

Graduate program reform in one department of physics and astronomy: From tragedy to more progressive policies and an evolving culture

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In 2017 the University of Utah experienced a tragedy which catalyzed already active changes in the department. In the aftermath, admissions to the graduate program was paused while new policies were developed and implemented. This article outlines this change process through the perspectives and accounts of those involved. Through in-depth interviews with students, staff, faculty, and administrators the process of change was found to be a complex path that involved robust practices of gathering input. This input was considered by a centralized group (the executive committee) advising the department chair and administrators. Findings indicated that the collective desire to reopen the program inspired most faculty to work together to find solutions, while some stakeholders did not fully buy in to large-scale programmatic changes. Further, interviews revealed the persistence of deep cultural challenges after the development and implementation of new policies. A new metaphor for this change is suggested to be a bonfire, as a tragedy sparked the fire of change structures which had already been built, and continual fuel is needed to sustain these changes. Moving forward the department is extending their graduate reform into undergraduate initiatives and normalizing evidence-based teaching practices. Content warning: This paper discusses the death by suicide of a graduate student.

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I. INTRODUCTION

In 2017, a tragedy occurred in the Department of Physics and Astronomy at the University of Utah when a Ph.D. student died by suicide. “[*Chair of the Department of Physics and Astronomy*]...said he was optimistic about providing more structure to students and healing the interpersonal tensions between the department’s employees. Investment in a common purpose is a powerful way to bring people together, he said, and the university has laid out clear expectations for the physics and astronomy department.” - Salt Lake Tribune [1]. This tragedy revealed a complexity of issues that had troubled the department for years [2], and occurred in the same time frame as the murders of three additional University of Utah students on and off campus in 2017 and 2018 [3–5]. Since these grievous events, there have been a number of resignations of top university safety officers

and leaders [6,7]; the creation of the McCluskey Center for Violence Prevention [8,9]; and, in the case of physics and astronomy, mandated university oversight and a complete reform of their graduate program. Sadly, further murders of University of Utah students have occurred since this time [10,11]. This article explores the redesign of the physics and astronomy graduate program as a case study to understand the impact of the changes on the program and the change process overall. Our analysis suggests that the tragedy served as a powerful accelerant for the change process, which was already underway when the death by suicide occurred. This work will shed light on the change process and its similarity to previous change work in physics education research (PER). This study will also document an early example of graduate program reform and may be useful in informing future efforts and research.

II. BACKGROUND AND LITERATURE REVIEW

Change is hard. The growing field of PER [12–20] has primarily explored change in the context of instructional reform in the classroom [21–25]. The study of change more generally has included looks at reorganization due to changing needs, reorganization due to disaster, and the splitting of one organization into two [26–28]. Physics education research has also explored graduate education, but primarily with respect to specific issues of equity and inclusion rather than sweeping program reform [29–34].

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This review will explore what lessons can be learned from change work, both in PER and beyond, to help frame this study on graduate program reform.

A. Change research

This review will pull together the growing areas of change research to support our work below. Change research in PER and discipline-based education research (DBER) looks at a variety of activities, such as how teaching staff learns about new innovations [35,36], changing teaching practices [25,37,38], and implementing new practices [35,36,39]. One model for studying change in postsecondary education was developed by Henderson, Beach, and Finkelstein [22] and contains four types of change: “disseminating curriculum and pedagogy, developing reflective teachers, enacting policy, and developing shared vision.” This model can be applied to the processes of change beyond just classroom reform, and will be useful in this analysis.

Although the research has looked at varying efforts, ranging from grassroots or emergent (e.g., course transformation led by faculty who were interested in doing better) to more structured programs (e.g., the American Association of Physics Teachers and American Physical Society’s New Faculty Workshop), there are common lessons in the literature. One common lesson is the importance of having a team that includes representation from a variety of stakeholders [40–42], which allows for buy-in and may help identify potential challenges in implementing changes.

Nuances exist, however, in creating change teams, particularly when considering power dynamics and hierarchies. For example, some teams strategically involve students [42]; research has shown that great care is needed to include students equally in processes of curriculum reform [43]. Although this study is not focused solely on curriculum changes and involves the entire department, we anticipate that navigating power dynamics and hierarchies to ensure true partnerships is an issue wherever power differentials exist (e.g., tenured vs nontenured faculty). The importance of a team approach, overall, should also not be understated. Research on change has found that teams produce sustainable and high quality outcomes more often than individuals [44]. However, teams are also noted to be more inefficient and have higher risk of failure [44].

Another common lesson from the literature is that change can be a slow, nonlinear process. Many departments may not be able to make the changes they want when they want to make them [45]. Departments can prepare themselves for change by learning about the innovations they wish to implement, building their team, and staying aware of their department’s interests and resources so that they can identify the right time to act [45].

Leadership is also important in change networks. Leadership in changing departments can be useful for any

of the four types of change articulated by the Henderson *et al.* [22] model, and can facilitate important work such as spreading information and developing policies [46]. Leadership can also provide support and resources [36].

A final common lesson is that a supportive culture, including beliefs and practices that allow for improvement, is much needed for lasting and substantive change in departments [47,48]. Corbo *et al.* [48] argue that holistic change across the entire institution is needed, as departments are embedded and, therefore, impacted by college or university policies and practices. Although departments have significant autonomy, they exist in a broader ecosystem of higher education.

Many of the findings in PER or broader DBER around change are similar to findings in other bodies of literature. For example, complexity leadership theory (CLT) emphasizes embracing emergent change, communication and discussion across levels, and formal and informal leadership [26,49]. Although there is an emphasis on novelty and emergent change, CLT posits that actions and change are guided by a particular, easy-to-understand message or purpose [26]. Some commonalities in a few CLT studies include a massive change in the system (considered disequilibrium), small novel actions leading to big changes (considered amplifying actions), creation of new interactions that change the system (considered recombination or self-organization), and being mindful of existing constraints that limit the changes (considered stabilizing feedback) [50].

Sense making is also an important aspect in change processes. As defined by Weick [51], sense making is an interactive process in which the goal is to create shared meaning and interpretation in new situations rather than arrive at a so-called universal truth. Key components of sense making include discussion of and reflection on a specific situation, particularly when the situation is poorly understood [51]. Sense making is a nuanced process where the people involved and the dynamics at play matter [27]. Factors such as power differentials and emotions can impact the sense making process, where more powerful or high status people’s perceptions might be more valued or that negative emotions can impede sense making [52]. In the education context, sense making can be useful for educators to understand the purpose of particular actions, how to implement policies, and ways to resolve issues [53].

B. Change in doctoral or graduate education

There have been calls to improve doctoral education in physics, with some progress already having been achieved. In 2006, the task force on graduate education (TGSE), supported by both the American Association of Physics Teachers (AAPT) and the American Physical Society (APS), published a report [54]. Recommendations included the following: a core curriculum with one semester each of electrodynamics, quantum mechanics, statistical mechanics, and classical mechanics; providing opportunities to

develop broad skills around communication, computation, and ethics; guidelines regarding graduate students' rights and ensuring students receive such information; ensuring students are making progress towards degree completion; and providing information and mentoring around a wide range of careers [54]. While the report does not make a recommendation on comprehensive exams, the authors recommend that "there needs to be some method of evaluating students' knowledge of the core subjects" (p. 3).

Since this report, there have been various studies that examine facets of physics doctoral education in hopes of improving the experience. Mentorship and development of a supportive community of practice in research groups have both been shown to support expert identity [55]. Investigations on admissions practices regarding the use of the physics graduate record examination (GRE) suggest that implementing a hard cutoff in the physics GRE score may put applicants who are from smaller institutions, as well as women, with fewer resources at a disadvantage [56]. Another study indicates that the factors considered most important in graduate admissions include grade-point average (GPA) in physics or math courses, letters of recommendation, physics GRE score, and what physics courses were taken at the undergraduate level; the authors suggest that the last criterion could pose problems for applicants from smaller institutions with fewer opportunities to take as many upper-level courses as those from larger institutions [57]. Many of the criteria in the aforementioned study do not predict whether a student completes the physics doctoral program, suggesting that these criteria are not useful and may adversely impact underrepresented groups [56,58].

Multiple efforts to address inequities in physics and astronomy graduate education have been undertaken by the AAPT and APS. The AAPT released a statement advocating against the use of the physics GRE in admissions criteria [59], while the APS launched the APS Bridge program and co-launched the inclusive graduate education network (IGEN), which seeks to enact systemic change in graduate and doctoral physical science education to increase the number of physical science doctoral degrees earned by Black, Latine, and/or Indigenous students [60,61].

C. Departmental change and timeline at the University of Utah

Prior to the graduate reform efforts described below, the graduate program in physics and astronomy at the University of Utah included approximately 100 students. "I think we're going to come together," he said. "We're going to make a lot of progress in a short amount of time." -Chair [1]. Many of these students were well beyond their 6th year of study, with some approaching a decade in the program [62]. Starting with the 2012 cohort, incoming students underwent a two-day orientation led by two faculty members and an experienced graduate student;

for many years prior to that, orientation was conducted completely by a single graduate student with no faculty involvement. The orientation program was expanded in 2014 to being one week long after a faculty and teaching assistant (TA) team attended a national workshop on graduate TA professional development. Since 2014, the orientation has included approximately one day related to department and university onboarding, but has otherwise focused on supporting students in their duties as TAs.

In 2013, a standard seven-year graduate program review was conducted by the graduate school, involving a departmental self study and both internal and external review committees. That review pointed out a number of issues regarding timely completion, student advising, and documentation and tracking. At that time, for example, student advising was inconsistent: incoming students were assigned a single faculty mentor with no regard paid to their intended research area. In 2015, a very difficult case between a faculty member and one of their graduate mentees involving concerns about the interpretation of some experimental data polarized and fractured the department, leading to long-term tensions and poor communication between faculty members, as well as some tension within the graduate student community. The issues surrounding this case also required intervention from several members of central administration.

Figure 1 presents some of these large departmental changes in a timeline format. Prior to 2016, changes were isolated events.

In the summer of 2016, a new department chair started. They began to address the tensions among faculty members and graduate students, and also continued to address some of the issues raised by the graduate program review. For example, a proposal had been circulating since 2015 regarding more regular and consistent graduate advising processes. This proposal was approved by the department

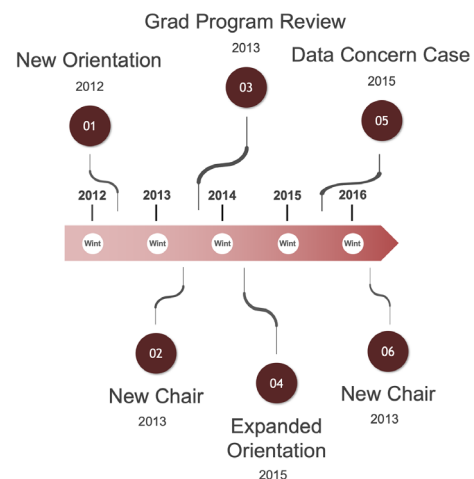


FIG. 1. Short timeline of change elements that occurred before the tragedy that sparked larger policy change.

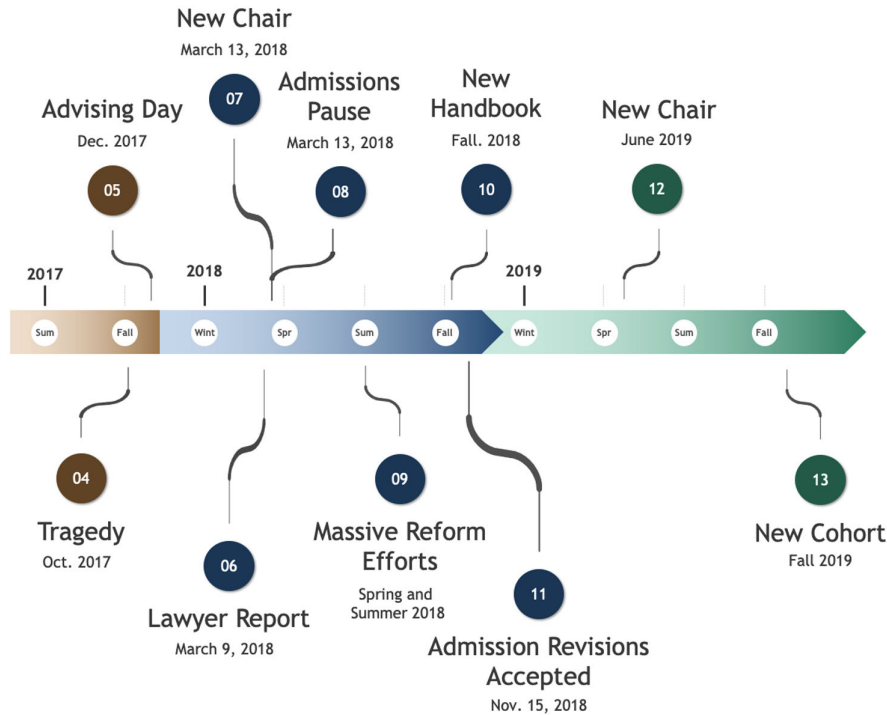


FIG. 2. Detailed timeline of change after tragedy.

in mid 2017, but major changes were not instituted until December 2017.

In the fall of 2017, an international graduate student died by suicide after spending over seven years in the graduate program. This student had been allowed to miss several program benchmarks without receiving adequate advising and mentorship, and their visa status had expired with little support and intervention from the department. This tragic event prompted an investigation by an external law firm commissioned by the university, beginning an intense period of both departmental introspection and external scrutiny placed on the department, the program, and the specific faculty members involved. In March of 2018, the law firm released their report; the University took several immediate actions in response, including instituting both an external chair and a program oversight committee, pausing graduate admissions, and establishing specific benchmarks that needed to be met before graduate admissions could resume [2].

During the spring and summer of 2018, the new external chair worked closely with a core group of faculty and staff to develop plans for a comprehensive overhaul of the graduate program and to produce a new graduate handbook. This plan was discussed extensively by both the faculty and graduate student communities, and was eventually approved after revision by faculty vote. The plan was also approved by the oversight committee, and in November of 2018 the university gave the department permission to resume graduate admissions, while maintaining close oversight of the program. In spring of 2019,

a new class of graduate students was admitted into the reformed program (to start in Fall 2019) with the new policies and processes in place. A second class of graduate students was admitted for Fall 2020, although some, particularly international students, opted to defer due to the coronavirus pandemic and related travel or visa restrictions.

The changes to the graduate program were comprehensive, impacting the following:

- the recruitment and admissions process;
- orientation and TA training;
- advising and student support;
- curriculum; and
- exam structure.

The 2019 and 2020 cohorts experienced significant differences in their graduate program relative to those students who started in Fall 2017 or before. Figures 1 and 2 provide an outline of this evolution. The complete overhaul of the graduate program involved significant reforms of all major curriculum and student-support components. These changes are summarized below.

1. Recruitment and admissions

Previous recruiting efforts were minimal and largely consisted of advertising to GRE physics subject test takers. Application materials included a “personal statement,” whose purpose and evaluation criteria were somewhat unclear. Recruiting efforts now include a number of personal interactions with prospective applicants at conferences,

including the APS Four Corners annual meeting, the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS), American Astronomical Society (AAS), Conference for Undergraduate Women in Physics (CUWiP), the National Society of Black Physicists, etc., and during visits to other institutions. The department webpage was also updated. Based on work from the inclusive graduate education network and the council of graduate schools, the department redesigned both the admissions application itself and the entire selection process to support holistic review and to solicit specific and relevant information from applicants, reforms which helped demystify the admissions process for prospective applicants [61]. This evidence-based approach, similar to that practiced by the APS Bridge Program, is designed to select a diverse group of students who possess qualities that will support their success in the program [60]. These qualities were synthesized into specific criteria that are each graded on a three-point scale. In the first admissions cycle with the new procedures nine criteria were identified and used for admissions. The criteria and relevant training materials are updated and refined with each admissions cycle. Though the specific criteria are not publicly available, they include aspects that speak to applicants' whole selves, such as research experience, leadership, and community engagement.

The graduate recruitment and admissions committee consists of the graduate program coordinator (a full-time staff position) and approximately ten faculty members chosen by the department's executive committee and appointed by the chair; as of 2021, the committee also includes a graduate student member. Faculty members are selected to ensure the committee represents all research areas in the department, as well as a diverse group of reviewers. It was initially considered advantageous to have the same committee engage in postacceptance recruiting efforts, though with an increasing applicant pool this structure may need to change to ensure equitable service responsibilities in the department. Members of the graduate recruitment and admissions committee undergo training to ensure they enact the new holistic admissions process properly. This training has included evaluating previous students' applications using the new criteria and discussions to establish interrater reliability.

2. Orientation and TA professional development

Since 2014, the department's incoming graduate students attended a one week orientation and development program before their semester began. Initially designed by a faculty member and experienced graduate students, this event focused on pedagogy and introduced soon-to-be TAs to practical skills and strategies for the classroom. In 2019, with the help of a new faculty member, the TA Orientation was expanded to include enhanced cohort development, social activities, and significantly increased programming on success strategies and the availability of on-campus

resources (including mental health and wellness resources). In previous years, TAs were supported by peer observations and feedback from a mentor TA. This has now been enhanced with additional resources for continued TA and cohort development throughout the academic year, including monthly lunches for all TAs to build community and discuss classroom-related topics.

3. Advising and student support

Previously, students were assigned a single advisor upon entry into the program, and were then advised by a full committee once they joined a research group and selected a dissertation committee. Students typically met with their committees only a few times during their tenure in the program, and could languish for years without committee members being made aware of any problems they were facing. The new advising structure begins with an assigned three-member committee upon entry, designed to be replaced or enlarged to five members once the advisee joins a research group. There are now mandatory "check-point" advising meetings each semester, which take place on advising day between each student and at least three members of their committee. These meetings include checks on funding, as well as discussion of administrative issues, program milestones and progress, coursework, scientific work, and more. Built into these meetings is a time when the advisor leaves the room so that a student can bring up sensitive concerns, as well as a time when the student leaves the room and the advisor can make comments to the committee.

Both students and faculty may request follow-up meetings for any reason. The results of all advising day meetings are discussed at a required faculty meeting (typically within a week of advising day), with specific attention given to cases where students are struggling to make degree progress or where other concerns are raised (e.g., mentor and mentee conflicts). These new advising check points and follow-up faculty meetings have elevated the importance of mentorship departmentally, and have increased accountability and transparency in mentoring relationships. In addition, the department now has a new graduate coordinator, director of graduate studies, and graduate Program committee, each of whom meet regularly and have well-defined responsibilities and expectations. The ombuds committee also provides support with conflict resolution and helps the department understand any trends that could be addressed broadly. In addition to the support students receive from faculty and staff in these roles, the department also supports a graduate student advisory committee (GSAC) that functions as a social and informal mentoring network, the leaders of which regularly update the chair on student concerns.

4. Curriculum

The program curriculum was completely reformed, eliminating old required courses such as graduate lab and math methods in favor of more specific requirements

for four Ph.D. tracks: Physics (condensed matter and high energy), astrophysics, biophysics, and physics education research. All students start with the same two courses in their first semester (Quantum Mechanics I and Classical/Electricity and Magnetism I), and have the opportunity to specialize in one of the four tracks beginning in their second semester. The new curriculum was designed with an eye towards considering what skills and knowledge students should gain to prepare them for research in their chosen field and for subsequent careers both in and out of academia. To help connect students with research advisors, a new course was designed to be taken in the first semester called faculty research opportunities. To assist with the development of relevant professional or complementary skills, students take a professional skills course in the fall of their second year, which covers CV and resume writing, scientific writing, inclusive teaching practices, professional ethics, and more.

5. Exam structure

Previously, students were required to pass a written “common exam,” which was purported to test advanced undergraduate physics knowledge, by the fall of the 5th semester. In recent years, it was possible for students to waive the common exam requirement with a 50th percentile or better score on the Physics GRE subject test. An oral “Qualifying Exam,” with an ill-defined format, was required prior to candidacy. In practice, this requirement was often pushed into (or even beyond) a student’s 4th year, a time by which students had spent far too much time in the program to make a graceful and productive exit if they were not successful. In the new exam structure, the common exam is replaced by a comprehensive exam, which tests understanding of material taught in the first-semester graduate courses: Quantum Mechanics I and Classical/Electricity and Magnetism I. The two components of this exam are written by the comprehensive exam committee, which includes the instructors of both courses, a committee chair, and two additional faculty members. The exam is given during the final exam periods for those two courses. Information about the exam and study materials, including example problems and past exams (as they’re accumulated), are available on an online page that’s accessible to all students who will take the comprehensive exam that year. Should a student fail to pass one or both sections of the exam, they work with their advisory committee to determine how to prepare for a second attempt at the exam, and may retake the relevant course(s). Tutoring is also encouraged and supported by the department. The qualifying exam has also been standardized: the structure is the same across the department, and each subfield has field-specific requirements. Students must pass the qualifying exam prior to the end of the 5th semester.

III. RESEARCH QUESTIONS

The following research questions guided the research design, collection, and analysis of this study.

RQ1: What events caused the department to change the doctoral program?

- What relationships or factors were important for supporting changes at the beginning?
- What relationships or factors were developed later during the change process that supported change?

RQ2: How were decisions regarding programmatic changes made?

- What informed these decisions?
- Who was involved with the changes, and how did that impact the decisions and reception of these changes?

RQ3: What was the departmental reaction to these changes?

- How were changes communicated in the department?

RQ4: What are the possible long-term impacts of changing this program?

- What are the long-term impacts of changing this program?
- What is the likelihood this will be sustained?
- Will these changes catalyze the department to do further or subsequent reforms?

RQ5: What challenges obstructed change?

- What challenges are still present?

RQ6: What was the guiding message for change?

A. Positionality statements

To answer the above research questions, each scholar came to this work with their unique perspective and positions within the department in question. This section outlines and explains each author’s positionality in order to provide the reader with more information as to how our positions may have impacted this work.

R. B. is a junior faculty member in the department profiled in this study. He was not present for the event that accelerated the change in the department, but is a participant in the resulting policies. Because of his positionality of being in the department, but also being the lead PI on the project, he only had access to aggregate anonymized data, which were processed by the second and third authors. R. B. previously completed his dissertation work with Charles Henderson, who is an expert in change in PER, however R. B. did not conduct change research with Henderson. This may, however, have impacted his perspective.

M. L. was a postdoctoral researcher in the department profiled in this study. They joined the department in June 2020 and were therefore not present for the event that accelerated change. They collected all interview data, attempted to anonymize data when possible, and only discussed specifics that may have been identifiable with A. K.; discussion with other authors was done in aggregate to protect the anonymity of interviewees. M. L. has never

met faculty, staff, administrators, or students in person but has interacted with some of them through online meetings and orientations.

A. K. is an independent consultant and researcher who also works as a half-time project manager at AAPT and was a former postdoc working with Charles Henderson. Although she had no relationship with the University of Utah and was not aware of the change work around the physics Ph.D. program prior to the larger study, she has previously published with R. B. She only discusses the data with R. B., J. G., and P. S. in aggregate form. She has met some of the faculty, staff, and students at a visit in November 2019 related to the larger study. Some of the meetings were interviews for data collection, others were more general getting to know one another meetings. When working on the analysis, A. K. has only relied on what is in the transcripts and has not seen the de-identified data. This was to ensure she only drew upon what was collected for a research context.

J. G. is a tenured professor in the department profiled in this study. He was present in the department during the entire timeline discussed here, was involved in some of the specific events described, but was not a member of the core group of faculty who worked most closely on the reform efforts in the spring and summer of 2018. Because of his positionality of being in the department, but also being a co-PI on the project, he only had access to aggregate anonymized data which were processed by the second and third authors. His primary research area is nanophotonics, with a growing involvement in science education research. He has been Director of the University's Center for Science and Mathematics Education since October 2014.

P. S. is a tenured professor in the department profiled in this study. She was present in the department during the entire timeline discussed here. P. S. advocated for and worked on reforms prior to the event that accelerated change and was a member of the core group of faculty working on subsequent reform efforts. In 2018–2019, P. S. served as associate chair of the department, tasked with overseeing department operations related to its educational mission. Since Fall 2018, she has been a member of the newly created executive committee, which serves in an advisory role to the chair. Since July 2019, she has been Associate Dean for Faculty Affairs in the College of Science. P. S.'s primary research area is high energy theory, though, due to her role in reforming the graduate program, she is a co-PI on this project. She only had access to aggregate anonymized data that were processed by M. L. and A. K.

IV. METHODOLOGY

A. Theoretical framework

Two theoretical frameworks were employed in this study to guide data collection [63] and analysis of the change process [26]. In data collection, standpoint theory (SPT)

was employed to ensure that data were being collected from the perspectives of various persons in the department that collectively represent the voice of those impacted [63]. SPT has previously been used in PER to study the experiences of marginalized groups from their collective positions in physics [30–34,64]. In this study, these standpoints could represent being a student, junior faculty member, or a leader in the change process. Using SPT reminded the researchers to continually look for the spoken experience of participants and delay personal interpretations of their experiences.

The theoretical framework used in analyzing the change process itself was complexity leadership theory [26,49]. This framework suggests three leadership mechanisms to enact and sustain change: (i) disrupting existing patterns; (ii) encouraging novelty; and (iii) acting as sense makers [26,49]. In this way, the data were considered for how past practices were addressed, how new practices were implemented, and how good ideas were amplified through buy-in and team propagation.

B. Ensuring confidentiality

Ensuring anonymity of participants was crucial in this work, and difficult to maintain considering the small size of the department. Consequently, quotes will not be presented, and no tally of individual groups will be reported. Furthermore, data access was limited to the researchers who were not long-term employees of the University of Utah. Only M. L. collected data with faculty; they anonymized the data to the best of their ability before giving access to the other coder (A. K.) who also collected some data from students. The remaining authors had no access to the raw data and only saw aggregate results.

C. Data collection

Data were collected in the form of artifacts from the events and in-depth one-on-one interviews with those involved in or directly affected by the change. Artifacts came in the form of policy reports from the time of change, articles published online, and website archives of announcements and past policies. Interview data were collected from 33 participants, with one being a written response. Although numbers of each category will not be shared, we list them from largest to smallest number of participants: faculty, students (past and present), administration, and staff. Interviews used an open ended protocol where each category of participant had a different set of questions based on their position in the department and change process. These interviews were the main source of data and the artifacts were used as a secondary source.

All members of the physics and astronomy faculty were invited to participate in the interviews. Emails were sent out in mass, with follow-up individual emails being sent out for recruitment. Two faculty members who were prominent in the change process helped identify administrators, staff,

and graduate students to be interviewed. One graduate student who was interviewed identified other graduate students to invite to the study. Further information on participants cannot be shared in order to protect their anonymity. Further, data representation in the results below is also limited because longer quotes and text could easily reveal the identities of interviewees.

D. Data analysis

The change artifacts were used to reconstruct the timeline of the change in the department to provide a detailed story to the reader in understanding what led up to the change process discussed by participants. Interview data were analyzed by M. L. and A. K. with aggregate anonymized data shared with R. B. J. G. and P. S. had no access to the data and only saw the results presented below. Data were analyzed using a constructivist grounded theory approach of line-by-line coding for actions, and the large groupings were combined to form overall themes [65]. The two coders met weekly to discuss and compare their codings until consensus was formed.

The codes and themes were then used to answer the research questions in narrative form. Counts for codes, however, were not particularly meaningful because each person experienced the change very differently. Each had their own perspective and relationship to change. The voices of all participants have been combined to inform the narrative presented in this article, creating a joint, albeit nuanced and complex, standpoint.

There were four basic steps to the data analysis. First, M. L. created a short narrative description that summarized the interviews they conducted. A. K. generated possible research questions based on her background knowledge of change theory and the narrative from these interviews. These research questions were then considered by M. L. and found to be relevant to the interview data.

Second, both M. L. and A. K. independently identified codes based on the formulated research questions from five transcripts. When sharing and discussing these initial codes they realized that they were of different grain sizes, but covered the same general topics. They decided to use the codes of smaller grain size as they could be collapsed later in the analysis if it made sense to do so.

Third, using the agreed upon themes, the researchers independently coded another ten interviews. After coding these transcripts, M. L. looked closely at the differences between the researchers' findings. It was observed that the researchers often coded the same event, using the same code, but with different quotes. Together, they decided that these codes would be used for identifying themes and reconciled the differential quotes attributed to each code.

Fourth, they coded the remaining 12 interviews. With all the transcripts completed they decided to alter their approach to consider differences between their codings after determining that a quote by quote analysis was not

useful. In the revised approach, they looked for instances where one researcher coded a participant discussing a theme and the other researcher did not. This allowed them to determine whether they agreed or disagreed with what codes and themes were discussed by each participant. Using this process, they were able to refine their understanding of the codes and create a more well rounded narrative of the change process.

Finally, after all differences were resolved, M. L. looked at which codes were used by the different participants. This final listing of codes is what we present here in a narrative as our results.

E. Limitations

The limitations of this study include the time at which the data were collected, the type of data, the positionality of the collectors, and access to participants. The data in this study were collected three years after the initial event that triggered the acceleration of change. The change, however, unfolded in these subsequent years and continues to do so. The time at which these interviews were collected may impact accurate recollections and personal feelings towards the results. Similarly, the type of data collected may limit our findings in that we are only able to report on recollections of the events. For example, as we were not present during the change process to directly observe the interactions between committee members, our themes may be more of a surface recollection of those interactions based on the memory of our interviewees. Further, the primary researcher (M. L.) was a postdoctoral scholar of a junior faculty member in the department. Their positionality of being in the department and working with a faculty member may have affected what participants shared. Data were also not collected on race, gender, sexuality, ability, and other demographic information in order to protect confidentiality, which may be factors in an individual person's experiences that the data collected might not speak to. Lastly, not everyone involved in or impacted by the events and changes was included in the study. Consequently, particular voices and story elements may be missing from our constructed standpoint and others might be overrepresented.

V. RESULTS

A. Interview results for each research question

Here we present the common themes found for each research question. Not all of these themes were mentioned by every participant, but we found that all are relevant to generating a complete picture of the change process within the department. For some themes, we found that a portion of interviewees did not discuss any aspect of the question we were trying to answer. This most commonly occurred with the students that were interviewed, as they were not privy to the work being done in some areas.

B. RQ1: What events caused the department to change the doctoral program?

1. Tragedy as a catalyst for ongoing change

Given the back story presented above, it might seem that only one event—the tragic death of a doctoral student—caused the department to change their doctoral program. While this event was mentioned by many interviewees, it was not the most common catalyst of change that was uncovered. This tragic event was often mentioned as a starting note, being public and a consequential occurrence that was obvious, but there were other underlying events that spurred change as well.

Two themes were equally prevalent when identifying what caused change: *new people* (namely, faculty who were new to the department) coming into the department and *outsider influence* (i.e., members of the central administration who were not in the department or those not affiliated with the university). Around 10 years prior to the tragedy, the department began hiring new tenure-track and research faculty members with new research specialties. This new influx of department faculty brought new ideas about how the department might evolve. Many of these new faculty had ideas of how to improve the graduate program; some of these ideas were implemented, but others were not due to resistance from faculty with longer standing in the department.

After the tragedy there were various outside influences that pressured the department to change. While these influences were related to the tragedy, we view them as separate events because they were described as an external component to the change. We categorized different types of outside influence into two categories: *university administration* and *influence from outside the institution*. University administration was a large influence in the change process as they imposed a pause in graduate admission, threatening the entire program. This closure was instrumental in getting change started as the department had to come together or potentially suffer the consequences of not having a graduate program. Influence from outside the institution was mentioned in two ways: (i) this becoming an international incident, and (ii) a published law firm report about the state of the department. Both of these influences led to change by placing public pressure on the department and for shaming the state of the graduate program for its role in the tragedy that occurred.

The final theme, mentioned much less frequently, related to *having small wins*. As discussed previously there were faculty working for change before the tragedy occurred. The small changes that were successfully accepted and put into action helped create the ideas for larger change. However, this theme was not discussed as much as the other four, implying that either fewer people knew about these small wins or that people did not believe that small changes were a driving force for change in the doctoral program.

2. Factors supporting change

Along with looking for themes about events that caused change, we also wanted to understand the relationships or factors that helped support change at the beginning and that came about to support the change process. Because of the nature of our interviews and the long timeline of change, it was difficult to distinguish between relationships and factors that occurred at the beginning or were developed throughout the change process. Therefore we choose to describe these without this distinction.

The most talked about factor that supported change was the *growing awareness of a large set of problems within the graduate program*. All but one of the interviewees mentioned that there was an awareness of a problem within the department. Awareness grew as the different events, including the death by suicide or the case of concern about data, occurred. Eventually people in the department began to realize that there were serious issues that needed to be fixed. The growing awareness of departmental problems thus helped people get on board with the overall change process and reduced faculty resistance.

We found that *people dedicated to the cause of change* was the most common theme when considering the relationships that helped shape the change. As discussed above, there were already faculty (particularly newer faculty) trying to make change before the tragedy. After the tragedy occurred, even more people in the department became dedicated to changing the system. These people formed connections through a communal sense of purpose and dedication, which helped produce more robust change. As people began to understand that they had a personal stake in the graduate program, the change process became easier as everyone began working together to solve problems.

A theme mentioned less frequently was that there was a *team of trustworthy people* who led the change process. Trustworthiness, as described by interviewees, was gained through past experiences and interactions with the different team members who had the department's and students' best interest in mind. As described earlier, a new chair from another department was brought in to help drive the change process. Some new systems were put into place, including a new executive committee to work on the change process. The formation and work of this committee was mentioned often as an important lever for change. Committee members were trusted by department faculty to do the work of finding good solutions and using the ideas that were already present in the department. Because they were well respected, the committee members were therefore able to move swiftly in the change process and exert influence over both the faculty and new chair.

We also found that about a third of interviewees mentioned that either they or someone they knew had a *sense of responsibility to change*. There was often mention of a moral obligation to assist in the change process. This factor motivated different members of the department to

become involved in or support the change process. We also discovered that a *sense of urgency* was a factor that influenced people's involvement in the change process. This sense of urgency manifested itself for different reasons: some noted that the closure of the graduate program made the need for change more pressing; others discussed how the change became more urgent after central administrators got involved; and some mentioned how the tragedy made evident that department-level change was inevitable. While the sense of urgency might not have been a main motivator for an individual to get involved in the process, it was a factor in getting all the faculty on board with the changes that were occurring.

An important factor that happened throughout the change process was *gathering knowledge or information*. The knowledge and information gathered was mainly about what other departments on campus were doing, as well as understanding best practices and how those might be adapted and applied to the new graduate program. The executive committee found that this type of information worked well at persuading faculty to support the proposed changes to the graduate program. One other factor that helped persuade faculty to support or agree to different programmatic elements of change were *small wins*, such as those mentioned above. These small wins came from making incremental changes that faculty agreed with and established credibility for those leading the change. The faculty leading the change were then able to leverage those small wins and their credibility to further convince the department to accept larger changes.

There were three more themes uncovered that were talked about less frequently by the participants: *the value of the graduate program*, *a loss of reputation*, and *the ability to connect to faculty norms and values*. Finding value in the graduate program was a factor that motivated change from the beginning for some. Observing a loss of reputation in the graduate program happened after the tragedy within the department. A few interviewees mentioned how this reputation loss encouraged members of the department to accept and work on change for a new graduate program so that they could help improve and regain their reputation. Similarly to the above themes, finding value in the graduate program encouraged people to aid the change process or accept the changes as it would help their own careers. Connecting to faculty norms and values was about people realizing the ways in which the graduate program may have not been in line with faculty interests. This disconnect spurred change by trying to align the faculty's ideals with the pragmatic elements of the graduate program.

3. Challenges to change

All of the themes discussed so far have been about the aspects that generated, supported, or created change within the department. When trying to answer this research question, however, we uncovered some impediments to the

change process. These themes included *small and insignificant changes that occurred*, *failure to follow policies*, *no sense of urgency*, and *general faculty resistance*.

Two of these themes, *small and insignificant changes that occurred* and *dysfunction with respect to policies*, were mentioned by about a third of interviewees. Changes described as small and insignificant all occurred prior to the tragedy. Interviewees, for example, discussed how there had been slight changes to curriculum that were different from the larger curricular overhaul instituted after the tragedy, as well as how approaches to managing the graduate program differed before and after the tragedy. Discussion of these small changes was accompanied by mentions of how they were not enough to address the larger problems within the graduate program. In contrast to the small wins that helped convince faculty to make larger changes, these small changes were often viewed as being simply not important enough to matter. Dysfunction with respect to policies also played an important role in how people viewed others within the department: it was observed that many faculty did not follow policies, whether new or old, when it came to working with graduate students. This dysfunction further harmed the students in that they did not know the policies or what their rights were.

While there were some individuals that gained a new sense of urgency throughout the change process, there were also some who observed or believed there was no need for urgency to change the graduate program. Faculty may have known that there were issues, for example, but believed they had more time to fix them, or that changes could be made one at a time rather than collectively. Students observed that the department might have seen the pieces of the program students identified as problematic as issues that could change over time rather than being a priority. For example, one student discussed how the department was unaware of issues with students' tuition benefits or salaries, and that once the department was made aware, they fixed the issues slowly from the student's perspective.

One final theme that we identified was that of *general faculty resistance* to change. While we will discuss this in more depth when presenting results to research question five, we mention it here because it presented a challenge at the start of the department's change process. General faculty resistance to change was persistent throughout the whole change process, and thus appeared in most of our analysis for each research question. For this question, we found that some faculty resisted change because they wanted to continue the "traditions" of how the department always ran.

C. RQ2: How were decisions regarding programmatic changes made?

1. Who devised the changes

At the beginning of the large change process, the department created an *executive committee* consisting of

three tenured faculty appointed to work on developing the overall change ideas for the graduate program. The executive committee communicated with two different populations about the ideas they generated: the *oversight committee* and the *department faculty*.

The *oversight committee* was made up of program administrators and was formed to oversee the change process and decide when the program was ready to re-open. They gave feedback and asked many questions, mainly communicating with the executive committee and the chair. While they helped by discussing the changes, the department as a whole was also responsible for coming up with the ideas and settling on what they wanted to do.

All tenure-line *faculty* would vote on the changes proposed by the executive committee in faculty meetings. It was not understood that this vote had a specific percentage of approval needed for a change to be implemented: instead, some majority was voted on, and the chair would ultimately decide. As stated previously, the executive committee consisted of three tenured faculty; there were, however, other committees within the department (e.g., the admissions committee) that could have junior faculty adjacently involved in the change process. Some interviewees mentioned that *junior faculty felt more or less left out* of the change process, either as a protection for the department or as a protection for themselves and their tenure process.

2. How feedback and discussion influenced change

Many of the themes we identified were related to discussion, as there was significant discussion during the change process. Many reported how they *engaged in many conversations* about the change process. Discussion between different members of the department was both formal and informal: formal conversation took place in committee meetings, in emails, as well as at faculty meetings, while informal discussion happened in hallways, offices, as well as at meals. Whether formal or informal in nature, these conversations were essential to the change process as they helped change agents communicate and edit ideas.

In addition to interviewees mentioning their involvement in many conversations, we also saw that many people discussed a *need for discussion rather than just email exchange*. While email exchanges were used during the change process, in-person discussion seemed to be the preferential form of communicating. Interviewees expressed that it was easier to generate ideas and communicate face to face, and that more ideas could be presented at the same time by communicating this way. Email exchanges were instead used mainly to schedule meetings and communicate written information prior to discussion.

Many expressed that conversation and discussion were often about *iterative feedback with other stakeholders*. These stakeholders included members of the department—faculty, staff, doctoral students—as well as administrators.

By communicating and soliciting feedback often, the ideas about change were constantly evolving, allowing for a faster timeline as well as fewer and/or less extreme arguments when voting. A few interviewees mentioned how this iterative feedback with other stakeholders could also be supportive in nature: for example, committees would discuss things among their members but discussion between committees was far less frequent.

Some mentioned how *regular goal oriented meetings were useful*. By presenting a common goal for a meeting, attendees were able to stay focused on and ultimately accomplish a set task. Some examples of these meetings were monthly e-mail communications from the executive committee to the oversight committee about the progress of the changes and faculty meetings that were set to discuss one specific change (e.g., the comprehensive exam).

Another fairly common theme was how *team members had specific tasks*. People were not necessarily assigned to specific tasks, but rather picked up tasks they felt they could accomplish. Some tasks were obvious based on the position of the person in charge of them: those on the executive committee, for example, were charged with rewriting the graduate handbook because it was one of the conditions of re-opening the graduate program.

A few of the themes identified mentioned how the decisions for change were aided. Some discussed how *approval or support from upper level administrators* (e.g., the oversight committee) was helpful in deciding which changes to make. Having benchmarks to work towards moved the change process forward, and people were kept informed about what changes needed to be completed. This needed approval also fueled the themes of discussion and iterative feedback as discussed above.

Interviewees mentioned how *focusing on the positive and not the punitive* aided in the decision making process. One interviewee, for example, discussed how “it was good to have a group of people who were positively focused on the tasks at hand.” By having people focus on the change process instead of the “punishment” of closing the graduate program they were able to make forward progress.

It was also helpful to see *visible change for students* when it came to deciding on different elements of change. This element was important as those changes that were more visible demonstrated that attempts to make a better program were actually happening. Graduate students, for example, created their own small change by starting a social hour. This social hour showed that community was important to the graduate students and it was an area they were lacking previously. By creating these visible changes, the department as a whole could better see how change would impact the program and aid graduate students.

3. What informed the change

One source mentioned by many as informing the change process was *student input and representation*. Student

input and representation appeared to be given mainly in the form of town halls. These town halls, often run by the GSAC, were a forum where concerns discussed among graduate students could be brought back to the faculty. The department also listened to students' concerns by meeting with the leaders of the graduate student committee directly: this labor was, namely, accomplished by the committee members who met with GSAC's faculty representative and the department chair. Listening to student concerns ensured that there was representation of their ideas in both the new policies specifically and the change process as a whole.

Two different sources of data were mentioned as informing the choices for change: *inside and outside data*. Inside data includes two forms of data that were generated within the department or the university: characteristics of other departments at the university, and data about the current physics graduate program. Data that were generated about the old program were mainly used as a way for showing what the current issues were. Data about other departments at the university helped demonstrate how graduate programs might thrive in the current university system.

Outside data provided new ideas for change in the department. For example, data about how peer institutions generated change ideas were mentioned. Reforms to the content and structure of comprehensive exams, for example, relied heavily on outside data to help convince members of the department that the GRE should not be used as part of the exam, as well as to provide examples of different types of exam structures that exist in similar physics departments.

These two themes, *student input and representation* and *inside and outside data*, were sources for the different types of reform. No theme was identified for how topics for reforms were chosen from these sources.

D. RQ3: What was the departmental reaction to these changes?

There were many positive reactions to changes within the department. One particular change that was mentioned as being a positive driver in the department was advising day—showing that *meeting with students regularly was viewed favorably*. On advising day, each graduate student is required to meet with their advising committee for a “check-point” meeting each semester. All faculty are expected to make themselves available for these meetings, and the department creates the meeting schedule to prevent conflicts. These more frequent meetings were viewed overwhelmingly favorably within the department as they allowed for increased observation of students' progress and provided space for students to communicate their concerns directly to the faculty.

Faculty reacted positively when there was *evidence of success*. Earlier small changes encouraged faculty to accept the larger changes to come. For example, advising day was implemented before the closing of the graduate program. It was initially difficult to convince faculty to change advising

practices and adopt advising day, but once it was implemented successfully, the faculty began to see the benefits of incremental change. When the university closed the department, a major requirement to re-open graduate enrollment was massive reform: this requirement was leveraged to encourage a positive reaction to change so that the program could reopen.

Along with the idea of earlier success contributing to a positive reaction, we saw that some mentioned *measurable outcomes* as being positive indicators for faculty. Faculty viewed measurable outcomes as sources of data; the main changes associated with such data were stopping the use of the GRE in admissions and modifications to the comprehensive exam. For example, some data showed faculty that the GRE and comprehensive exams were biased towards minorities. Communicating these realities through data led faculty to feel assured that change was necessary, making them more likely to positively view and accept change.

There were also faculty members who *felt good about the changes even if they were not directly involved* in the change process. Such faculty said things along the lines of *people who were not largely involved in the change process were happy to have the program back, to have control of the program and see things moving in a better direction*. On the other hand, there were negative responses to change within the department. One such negative response was an *ambivalence around supporting a better culture* within the department. A student explained that their advisor, who had accepted changes, expressed enthusiastic approval when the student would break new policies surrounding working hours. This was an example of how some who support change policy might have trouble adapting to a new culture and could relapse to prior behavior that might be in opposition to new policies.

Some interviewees also *disagreed with the university administration's decision to close the graduate program*. Faculty in particular oftentimes mentioned that this choice was unfair to many stakeholders. Some, for example, expressed the closure was detrimental to junior faculty, as they are most in need of new graduate students to advance professionally. In the view of these participants, those who least deserved to be punished were facing the consequences of the old system.

As with research question one, we also found *faculty resistance to change* to be an important theme when looking to understand the departmental reaction to these changes. Many of those who discussed faculty reactions to change in their interviews mentioned that faculty were not supportive of and were resistant to the change that was happening. Interviewees recalled faculty saying things like “that's not how we did it when I was in grad school” as evidence of why the system was fine. This more traditional sentiment was in direct reaction to changing the policies to be more nontraditional.

Change was communicated in three main ways: informal gatherings, email, and faculty meetings. Informal gatherings

consisted of people meeting in hallways, walking into each other's offices, casual dinners, and lunches together. These informal gatherings appear to have been an important mechanism to communicate change among faculty, and those who were less connected found it difficult to get information. Email was a large part of how faculty communicated with the administration. One benefit to email communication was the speed at which communication could occur, since finding times when the admin and faculty could all meet was not simple. In lieu of providing specific information about the actual changes occurring, however, emails sent to the whole department instead often times provided a cursory overview of changes, as well as when to expect more detailed information in the future. Faculty meetings were the more formal method of communicating change ideas to the department, and also served as the forum where other members of the department could comment on those ideas. While effective in getting information to and from the larger group of people, faculty meetings were also not happening on a weekly basis, so there was not constant communication in this way.

E. RQ4: What are the possible long-term impacts of changing this program?

1. Long-term impacts

There were a few themes that we identified as long-term impacts that were already evident to the interviewees. One such theme was *visible long-term change*. Many interviewees discussed visible elements of change that were more resistant to changing views, such as the physical space for graduate students to socialize in or the graduate handbook that was put on the department website for all to access. By making more of the elements of the graduate program visible to all, it becomes harder to ignore the changes, in turn causing more people to participate in the new system. Increasing the visibility of changes can also demonstrate that a change was successful, or that a change needs further reworking to become so.

Two positive community elements were apparent from the interviews: a *burgeoning sense of community in the department* and *students feeling supported*. One way burgeoning community was described was in how the graduate students interacted more frequently and became more supportive of each other. By adding graduate student social events, creating a graduate lounge space, and GSAC becoming more involved in the everyday affairs of graduate students' lives, interviewees saw a deeper sense of community beginning to form amongst graduate students. There were less obvious examples about the increased solidarity among faculty members, but it was still mentioned that more faculty were working together towards creating community and supporting students than before. While there were similarities between how increased student and faculty communities started, the emergence of a stronger student community appeared earlier on in the

change process than did the emergence of a more unified faculty community.

It was also mentioned how graduate students were feeling better supported by the department throughout the change process. Faculty mentioned the ways in which their overall relationship with graduate students had changed as a result of listening more to their needs and wants. For example, when students said they needed formalized maternity leave, faculty listened and created a maternity leave policy for the graduate student handbook. Students mentioned they felt the overall department was listening more to their requests than ever before, pointing to items like maternity leave and the graduate student lounge as positive evidence the faculty were paying increased attention to their concerns.

Despite these positive changes, we also found that interviewees mentioned that *negative research group cultures still remain* within the department. Particularly, some students mentioned that those from traditionally marginalized groups in physics are still treated worse than their peers who are more traditionally represented in physics and astronomy, even after changes had been made to the program. Interviewees mentioned that the masculine-driven culture surrounding research pushed out those not "made of the same cloth." Words like "tribal" and "toxic" were used to explain the environment of research groups as a whole, impacting students' interactions with each other and their understandings of themselves.

2. Sustainability of policies

When determining the sustainability of the program, we sought to understand whether changes would continue to be carried out should the leaders of the department (and the leaders of the overall change process) leave or become less involved. However, we note that it is too early to understand future sustainability. Rather, we identify themes that might signal ways in which this process might be sustainable that were mentioned by interviewees.

Two themes were identified related to the sustainability of the changes made to the graduate program: the *importance of policies and following them*, and the *seriousness of consequences being apparent*. For the importance of policies and following them, many interviewees mentioned that faculty had previously not been following written policy, making it difficult for graduate students to understand what was expected of them. By noting how policy was not followed, many could identify how important following policies as written would be in sustaining change. Other interviewees discussed discrepancies in how new policies were written, enforced, and followed. One interviewee, for example, mentioned how it was difficult at first to convince faculty to act on the new policies. Once they were able to (a process they found was simple), however, faculty began to follow them more. This suggests that these changes are on their way to being sustainable within the department.

A few people mentioned that the seriousness of the consequences (e.g., program closure) was apparent. The university shutting down the program showed that there were real problems that necessitated change. This led some interviewees to discuss the ways in which not having a graduate program would affect the junior faculty and the whole department long term. Interviewees realized that sustainable changes were needed to prevent the program from being administratively shut down in the future [66]. Faculty were also open to making changes in order to prevent any further student tragedies.

3. Further reform

One theme was identified when considering further change to the department, *change as a continual process*. This theme was identified by many faculty, which may bode well for further reform. One example that further reform may already be occurring can be seen in the comprehensive exam: because this exam is only given once per year, figuring out the best approach for its administration may take multiple years, therefore opening avenues for change to continue over time. We also know that the department has now reformed the undergraduate curriculum, showing that they are continuing to analyze different elements of the broader physics program. By working on the department as a whole, one hopes that the faculty will continue to evaluate their own ideas and implement positive changes for the years to come.

F. RQ5: What challenges were present that obstructed change?

Many different challenges and obstacles can get in the way of change. Here we present the different things that our interviewees observed as obstructing change. The largest challenge the department faced was *faculty resistance to change*. As discussed briefly in answering other research questions, there was a subset of faculty that had a sense of tradition such that they did not believe change was needed. Multiple interviews mentioned faculty saying things like “this is how it’s always been done” when discussing why change within the department should not occur. Some minds were broadened over the change process, as can be seen throughout the themes in Sec. VD; faculty resistance was still, however, a prominent factor throughout the entire change process.

We found a few other challenges to change present within the data, all of which compounded on the general resistance to change and sense of tradition that faculty had. There, for example, was a *lack of urgency or not seeing the seriousness* of the problems with the graduate program. Faculty who felt this way are different from those that resisted change as they saw that there were issues within the graduate program, but believed the changes needed to address these issues could occur over an extended period of time. A lack of urgency meant that the changes that were

already underway were enough for these faculty, who saw that change was occurring slowly and thus did not feel that the situation was dire enough to push the change to happen at a faster rate.

Time constraints were also described as a large obstacle that obstructed change. Faculty generally do not consider change efforts part of their jobs, and the changes made before the tragedy were largely driven by those who took on the responsibility of enacting change on their own. Because faculty have a lot of responsibilities, some described that it is difficult to develop and make changes when their schedules are full. Similarly, graduate students, staff, and administrators also have full schedules and lists of responsibilities, and therefore described time constraints as complicating their ability to partake in efforts to make change happen.

Along with time constraints and no sense of urgency, interviewees also mentioned *potential slowness* as a barrier to change. We observed that faculty could be slow in acting due to their extensive conversations surrounding change. One interviewee mentioned that the method by which everyone learned about change ideas was slow. They observed that the committees would generate ideas which would then be given to other committees. In the case of larger changes, these ideas would then be presented to administration for further comments and conversation before the whole faculty would be made aware of changes through emails or in faculty meetings. These changes would then be voted on before being implemented. If a vote was not successful, the original committee would then have to make alterations, meaning the process would begin again. This long process ensured that many ideas were presented to come up with the best options, but its slow, often circular nature could therefore impede change as well.

Another obstacle that was mentioned concerned the *lack of written policy*. Within the department, there is a lot of institutional knowledge needed to understand how the program works that is often not written down. With no easy access to this knowledge, it is difficult for those who are new to the department to make change as they don’t know all of the ins and outs of the program. It was also mentioned that change is, simply put, just hard to accomplish. While statements like this do not include the depth of obstacles described above, it is still telling that there were those who knew obstacles were present, even if they could not expand on the specifics.

The above obstacles involve people realizing that there were issues within the graduate department and reacting in different ways. However, there were also interviewees that either stated they *didn’t face any obstacles to change or they didn’t mention any obstacles* in their interviews. Those that did not observe or did not mention any of these obstacles were either faculty who only became involved in change after the tragedy or students.

Many of the obstacles mentioned above are still present to creating change. The resistance to change and traditionalist sentiment seems to be still present within the department.

However, the tragic events that occurred and subsequent changes that have been made have helped some to overcome these views. Change makers still lack time, though, and the process of change is still a slow one that requires many ideas and different people to make happen. Ultimately, however, the tragedy rendered change as a necessary, albeit difficult, process for faculty to engage in.

G. RQ6: What was the guiding message for change?

In the literature review section above, we discuss complexity leadership theory as one lens for analyzing change. Within CLT-informed scholarship, researchers often discuss how change can be guided by a particular and easy to understand message or phrase. Therefore, we sought to understand what message or phrase might have been used among the department of physics and astronomy throughout the reform of their graduate program.

There were a few different guiding messages that we found within the interview data, all of which created a common goal for those involved in the change process. One such message was that of *students being people and that the department has a responsibility to treat them well*. This emerged as a message when the faculty were made aware, in multiple ways, that the students were being mistreated. Faculty used this as a way to think about what changes were needed (e.g., the expected working hours of graduate students), or as a way to convince others that change itself was necessary. Students also mentioned this guiding message in terms of the unjust treatment of themselves or their fellow graduate students: their mistreatment was apparent, leading them to push for departmental change.

Another guiding message was that the *department had a responsibility to clearly communicate expectations to students*. As discussed briefly above, some members of the department had difficulty following existing policies for students, and students could easily get lost in the system as a result. By realizing that the department had a responsibility to make sure there were clear benchmarks and policies in place for students to follow, they could focus on relevant change.

We also found the guiding message of the *department admitting students it can support*. Because the program had a history of students getting lost in the system or not having the support they needed to succeed, this became an important message for those involved in change. In particular, interviewees discussed how the department wants to make sure they have the proper supports in place for students prior to admitting them to the institution. This was also a guiding message in changing the admissions process to ensure that they were admitting students who would thrive within the program's new system.

We also found some evidence of the *start of a culture of caring* in the department, demonstrated in part by how junior faculty felt protected during this change process.

It was found that junior faculty were encouraged to reduce service appointments and were thus not as involved in the change events and procedures so as to not have their potential for tenure threatened. This shows that some senior members of the department realized they had a job to do, and that they ultimately should not burden junior faculty who just arrived at the university with being responsible for implementing change as the program's issues were not their responsibility to begin with.

VI. DISCUSSION

Change is a hard, slow, unpredictable process, a reality that was made clear throughout all of the data collected and was reflected in the timeline of events that led to programmatic change (Figs. 1 and 2). Though the process truly began in 2013 when a graduate program review and subsequent report coincided with a new chair being appointed, a tragedy was unfortunately required to catalyze the ideas that were already being proposed. Faculty in the department had been pushing for change in the period between 2013 and 2017, with some being considered and implemented early. An example of this is the advising day implemented in 2017. However, the larger structural changes required a spark to ignite them. Some similarities can be seen between this work and other large changes pushed in PER, such as SCALE-UP [45]. We can see how complexity leadership theory is relevant, as new people to the department helped implement these changes by bringing in new perspectives. Further, CLT demonstrates that input was needed from multiple levels, with multiple goals in mind (i.e., supporting junior faculty as well as the graduate students) to facilitate broad sustainable changes.

The genesis of the changes at the University of Utah, however, was fundamentally different from the catalysts of other larger-scale changes in PER. It was a tragedy, and not a physical infrastructural change (e.g., the need for physical classrooms that led to SCALE-UP) or a shifting of ideologies and opinions of the community, that prompted the large overhaul in the department of physics and astronomy. Research in the field of disaster sociology has documented the communal impacts of tragedies [67,68]. Reviews of this literature have shown that disasters largely bring communities together, and that the impacted persons are the first to try and help themselves and take on important tasks and responsibilities [67,68]. This same pattern clearly emerged in the department discussed here: the tragic death of a student by suicide sparked the community to come together, facilitate change, and vote in a way that would sustain and protect the program. It is possible to reflect on this change both through the PER literature and a new metaphor relevant to this specific context: a bonfire, discussed further later. Unfortunately, though, participants also revealed continuing concerns and lack of underlying social change.

A. How change literature in PER relates to the University of Utah

Findings by Henderson *et al.* (Fig. 3) in the change process of departments adopting evidence based teaching offers a point of comparison for this discussion [22]. In their findings, the authors point to four key strategies in change: proposed curriculum and pedagogy, creating reflective teachers, enacting new policies, and sharing one vision. Of these change strategies, the first and third are prescribed (strategies that someone can be told what to do and then do it). The second and fourth change strategies, however, are emergent, as they are created over time with no concrete goals, and take work to both achieve and sustain. For example, it is one thing to say “this is the vision of the department,” and another to have faculty embrace that vision and employ it in their activities. These four strategies are also split between being something that is individual based (e.g., classroom curriculum; individual faculty reflection) and environmental based (e.g., policy and shared vision).

The change strategies employed in this study were a combination of approaches similar to the ones described by Henderson *et al.* [22]. With the pause in graduate admissions and appointment of new leadership, existing ideas about policy were enhanced, discussed, and finalized through a complex sense making process. These policies are prescribed in that they are enforced by the department and available for all to see and enforce. Along with being prescribed, the policies also focus on changing the environment or structure of the graduate program. The policy reform was a large focus of the change effort in this example, but other changes also occurred. Curriculum reform, for example, was also discussed and implemented on a larger departmental scale: the types of classes taught, as well as how many and which classes students are

required to take, became a prescribed element of change because students are now allowed to pick a track based on their research interests and are then recommended courses to take. On the larger scale, this curriculum reform looks to be a subset of the policy reform. There is, however, a delicate interaction of these broader policy changes with individual choices in the actual classroom. This manuscript is focused on the change process and the changes implemented by the change agents, who were largely faculty and staff; a second paper will discuss the student experiences with these policies and the curriculum will be discussed there.

This change process was led by a particular committee of tenured faculty, but often evolved their thinking and ideas through informal input from junior faculty and formal input from all faculty in meetings. Ideas and input were often influenced by simple guiding messages focused on rebuilding and saving the graduate program. Although this could be seen as being similar to the shared vision component of the Henderson *et al.* model, such a vision was never explicitly created by the change agents. Sense making was important for these conversations for other faculty and staff to gain understanding, acceptance, and buy-in for these changes, helping create a communal goal. The need to engage different stakeholders in conversations is also a theme in CLT literature [26].

We also see that there is some element of continual change surrounding the graduate program, showing the emergent nature of the change as it is still in motion. As change agents continue to alter and tweak the program they may do so with their communal goal of preserving the graduate program as well as having simple messages to guide their continued work. Because of the nature of our data, we do not see evidence of the individual reflective teaching practices so that is one element of this framework that we can not relate or discuss with our findings. Figure 4 summarizes the change process in the department.

Although the physics department created this new structure for their graduate program, many of the new aspects in the department are reminiscent of recommendations from literature such as the TGSE report or the more recent efforts around GREs and other admissions practices [54,59]. Key members driving the change have been active in various spaces around improving physics graduate education. Engaging in these spaces likely helped with sense making around why changes should occur and how to do these changes in their department. This is also in alignment with other literature regarding the importance of preparation for change, even when one cannot implement the changes they would like to make [45]. However, we have to carefully interpret the results presented here, as many of the policy changes and reforms were made necessary by the university administration. Without making these changes, the program could have been closed permanently.

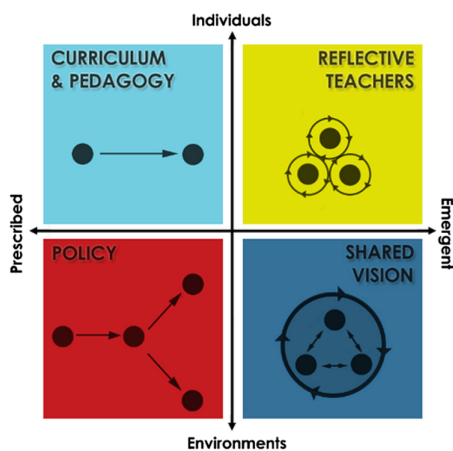


FIG. 3. Four types of change strategies. Adapted from Henderson, Beach, and Finkelstein [22]; image credit to Alexis Knaub.

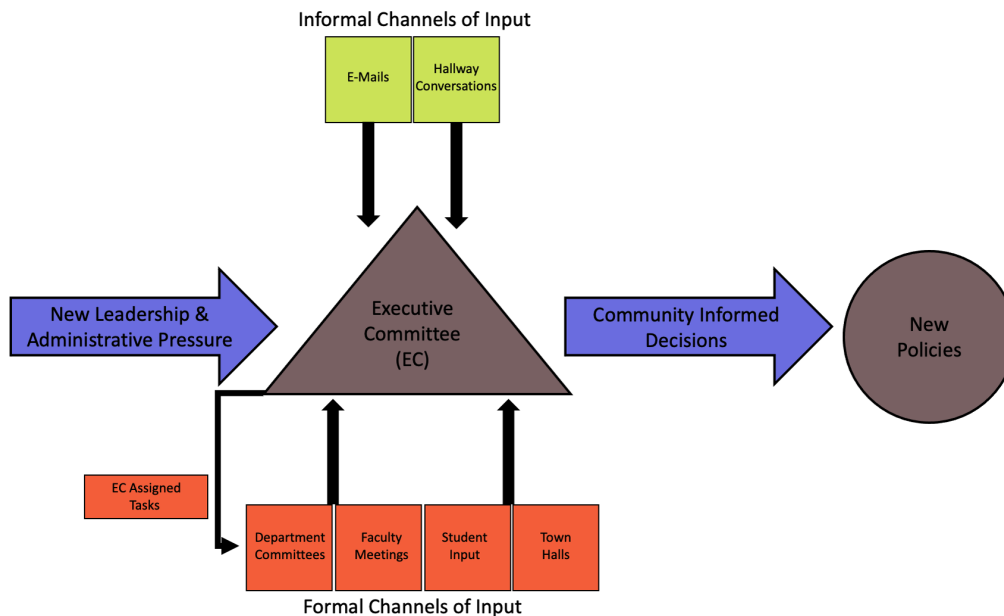


FIG. 4. Flow diagram of the change process.

B. A new metaphor for the genesis of change: Bonfire

The process of change observed here was both prescribed and emergent. Faculty were told and approved (with input) of the new policies being enacted. Faculty then had to themselves ensure these changes were applied. Actualizing change, however, took years of dedicated work. From the release of the initial graduate review in 2013 onward, faculty leadership in the department created many ideas for potential change in the graduate program to address student challenges. Built on top of the kindling of the department's underlying challenges, these ideas and policies served as the fire base of the bonfire. However, this kindling and fire base sat inert until the spark struck by the flint of tragedy set them ablaze. Figure 5, below, shows a metaphor we created to describe these changes, a bonfire. The bonfire's continued burning, though, relies on oxygen, which is provided in the form of continual review, policy tweaks, reflection, and assessment of the graduate program.

This metaphor is apt for this project as it clearly lays out the existing foundations, as well as the tragedy that

facilitated its implementation. The change was not manifested purely through notions of social good and program improvement; they came about because of the potential closure of the program. It is not possible to say if the program would have been reformed without the tragedy, as it may have, but the tragedy clearly put a focus on ongoing efforts. This top-down focus was a forcing function in catalyzing change to protect the program. In this view, the bonfire metaphor offers a poignant starting point in considering how exactly this change process emerged.

It is also important to note that, unfortunately, student deaths by suicide have occurred in other graduate programs without sparking the fire of change. Existing conditions can be viewed as a base for our fire, as at this institution, there was a base in place allowing for the spark to take hold. Change leadership can be viewed as those tending the fire, because without them the fire might not have started burning, or may have only burnt for a short while.

C. Remaining concerns

Although new policies were adopted, integrated, and are now actively employed, underlying concerns and cultural issues remain, according to the perspectives of some participants. As revealed in the data, toxic research group cultures and interpersonal fissures still remain in the department. Further, many persons still feel aggrieved by the way the change process started and took place. The new policies, and the shared vision of sustaining the program, reduce the risk of abusive practices in research groups and negative student experiences in the program. These policies act as bumpers, giving students opportunities to discuss challenges, find solutions, or consider alternative pathways.

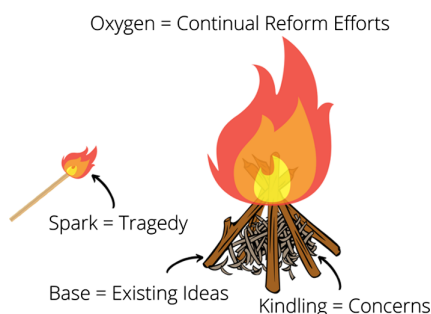


FIG. 5. Visual description of the bonfire metaphor.

In some ways, the change work done in this department is reminiscent of the work on creating SCALE-UP classrooms; similar to changing a physical space, changing policies is a nontrivial task. However, that does not mean that changes cannot be reverted or abandoned. Furthermore, these types of changes need to be maintained in some fashion. With SCALE-UP classrooms, instructional staff need to know how to effectively teach in those spaces. With implementing policy, faculty and staff need to understand how to do so to not only follow the exact wording but also reflect the intentions and spirit of the policy.

Furthermore, the department still has many much-needed changes to make to their graduate program. While it appears promising that the department will continue to build upon these changes and not only mitigate harm but also build a better department, the future is still uncertain. As described in the metaphor, the department must keep working to improve and perhaps overcome these remaining concerns; the bonfire must continue to be fueled.

D. Moving forward

Ongoing work for the department includes continued refinement of all aspects of the graduate program: recruiting and admissions practices; student supports (financial, mental health, etc., better connecting students with on-campus resources); details related to implementation of the comprehensive and qualifying exams; a continued focus on educating faculty, staff, and students about equity, diversity, and inclusion (EDI) issues including inclusive teaching and mentoring practices; and improving communication and collaboration among all department members. As examples of policy improvements related to communication and collaboration, procedures for advising day and the prompts that committee address are refined each semester, and the format of the follow-up faculty meeting during which each student's progress is discussed continues to improve (e.g., increasing discussion). It is becoming more broadly understood that upholding the status quo is not adequate and that the path the department has defined is fragile and can quickly be overgrown if not for careful stewardship.

The department also recently completed the first stage of a substantial change effort related to the undergraduate program. Since spring of 2020, the department has undertaken a complete reform of the undergraduate curriculum. This work, coupled with efforts to improve the quality and uniformity of instruction, constitutes the

work of the departmental action team, which was supported through the departmental action leadership institute as a member of the inaugural cohort in the 2020–2021 academic year. Through the departmental action leadership institute project, members of the departmental action team had the opportunity to learn about theories of change and develop department-specific strategies for future change efforts.

VII. CONCLUSION

A tragic incident and departmental concern for students was enough to bring faculty together to ensure their own survival, but not enough to immediately change all aspects of the underlying culture and climate as described by the participants. A leadership-driven process of change led to the current state of the program, with some faculty resistance that largely acquiesced to the larger need of program survival. This research suggests that policy change can make a large difference in the lives of graduate students, and help mitigate potential negative experiences, but is not enough to address all challenges and issues within the department culture. Further research is needed to understand how to change underlying social issues and constructs in the physics context, with a focus on sustainable practices for long-term improvement. Time will tell to what extent continual improvements will be made so that students can thrive and flourish in this department.

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APPENDIX A: CODEBOOK

Each code discussed in the results section is presented in Table I.

TABLE I. Codebook organized by research question, then themes, then individual codes.

Research question	Theme	Code
RQ1	Tragedy as a catalyst for existing change	Tragedy
		New People
		Outsiders (upper level admin) Outsiders (not affiliated with university)
	Factors supporting change	Having small wins
		Awareness
		Dedicated to the cause
		Team of trustworthy people
		Sense of responsibility
		Sense of urgency
		Gathering knowledge or information
		Small wins
		Value of the grad program
		Loss of reputation
Challenges to change	Ability to connect to faculty norms and values	
	Small and insignificant changes	
	Dysfunction with respect to policies	
	No sense of urgency General faculty resistance	
RQ2	Who made the changes	Executive committee
		Oversight committee
		Faculty
	How were decisions Made	Junior faculty excluded
		Engaged in many conversations
		Need for discussion rather than just email exchange
		Iterative feedback with other stakeholders
		Supportive feedback
		Regular goal oriented meetings were useful
		Team members had specific tasks
	Approval or support from upper level administrators	
	What informed the change	Focusing on the positive and not the punitive
		Visible change for students
Students input and representation		
Inside and outside data		
RQ3	Departmental reaction to change	Meeting with students regularly viewed favorably
		Evidence of success
		Measurable outcomes
		Felt good about the changes even if not directly involved
		Ambivalence around supporting a better culture
		Disagreement with administrators decision to close program
		Faculty resistance to change
RQ4	Long term impacts	Visible long-term change
		Burgeoning sense of community in the department
		Students feeling supported
	Sustainability	Negative research group cultures still remain
		The importance of policies and following them
	Further reform	Seriousness of consequences being apparent
		Change as a continual process

(Table continued)

TABLE I. (*Continued*)

Research question	Theme	Code
RQ5	Challenges that obstructed change	Faculty resistance to change Lack of urgency or not seeing the seriousness Time constraints Potential slowness Lack of written policy Didn't face any obstacles to change or they didn't mention any obstacles
RQ6	Guiding message for change	Students being people and that the department has a responsibility to treat them well Department had a responsibility to inform students of their expectations Department accepting students they can support Start of a culture of caring

APPENDIX B: INTERVIEW PROTOCOLS

Here are the three different interview protocols used to interview different populations of participants in this study.

1. Faculty and administrator questions

1. What do you believe initiated the changes made within the department?
2. Do you believe there is a common thread that influenced all the changes?
3. How long did it take to make these changes?
4. How long did it take to make these changes?
5. What, do you believe, stopped these changes from happening before the catalyst event?
6. Who did you collaborate with when discussing/making these changes?
 - (a) What did you collaborate on?
 - (b) How did you communicate while collaborating?, e.g., meetings, emails, video chat.
 - (c) How was work divided?
 - (d) What was productive/nonproductive about your collaborations?
7. What influences went into the changes?
 - (a) Other departments within the U?
 - (b) Departments outside of the U?
 - (c) National programs?
 - (d) Journal articles?
 - (e) Lived experiences?
8. What influenced the changes that you made?
 - (a) How did you decide on these large categories of change?
 - (b) Were there elements of change that were discussed but ultimately not changed?
 - (c) If so, why weren't they changed?
9. Why did you become involved in these changes? Were you asked or did you initiate your involvement?
10. What do you believe was the biggest change made?

11. What obstacles did you observe for making these changes?
12. What do you believe was the most important change made? Least important?

2. Administration questions in addition to faculty and administrator protocol:

1. Why did you become involved in these changes? Were you asked or did you initiate your involvement?
2. How involved were you with the changes being made?
3. What role did you play in these changes?
 - (a) Were you directly involved in the changes?
 - (b) Were you overseeing things or more hands on changing elements?
4. Did you collaborate with anyone during this change process?
5. How do you believe your position within the university helped or hindered the changes that were made?

3. Student questions:

1. What do you believe influenced the changes made within the department?
2. Do you believe there is a common thread that influenced all the changes?
3. What structural and programmatic elements of the program do you believe needed to be changed?
 - (a) Do you believe that these elements of the program have been changed? In what ways have, or haven't, they been changed?
4. Were you able to give input on the changes in the department? If so, how.
 - (a) Were your ideas implemented? If so, how.
5. What changes did you personally work on within the department?
 - (a) How did you decide on what needed to be changed?

- (b) What influenced your ideas surrounding those changes?
- (c) How did you aid in implementing those changes?
6. How did you work with the faculty/staff/administration when it came to the changes being made within the program?
- (a) Which group of change makers (faculty/staff/administration) did you work with?
- (b) How often did you work with them?
- (c) Did you have meetings with them? Email conversations? Respond to surveys?
- (d) Were your encounters productive? Not productive?
- (e) What were your best and worst experiences while working together?
7. Do you believe you gained anything from participating in the change efforts? What did you gain? Why didn't you gain anything?
8. What influence did your involvement in the change efforts have on your own degree?
9. Why did you want to participate in the change effort?

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