy's *Anna Karenina*: "All happy families are alike; each unhappy family is unhappy in its own way."

While we asked explicitly about external factors that impacted the DATs, either positively or negatively (see question 8 of the interview protocol in Supplemental Material [44]), the relative lack of excerpts related to categories 2.3 and 3.4 indicated that external factors were not particularly salient to the DAT members. This may be because external factors actually did not have much of an impact on the DATs, or it could be because the impacts of external factors, while present, were not visible to the DAT members. It would require a different study design to provide a focused analysis of the impact of external systems on departmental change work. Nevertheless, this result suggests that it may be beneficial for DAT facilitators to more explicitly focus on helping DAT members to analyze and engage with external factors that may impact their work.

We conclude from these findings that specific support elements need to be ensured for all departmental change teams, while specific constraint elements may only be able to be addressed as they arise. Therefore, it may make sense for leaders aiming to support departmental change teams to prepare to provide the known effective sources of support. On the other hand, while leaders' understanding of the categories of constraint identified by this study may help them anticipate and even avoid some constraints, not every change team will be challenged by every constraint, and additional constraints may exist that were not identified within this study. Therefore, leaders may want to adopt practices that allow change teams to discuss and air sources of constraint at regular intervals as they work together and to offer general support around troubleshooting the constraints that emerge, which is a function that DAT external facilitators typically provided to DATs [23].

E. The DAT model supports sustained change by engaging organizational learning processes and additional levers of change

In this study, we applied the lens of the 4I OLF as a *post hoc* means of enhancing the interpretation of our coded data. We find plentiful evidence of all four processes of the 4I OLF among the excerpts describing the varied impacts of DATs (cluster 1). These include the more individual processes of intuiting and interpreting, and the more group-based processes of integrating and institutionalizing. We interpret the latter two processes as particularly important mechanisms for supporting sustained change. We believe the three DATs in this study exemplify the organizational learning process and provide evidence that the DAT model has the potential to support DATs in using

all four of these processes. Further, we speculate that intentional inclusion of all four 4I OLF processes in change models, and in the course of engaging in change efforts, may help support the development of sustained change in departmental organizations. In particular, it may be useful for facilitators of change efforts to reflect on engagement in the four processes to identify gaps. More intentional inclusion of, or focus on, activities that align with the institutionalizing process may yield more sustained efforts.

We were curious to find fewer alignments between 4I OLF processes and the categories in cluster 2 and cluster 3, which describe supports and constraints, respectively. Across these factors that influenced the DATs' impacts, we identified several that did not directly connect to the 4I OLF: organizational structures that supported the DATs' work; support from chairs; lack of engagement from other department members; prioritization of work due to time constraints; and the relative prioritization of relationship building, deliberative conversations, and action-oriented conversations in DAT meetings. It is possible that future research might fruitfully endeavor to better understand the indirect interrelationships between these factors and organizational learning and to understand how they are or can be conceptualized within sustainable change models.

F. Limitations

The generalizability of this study is limited due to the sampling strategy employed. The dataset only reflects the perspectives of DAT members, which was sufficient to provide insight into the mechanisms of change that impacted those DAT members and departmental groups with which those members interacted. However, this study unexpectedly documented how the work of these DATs spurred the formation of additional groups that undertook change initiatives. Because we did not sample the perspective of departmental members in those groups or the wider department, this study is not able to provide much detail or insight about how these additional groups formed and functioned or about how wider changes in the beliefs, values, and behaviors of non-DAT department members may have occurred.

Furthermore, the DATs in our study were from medium-to-large STEM departments at a large research-intensive public university. Based on our experiences with DATs in different contexts, we expect that many of the patterns that we observed for the DATs in our study would carry over to other types of departments and institutions. However, the data in this study do not let us say this with certainty.

Additionally, we note that departmental improvements that were driven by the DATs may well have also been driven by other individuals or groups (e.g., campus or departmental leadership) that were outside the scope of the study. While the DAT members that we interviewed provided their interpretations of how external factors

contributed to their work, departmental change is too complex to be able to perfectly separate the effects of any particular driver. Nevertheless, based on our interviews and DAT facilitation experience, we are convinced that the DATs were major contributing factors in the changes discussed, even if additional factors sometimes contributed to those changes.

Finally, undergraduate DAT members are underrepresented in this study because we lacked contact information for some students post graduation and most undergraduates that we were able to contact did not respond to participate in the study.

V. CONCLUSION

DATs in this study made a wide range of sustained impacts on individual DAT members and their departmental organizations. We found evidence of all four processes of the 4I OLF: intuiting, interpreting, integrating, and institutionalization, and we suggest that supporting all organizational learning processes may be important for groups aiming to achieve sustained departmental change.

The impacts of all of the DATs in this study were supported by a set of factors that were largely internal to the DATs and their departments. Most notably, departmental chair support; the team-based, collaborative processes taught to DATs by external facilitators; and the value that department members expressed for the DATs' work were important in ensuring sustained impacts. DATs also faced constraints that varied widely in form and intensity and that appear to be idiosyncratic to each DAT. Key constraints included limited DAT member time, lack of department member support, and weak DAT-to-department communication.

Both supports and constraints noted in this study reflect some levers of change that operate somewhat independently from (but may influence) the processes of organizational learning, as discussed in Sec. IV E. These change levers include positional power and mechanisms for prioritizing work. Despite the constraints they faced, DATs in this study were buoyed by the support of their departments, persisted in their work, and passed on their learning to individuals and groups outside the DAT. The influence of DATs on these outside groups unexpectedly served to catalyze further change initiatives in their department. Thus, this study serves to confirm that the DAT model can support sustained, team-based departmental change.

A. Future directions

While this manuscript focuses on the implementation of the DAT model at two R1 universities, features of the DAT model have been adopted in several other contexts, with similar general findings. For example, the DAT project team supported departmental change efforts in the community college context through a series of workshops [47] and found a set of challenges and supports in that context

[48] that mirror those in this study (e.g., time constraints and limited resources as challenges, diverse teams and proactive leaders as supports). As an example specific to physics, the EP3 Departmental Action Leadership Institute (DALI) [49] trains physics faculty members to lead DATs in their departments, which often serve small student populations and are primarily undergraduate-focused. DALI participants have experienced outcomes related to their skills and attitudes about change [50,51] that are similar to those of members of DATs in this study. We anticipate that opportunities for in-depth longitudinal impacts and sustainability research will increase as more DAT model adoptions (and departmental change efforts in general) become reported in the literature. This could also provide more opportunities to investigate evidence of the 4I OLF processes, which could further illuminate the differences and similarities in how team-based change efforts create and sustain impact at different institution types.

Our research team is currently working on a project to catalogue as many team-based departmental change efforts as possible, whether they use the DAT model or other change frameworks. We plan to summarize the similarities and differences in design features across these efforts to get a better sense of the historical and current landscape of departmental change efforts in STEM departments in the United States. Through this work, we will investigate the

ways in which teams catalyze and sustain different types of change across different contexts.

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DATA AVAILABILITY

The data that support the findings of this article are not publicly available because they contain sensitive personal information. The data are available from the authors upon reasonable request.

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