# Panel: Influencing Culture and Curriculum Via Revolution

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***Abstract*—The goal of this panel session is to introduce audience members to the challenges and successes of significant cultural and curricular change as enacted by awardees in the NSF program Revolutionizing Engineering and Computer Science Departments (RED). This panel will explore how organizations go about the process of cultural investigation and how they embark on culture change, using RED awardees of 2016 as the featured panelists (the second cohort). These teams are engaged in high-risk, high-trust-required activities focused on both the organizational and operational structure of their departments, and on re-envisioning engineering and computer science curricula to create professionals able to solve 21st century problems. A panel session allows the wider community to peek into these projects to see from the inside what's happening, even if only a bit. This paper captures short narratives on different themes of interest, developed by the individual teams and aggregated here as a first glimpse into the operations, challenges, and successes of these projects.**

***Keywords—organizational change, teamwork, revolutionizing engineering education***

## I. Introduction

STEM education is considered to be in crisis. At the collegiate level, STEM programs (and especially those in engineering and computer science) face challenges with student retention, professional competency of graduates, diversity in both faculty and student populations, and student (and faculty) enjoyment and motivation. Copious, excellent evidence exists to support improved STEM education [1], yet adoption by practitioners remains a persistent challenge (known as the research-to-practice gap) [2]. As Prince et al. [3] noted "the greatest impediment to improving engineering education lies not in finding more effective instructional strategies but in increasing the use of those strategies already known to be more effective than the traditional methods still found in most undergraduate classrooms". Unfortunately, efforts focused on single classrooms have not diffused to a broader audience [4]. Scholars are increasingly calling for a shared vision approach [5], in which various stakeholders co-create the emergent structures and processes that support change in their institutional contexts. These various elements

KC, TF, AJ, LM, MM, MM, EV are listed in alphabetical order; they contributed the individual themes in this paper. EI contributed the introduction and summary.

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together call for innovative solutions that involve step-functions rather than incremental change.

To address the challenges facing engineering and computer science education, the National Science Foundation established the multi-directorate program "Revolutionizing Engineering and Computer Science Departments" (known as RED). This program specifically targeted professional formation occurring in the middle two years of a four year program, and specifically emphasized "recruiting and retaining students and faculty reflective of the modern and swiftly changing demographics of the United States" [6]. One innovative aspect of this program emerges from the personnel requirement: proposals must be headed by a department chair, and must include an expert in engineering or computer science education and an expert in organizational change. This personnel framing emphasizes that success in revolution requires "an understanding of department organizational and cultural changes needed to create and sustain change". In the three years of the program, twenty institutions earned grants of up to $2M to implement their projects; these projects include activities like reorganizing curricula, reframing student-faculty relationship, significantly enhanced professional experiences, and integration with non-technical courses and curricula. These teams collaborate extensively as a cohort - known as REDCON - to develop shared lessons and to amplify their success and help others avoid their challenges [7]. The coordination of and research relating to REDCON is provided by a collaborative team from Rose-Hulman Institute of Technology and University of Washington (represented in this paper by Ingram) [8].

This paper, submitted to support the panel "Influencing Culture and Curriculum Via Revolution", centers on key themes as identified by RED-recipient teams in their first year of implementing their RED-funded organizational change. This collection of seven contributions emerges from the teams funded in 2016, and captures the unique voice of each department. These voices contribute to the work presented at FIE 2016 [9]. The panel discussion occurring at FIE 2017 will explore these themes and more, and will include ample time for questions from the audience. The seven themes explore relationships within and outside the departments, challenges anticipated and experienced, and new approaches to learning and working. The work of these seven teams - identified below by institution and department - represents the best available knowledge to date in engineering education regarding culture and change. Two prevailing concepts among the narratives are intentional hard work and cultural curiosity.

## II. Team Contributions

### A. *Creating and Using Tension (Iowa State University - Electrical and Computer Engineering Department)*

Through the RED project at ISU, Reinventing the Instructional and Departmental Enterprise, we aim to revolutionize engineering departments by identifying the gaps in practice and challenging the departmental status quo. Our hope is to change the learning cultures, update teaching approaches, build a sense of community between faculty, staff, and students, and support these changes via updates in departmental cultures, practice, and habits. To accomplish these changes, we're using what we call X-teams. These teams act as change agents and are collaborative and cross-functional groups to promote design thinking and positively affect professional formation in the middle years of the curriculum. This updated approach to evidence-based engineering education practice will enable the professional formation of students as engineers.

Creating tension is a way to initiate change. Tensions are inevitable, and a calculated imposition of change would be beneficial for a faster and a more in-depth transformation. All members of the community that constitute the department should feel the tension. Two groups in our engineering department are of great importance in the transformation: the students and the student support and advising teams. This latter group is more common in larger engineering departments, and is the natural ally of the transitions needed for revolutionary change. The RED team maintains close interaction with the advising groups, as they are closest to the students' needs, challenges, and overall cultural perspectives (and not to forget their hopes, achievements, glories and despairs). The advising groups help and convey to the RED team areas to target and the tensions that can be transformative to help change happen.

Beyond relying on the advisors, a healthy, dynamic interaction with the student body is necessary for the change to be understood and rooted in departmental culture. We have regular informational and discussion meetings with students. The message of the change, the ideas, the process, and the objectives are discussed with the students. Students help us achieve a more effective voice, see alternative options, and improve the process of change. Students will reveal and verify what are the essential tensions and can be our partners to resolve the tensions toward an effective cultural transformation. Students will also help restate our ideas and questions and reexamine our visions and approaches.

Cultures and habits are hard to develop and hard to change. Change takes time; healthy logical debates, careful listening, and inspirational engagement from all parts are important aspects of our work. As we develop the teams and institute the changes, there will be oppositions. Our colleagues who align more closely to the traditional educational approaches will oppose the change. They would feel the tension and would more adamantly advocate their approaches. The RED team needs to be patient, understanding, and provide them the freedom to do what they are comfortable with. We need to keep doing the right level of activities and engage students and the advising groups. As we gradually share our message, make the new classes, and initiate the new culture, the promising vision for the better and more inclusive future will become clear, and the change will be accepted and propel the cultural transformation.

In summary, we hope to create a cultural transition through the electrical and computer engineering community at ISU. This change can only propagate via the agents, advisors, and most importantly the student communities. The creation of tension, and the contrast of the approaches together with student leadership and engagement would be the best way to advocate the need and the importance of the change that we are

trying to bring to the departments. We believe that the new educational paradigm needs new approaches, and more inclusive, open, and engaging environments. Together these approaches and environments will help develop future leaders that are more capable and more effective when facing the diverse, and at times wicked [10], problems that we will face in the future.

### B. *Promoting Involvement (Boise State University - Computer Science Department)*

How do we help graduates be not only technically adept and effective team members, but also empowered to be agents of positive cultural change in their workplaces? Boise State's RED project seeks to answer this question by transforming undergraduate computer science education by offering a multi-year curriculum known as Computer Science Professionals (CSP) Hatchery. The CSP Hatchery replicates the best elements of a software company environment, layering in moral, ethical, and social threads with entrepreneurship and professional skills. The project's intent is to adjust faculty and student behavior in partnership with industry to improve workplace integration and to more intentionally address increasingly urgent workplace issues such as ethical practices and diversity. Two critical curriculum features are: (1) Vertical Integration: instead of being siloed, students at all levels will work with and learn from each other across classes; (2) Hatchery Units: to complement regular course work, short, narrowly focused units present specific foundational and professional concepts or skills that cut across the curriculum. In the first year of the project, The RED team is focusing on the development of Hatchery Units.

Involvement from industry partners and faculty are critical to the development of the CSP Hatchery. Industry partners need to be convinced that their input and participation has a real effect on the curriculum, faculty, and students. To accomplish this outcome, we involve them directly in the design and, in some cases, delivery of the Hatchery Units, as well as by giving them periodic feedback on the change process. We started with a meeting in September with our industry partners, where the aims of the project were explained. We then let the industry partners (seventeen professionals) brainstorm ways in which the curriculum could change. Six knowledge, skills, and abilities categories came out of this brainstorming process: Business, Collaboration & Teams, Entrepreneurship, Professional Skills, Research & Development, and Technical. Meanwhile, the HU proposal passed the University Curriculum Committee. Faculty from other departments liked the concept of HUs enough to want to adapt it to their fields.

We received fourteen Hatchery Unit proposals that involved seventeen faculty and eight industry professionals so far (from a department of twenty-six faculty, so participation represents a high degree of involvement). We held multiple meetings to update our industry partners. Some faculty see the excitement from our industry partners and are aligning to the changes proactively. Others will see successes from the innovators and may be inspired to follow. Building a community of faculty that is aligned with the goals of this project is the primary sustainable means for faculty involvement and promoting lasting change as a result of this project. The annual evaluation by the chair specifically evaluates faculty work in this departmental transformation as another incentive. Faculty were also offered summer salary and course buy-outs to develop HUs. After a follow up meeting with industry partners in October, the RED team evaluated and ranked Hatchery Unit (HU) proposals by HU teams using a rubric. Each HU team was required to have at least one industry professional. Full development of six HU proposals is proceeding for AY2017/18: Foundational Values, Navigating Computer Systems, Introduction to Version Control, Agile Development, Introduction to Database System Usage, and Technical Interviews, Jobs and Careers.

Involvement can be strengthened by threading the HU courses with regular courses. For example, the HU units for Agile Development and Database Usage will be taught as a co-requisite for a junior-level Data Structures course. The students will then use those concepts in a large team project at the end of the Data Structures course. This threading not only reinforces the skills for the students but also creates a stronger sense of community between HU course instructors and the regular course instructors, and will help faculty become more familiar with the entirety of the undergraduate computer science curriculum. Another example is the threading of foundational values of social justice and ethics. This work is being accomplished by embedding the social science co-PI in all HU teams so those values are reflected widely in the HUs and the wider curriculum. In summary, we are promoting involvement by inviting industry to participate more deeply, by incentivizing faculty buy-in, and by threading short targeted Hatchery Unit courses through the curriculum in novel ways.

### C. *Respecting Department Culture (Virginia Tech - Electrical and Computer Engineering Department)*

The Virginia Tech team likens their process to the fan-in and fan-out of a logic gate, recognizing that broadening the pool of students entering engineering departments and increasing the range of careers they pursue requires redesigning departmental curricula and culture. The goal is to create and implement a reproducible process that supports a diversity of learning experiences and dramatically enhances the emphasis on design and innovation. Objectives are to combine threshold concepts theory and design-based learning to provide multiple pathways anchored in real world problems, and to forge new connections to K12 education and to 21st century industries, including start-ups, design consultancies, and non-governmental organizations. To begin working toward these goals, we needed to better understand the existing cultures of the department, from the perspectives of the faculty, the advisors, students, and the work force. We knew that our focus on culture and perspectives would be new to the department, but we did not have a clear view of the values and attitudes of the faculty. We expected resistance, and wanted to take a participatory approach to the work of revolutionizing the processes of the department. To avoid a top-down approach and gain true buy-in, we needed to find the areas where we could focus our work in ways that mattered to many stakeholders.

We began by introducing the project to the faculty at the end-of-summer retreat, presenting the award, the reasons for needing change, and an initial activity of brainstorming threshold concepts. Within the first month of the school year, we repeated this presentation and activity with our industry advisory board. Next, we embarked on a series of interviews with faculty, students, alumni, career/academic advisors, and industry advisory board members. These interviews deeply explored the experience of becoming an engineer and the future of engineering within academia and the industry. We found several expected responses, such as the need for rigor and the importance of specific subject skills. However, several surprising patterns emerged, including the need to cultivate a culture of creativity and the importance of the societal impact of engineering within society. Meanwhile, we attended each faculty meeting, giving brief updates on the project and keeping everyone "in the loop." The research team met every week and often shared stories of their interactions with curious faculty members, always gauging how to introduce projects and engage participation without imposing pre-conceived structure.

The next step was to zero in on threshold concepts. We again presented background on threshold concepts at a faculty meeting, and asked faculty to complete worksheets in which they described five "big ideas" that undergraduates need to become practicing engineers. We wanted to get people thinking about not only the content of the curriculum, but also gaps as well as barriers to change. We wanted to explore how they saw these big ideas being taught and learned in the context of the program and the workplace. This worksheet was used as a tool to guide follow-up focus groups, with faculty, industry advisory board members, and students. We also held a mixed-participant focus group to hear conversations between faculty, students and advisors. We are finding a culture of faculty who see concepts and skills in the context of a complex system, but also see that the teaching and learning practices do not always make those concepts or the system clearly visible or grounded in real world applications. These activities have been aimed at collecting data that helps us explore the culture while simultaneously building trust, describing a baseline, and beginning our collaborative work of redesigning the ways we form future engineers.

### *D. Fostering Engineering Engagement within a Diverse Student Body (University of New Mexico - Chemical Engineering Department)*

Retention of students within STEM fields, particularly engineering, has been historically challenging for programs with a high percentage of students who are underrepresented minorities, first generation college students, rural, low income, and/or non-traditional. Our project, Formation of Accomplished Chemical Engineers for Transforming Society (FACETS), is aimed at supporting, encouraging, and preparing a diverse group of students to become successful engineers and professionals within the global workforce. Our focus is to engage and excite students through Community, Industry, Research, and Entrepreneurship projects while also helping them develop their engineering identity and interests by earning competency badges. These design projects and identity/interest/competency badges help students build a unique student portfolio and elucidate their vital role in engineering practice. To accomplish these goals, within the first year we have implemented research-validated teaching and assessment methods in the Freshman and Sophomore courses and explored and established foundational aspects including stakeholder support and faculty development.

Revolutionary change can only be successful when people buy into the revolution and drive in the same direction. To establish buy-in, we held presentations, workshops, and retreats for various stakeholders. We have presented our project and engaged in dialogue with many groups including university leadership at the Provost level, college leadership at the College of Engineering, College of Arts and Sciences, and College of University Libraries and Learning Sciences level, teaching leadership at the faculty level in Chemical and Biological Engineering, and external leadership with the Chemical and Biological Engineering Department Advisory Board. We communicated the vision, strategies, and plan to enhance and improve student learning while creating a more engaging educational experience. We received positive support and relevant feedback from these stakeholders who informed us of helpful resources, potential challenges, and prior approaches.

The pedagogical development and commitment of department- and university-level faculty play key roles in the success of this project, since partnerships with faculty and their participation in the project are the key factors to implementing change throughout the curriculum. To that end, we have engaged with the Chemical and Biological Engineering faculty at two day-long retreats to solicit feedback and create buy-in, thus laying the groundwork to establish long-term support and individual contributions to the project. To help faculty with pedagogical development, we held four university-wide faculty development workshops, featuring the expert engineering educators Scott Fogler (Teaching Creative Problem Solving), Rick West (Instructional Technology: Open Digital Badges), Nikolai Kalugin (Concept Tests for Proficiency Assessment), and John Falconer (Active Learning in Chemical Engineering and How to Study). These workshops were attended by Chemical and Biological Engineering faculty, faculty from other departments university-wide, and students. Also, to further support faculty through this process of departmental change, we interviewed four faculty to understand their perception of our initiative and examine their mindset change.

So far, these buy-in efforts are successful. Course structure and curricular change has already begun in the two courses which are the most critical in student engagement and retention in the chemical engineering discipline. Two rounds of design projects have been administered in our Introduction to Chemical Engineering freshman-level course, and a jigsaw parley-style design project was administered in the Material and Energy Balances sophomore-level course. Our feedback from the students thus far have indicated that our program is helping students engage in chemical engineering more creatively, collaboratively, and enthusiastically.

### E. *Managing Difficult Conversations (University of Illinois Urbana Champaign - Bioengineering Department)*

Current engineering curricula prioritize technical problem solving expertise at the expense of other critical skills such as needs analysis, communication, and problem identification. These traditional priorities reveal a value system that is at odds with the values that underlie calls to create more holistic engineering education. Traditionally, engineering faculty, including our departmental faculty, valued solving technical problems; however, our Bioengineering RED team has proposed a shift to place more value on needs and problem identification. This shift will entail the creation of clinical immersion experiences for students to practice problem identification and a restructuring of the curriculum around the health and medical needs that drive bioengineering. Driven in part by students' waning satisfaction with the department as they progress through their degrees, we are realigning our Bioengineering Department with medical practice and education by driving our curriculum around the simple message of "no solution without a need."

Convincing faculty that did not see the value or purpose for changing the curriculum led to difficult conversations. We have had success managing these difficult conversations through "interest convergence" [11]. Interest convergence is a conflict management strategy that suggests that people will only support a change when they understand how the change will benefit them and that the change does not negatively impact their standing. We have been applying the concepts of interest convergence to our reform efforts to align the values of our faculty with the goal of centering the curriculum around needs analysis and problem identification. This process begins by seeking to deeply understand what our faculty know about the current curriculum and what they want the curriculum to do. The success of interest convergence depends on listening, promoting dialogue among stakeholders, and "over-communicating." Our efforts to change our curriculum began with a day-long faculty retreat, during which our RED leadership team cast a vision for our proposed curriculum revision and then spent the rest of the day listening to the concerns and fears of the faculty. We listened to what they thought were our department's strengths and weaknesses. We followed this listening exercise with a survey asking faculty and students to identify the most important skills that our students would need upon graduation and what health and medical needs motivated them to be in bioengineering. We found that despite this careful communication and listening, many faculty, including those on the curriculum committee, still did not understand our vision and goals. We have found that we needed to over-communicate, rehashing the same ideas and goals from different perspectives, and inviting these faculty into our decision-making processes even more.

We have also experienced the importance of being flexible in our language. To execute our curriculum reform, we proposed to organize our faculty and students into communities of practices (COPs) that would mutually explore health needs that motivated them. These COPs were meant to build on our faculty's intrinsic interests and values. Our faculty complained about the terminology, expressing discomfort and a lack of understanding of it. To move forward, we had to let go of the language that made sense to us and instead focus on creating experiences and opportunities for faculty to experience COPs apart from the language. By responding to their discomfort and instead focusing on tasks and goals (essentially having an internal difficult conversation), we successfully created the desired COPs. By understanding what our faculty know about the curriculum and what they want it to do, we have found success in creating alignment between our faculty's values and knowledge with the goals of our reform. Using interest convergence to manage difficult conversations helped our faculty see that our proposed change is not in conflict with their current values.

### F. *Finding Shared Understanding (Rowan University - Civil and Environmental Engineering Department)*

The Revolutionizing Engineering Diversity (RevED) team at Rowan has set out to diversify the Civil and Environmental Engineering (CEE) Department by changing admissions requirements, increase targeted recruitment of students with visible and nonvisible elements of diversity, increase support for underrepresented minorities and nontraditional students through peer mentoring, and transform the curriculum used by the CEE Department. Transforming the curriculum of the CEE Department may seem particularly simple due to the small size of the department (~12 faculty and staff); however, all the typical challenges exist when changing the curriculum.

While the CEE Department faculty work well together as peers, some faculty members are hesitant to implement inclusive curriculum. The first major obstacle to overcome is to establish common ground with faculty who are not participating in RevED. Faculty are in the CEE Department are spread out among multiple sub-disciplines within civil engineering (e.g., environmental engineering, water resources, geotechnical engineering, transportation engineering, and structural engineering). Minor differences within civil engineering can be a hurdle to implementing inclusive curriculum. Inclusive pedagogy naturally applies to environmental engineering and water resources due the implications these fields have to everyday life across the globe. The other sub-disciplines (e.g. geotechnical engineering or structures) require some level of work to make them more inclusive. To pave the way toward a more inclusive pedagogy, a helpful first step is to have all faculty from all sub-disciplines create a functional definition of what diversity and inclusive pedagogy are. To this extent, the RevED team hosted a departmental workshop to establish a common language and understanding to connect faculty with one another's efforts to diversify the CEE Department. In that workshop, faculty members used their common ground to critically analyze their courses to see what elements can be easily changed to be more inclusive and what elements would require more effort.

Another challenge to overcome in developing more inclusive pedagogy is developing methods to increase inclusive elements in heavily technical classes. While inclusivity can come naturally to certain sub-disciplinary coursework, some faculty expressed concern that essential technical elements would have to be sacrificed. To promote the adoption of inclusive pedagogy, the RevED team uses a project coordinator to establish ties with individual faculty members. The project

coordinator establishes a rapport with faculty to see what are the essential learning goals and outcomes. Later, the project coordinator searches for ways to develop inclusive material within the bounds of a given course. Through continued discussions regarding course goals and the project's goals, the project coordinator and faculty are able to develop methods to incorporate inclusive practices without sacrificing technical knowledge, and to use inclusivity to help augment the application of technical knowledge to different situations. These strategies showcase a transferable route to engage with inclusive practices in any field of engineering and coursework. Developing shared understanding and aligning goals have led to success with the project.

### *G. Reimagining Knowledge Development (University of Texas El Paso - Computer Science Department)*

UTEP's RED effort, A Model of Change for Preparing a New Generation for Professional Practice in Computer Science, aims to transform teaching and learning in computer science with deep change in curriculum that is grounded in social consciousness, cultural competency, and practices informed by our unique expertise and experiences as an Hispanic-Serving Institution. The overarching goal is to cultivate socially-conscious connectedness among students, faculty, and industry by expanding a curriculum centered on heightened social interaction. This curriculum is driven by an understanding and appreciation for the cultural contributions of diverse students to computer science in a globalized world. Our challenge is to reimagine what it means to learn, whose knowledge counts, what knowledge is needed, and what counts as knowledge in the context of computer science.

In the first six months of the project, the department held two two-day faculty retreats. The facilitator applied the Critical Friends methodology [12, 13] (cooperative development through collegial relationships) to: 1) arrive at a shared sense of purpose and common goals focused on establishing cultural competence and inclusive environments; 2) engage in reflective dialog to move toward a professional learning community; and 3) learn strategies for understanding and possibly integrating differing perspectives. A software engineer from a Fortune 500 technology company attended the retreat to provide input regarding industry needs. The retreats were successful in starting conversations for revolutionizing existing curriculum by proposing and evaluating new models of curriculum, such as competency-based curriculum and introduction of short courses focused on problem solving, innovation, and social impact. In addition, the retreats provided an approach for addressing dilemmas using the consultancy protocol [14] (emanating from the Critical Friends method) to ensure that diverse and possibly conflicting opinions are heard. These retreats resulted in the establishment of brown bag lunches, where faculty can propose and discuss new ideas around curriculum and departmental policies and procedures, in particular those focused on inclusion. In this way, we reimagine knowledge regularly.

The strategy for the first year was to focus on retention and engagement of students in the introductory sequence. Rather than tackle a major transformation of the CS curriculum in the first year, three instructors worked on content, pedagogical principles, and faculty interaction with students outside of the classroom. The department provides peer-led team learning and instructional assistants, which are funded through external sources. The department started training in AY2016/17 for teaching assistants assigned to the introductory courses, to focus on student success. In addition, the department assigned a professor of practice to oversee advising students transferring from the community college. The department started a film series for students and faculty to facilitate discussions around inclusion. The first edition of the series, two showings of the Hidden Figures movie, involved a social scientist who facilitated discussion following each show. Other films to be shown are the Theory of Everything and the Imitation Game. These various efforts illustrate that knowledge-building opportunities come in many forms.

Evaluation has focused on the change process as faculty have experienced it through activities of the grant. During fall focus groups with faculty, it became clear that faculty were interested in analyzing and considering student climate data as a method for developing plans for departmental improvements. To generate new knowledge about UTEP RED's process-oriented approach to transform educational change with particular attention to culture, social interaction, identity and practice, UTEP RED is conducting an ethnographic study of the change and education processes. Preliminary findings from sustained ethnographic observations in three sections of a required, entry-level computer science course show that instructors placed value on experiential learning in the form of course assignments that required students to engage with computer science outside of the classroom or lab environment. Collection of data to help us to understand the effects of these experiences on student learning is a next step in this project.

The challenges of the RED effort have been related to tacit resistance and acknowledgement of the need for change, competing concerns between research productivity and RED activities, and time constraints. Another challenge, which was uncovered in evaluation, relates to issues of faculty ownership of the RED project, primarily because typical methods of receiving recognition for grant work (e.g., being named a co-PI) do not apply in department-wide grants such as RED. Faculty are concerned with the sustainability of changes in the introductory course when different faculty are assigned. Finally, moving from the curriculum models proposed at the first faculty retreat to a cohesive revolutionary curriculum will take time. These challenges illustrate further issues relating to whose knowledge counts and what counts as knowledge.

## III. SUMMARY

These seven themes provide rich information regarding the processes of institutional change, emerging from groups as they experience the change. The common element in these themes is intentional action, emphasizing the need for teams to engage in regular, meaningful "over-communication" (to quote UIUC) regarding the strategic approaches they use. Making the time to do this work is challenging, especially when other activities like planning workshops, preparing surveys, and the other daily actions needed to move a large-scale project forward seem so pressing. However, the effort spent on strategy and internal planning is repaid through increased buy-

in, smoother operations, and improved institutional coordination. These lessons are consistent with the research literature in institutional change [15, 16, 17]. We anticipate that within five years, NSF's RED program will produce tens or hundreds of artifacts illustrating the successful and not-so-successful approaches that these twenty schools used to make academic change happen. Dissemination efforts, like the panel this paper supports, will continue to address the need for high-quality information for peer institutions.

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