6-24-2017

Talking About a Revolution: Overview of NSF RED Projects

Noah Salzman
Boise State University

Talking about a Revolution: Overview of NSF RED Projects

Dr. Susan M. Lord, University of San Diego

Susan M. Lord received a B.S. from Cornell University and the M.S. and Ph.D. from Stanford University. She is currently Professor and Chair of Electrical Engineering at the University of San Diego. Her teaching and research interests include electronics, optoelectronics, materials science, first year engineering courses, feminist and liberative pedagogies, engineering student persistence, and student autonomy. Her research has been sponsored by the National Science Foundation (NSF). Dr. Lord is a fellow of the ASEE and IEEE and is active in the engineering education community including serving as General Co-Chair of the 2006 Frontiers in Education (FIE) Conference, on the FIE Steering Committee, and as President of the IEEE Education Society for 2009-2010. She is an Associate Editor of the IEEE Transactions on Education. She and her coauthors were awarded the 2011 Wickenden Award for the best paper in the Journal of Engineering Education and the 2011 Best Paper Award for the IEEE Transactions on Education. In Spring 2012, Dr. Lord spent a sabbatical at Southeast University in Nanjing, China teaching and doing research.

Dr. Edward J. Berger, Purdue University, West Lafayette (College of Engineering)

Edward Berger is an Associate Professor of Engineering Education and Mechanical Engineering at Purdue University, joining Purdue in August 2014. He has been teaching mechanics for nearly 20 years, and has worked extensively on the integration and assessment of specific technology interventions in mechanics classes. He was one of the co-leaders in 2013-2014 of the ASEE Virtual Community of Practice (VCP) for mechanics educators across the country. His current research focuses on student problem-solving processes and use of worked examples, change models and evidence-based teaching practices in engineering curricula, and the role of non-cognitive and affective factors in student academic outcomes and overall success.

Dr. Nadia N. Kellam, Arizona State University

Dr. Nadia Kellam is an Associate Professor in the Polytechnic Engineering Program at Arizona State University. In her research, she is interested in the identity development of engineering students, the role of emotion in student learning, and improving the culture for engineering students and faculty, especially those from underrepresented groups. She has methodological expertise in qualitative research methods with a focus on narrative research methods. She is interested in curricular design and has developed design spines for environmental and mechanical engineering programs, and recently helped design the engineering education systems and design PhD program at ASU. She teaches design courses, engineering science courses, and graduate courses focused on qualitative research methods.

Dr. Ella Lee Ingram, Rose-Hulman Institute of Technology

Ella L. Ingram is an Associate Professor of Biology and Director of the Center for the Practice and Scholarship of Education at Rose-Hulman Institute of Technology. Her educational research interests include promoting successful change practice of STEM faculty, effective evolution and ecology instruction, and facilitating undergraduate research experiences. Her teaching portfolio includes courses on: nutrition, introductory biology, ecology and environmental studies, evolution, evolutionary medicine, and research practices in science.

Dr. Donna M. Riley, Virginia Polytechnic Institute and State University

Donna Riley is Professor of Engineering Education at Virginia Tech.

Dr. Diane T. Rover, Iowa State University

Diane Rover is a University Professor of Electrical and Computer Engineering at Iowa State University. She has held various faculty and administrative appointments at ISU and Michigan State University since

1991. She received the B.S. in computer science in 1984, and the M.S. and Ph.D. in computer engineering in 1986 and 1989 (ISU). Her teaching and research has focused on embedded computer systems, reconfigurable hardware, parallel and distributed systems, visualization, performance monitoring and evaluation, and engineering education. She has held officer positions in the ASEE ECE Division, served as an associate editor for the ASEE Journal of Engineering Education, and served on the IEEE Committee on Engineering Accreditation Activities, the IEEE Education Society Board of Governors, the ABET EAC (2009-2014), and EAC Executive Committee (starting 2015). Dr. Rover is a Fellow of the IEEE and of ASEE.

Dr. Noah Salzman, Boise State University

Noah Salzman is an Assistant Professor at Boise State University, where he is a member of the Electrical and Computer Engineering Department and IDoTeach, a pre-service STEM teacher preparation program. His work focuses on the transition from pre-college to university engineering programs, how exposure to engineering prior to matriculation affects the experiences of engineering students, and engineering in the K-12 classroom. He has worked as a high school science, mathematics, and engineering and technology teacher, as well as several years of electrical and mechanical engineering design experience as a practicing engineer. He received his Bachelor of Science degree in Engineering from Swarthmore College, his Master's of Education degree from the University of Massachusetts, and a Master's of Science in Mechanical Engineering and Doctorate in Engineering Education from Purdue University.

Prof. James D. Sweeney, Oregon State University

James D. Sweeney is Professor and Head of the School of Chemical, Biological and Environmental Engineering at Oregon State University. He received his Ph.D. and M.S. degrees in Biomedical Engineering from Case Western Reserve University in 1988 and 1983, respectively, and his Sc.B. Engineering degree (Biomedical Engineering) from Brown University in 1979. He is a Fellow of the American Institute for Medical and Biological Engineering and a Senior Member of the IEEE and AIChE.

Talking about a Revolution: NSF RED Projects Overview

Abstract
A significant initiative in engineering education in the U.S. began in 2014 when the National Science Foundation (NSF) initiated the IUSE/PFE: REvolutionizing engineering and computer science Departments (IUSE/PFE: RED) program. The goals of IUSE/PFE: RED (hereinafter referred to as RED) are to "enable engineering and computer science departments to lead the nation by successfully achieving significant sustainable changes necessary to overcome longstanding issues in their undergraduate programs and educate inclusive communities of engineering and computer science students prepared to solve 21st-century challenges." In 2015, six RED projects were funded followed by seven more in 2016. In addition, NSF funded researchers at Rose-Hulman and the University of Washington (called Revolutionizing Engineering and Computer Science Departments Participatory Action Research REDPAR) to facilitate communication and collaboration among the RED teams and to study the processes followed by RED teams. Overviews of funded RED projects and the collaborative projects across teams are included here. In the conference session, a former RED program officer will introduce the RED program. Then seven RED teams (ASU, Purdue, Oregon State, USD, Colorado State, Iowa State, and Boise State) and the REDPAR team will present highlights from their projects. Session attendees will then engage with RED team members in an interactive format to learn more about the projects, gain insight into how they might prepare their own future RED proposals, see how these projects are changing the landscape of engineering education across the U.S., and consider approaches for applying lessons to their own institutions to enact change.

Revolutionizing Engineering and Computer Science Departments (RED)

A significant initiative in engineering education in the U.S. began in 2014 when the National Science Foundation (NSF) initiated the IUSE/PFE: REvolutionizing engineering and computer science Departments (IUSE/PFE: RED) program described in this work in progress. The goals of IUSE/PFE: RED (hereinafter referred to as RED) are to "enable engineering and computer science departments to lead the nation by successfully achieving significant sustainable changes necessary to overcome longstanding issues in their undergraduate programs and educate inclusive communities of engineering and computer science students prepared to solve 21st-century challenges."

The idea for RED emerged from a high-level review of Engineering Education investments at the NSF. Informed by both internal program evaluations of current and prior programs and external assessments in the engineering education literature [1, 2], the review revealed that while there had been significant progress made in diffusing engineering education innovations in first-year engineering and in capstone design, change had been much slower in the middle years of the curriculum. In particular, while certain workplace-relevant engineering skills such as communication, teamwork, design, ethics, and socio-political contexts of engineering work were by then well embedded in first-year and to varying extents in capstone experiences, these had yet to be threaded through core engineering courses. These core courses in the middle years are critical for retention of all student populations, including especially those entering as transfer students. Senior management felt strongly that department head commitment was critical to any change strategy affecting the middle years, and recent literature on change management

highlighted the importance of organizational structure and reward systems both at and beyond the department level [3, 4, 5].

Thus the RED framework, in contrast to prior NSF investments in department-level reform, demanded nothing short of a revolution: built into the key program features were evaluation criteria that efforts be "radically, suddenly, or completely new; producing fundamental, structural change; or going outside of or beyond existing norms and principles" [6]. With an innovative department head or dean at the helm, change had to be rooted in engineering education research, a social science understanding of organizations, and a theoretical change framework that could move research to practice, with team composition reflecting this varied expertise. Faculty development efforts, incorporation of professional practice, and a plan for scalability that countered anticipated obstacles had to be baked in to the original vision and project plan.

With NSF investing relatively large amounts of money in unique departmental experiments, it was critical to ensure that each team would serve as a model, propagating change to other institutions in similar and related disciplines. An additional group with expertise in academic change was sought to undertake a meta-study of the entire RED awardee cohort, facilitating communication across awardee teams, ferreting out patterns in change efforts, and identifying differences in change strategies, institutions, disciplines, and other factors that might influence the shape, direction, and rapidity of the revolution locally and nationally.

As described by a current RED program officer, Elliot Douglas, the focus of RED projects is on cultural and organizational change. "Faculty often start by thinking about what educational activities they want to implement. But this approach will not be effective if the culture of the department doesn't change. RED projects start with the cultural change they want to make, and then identify educational approaches to support that cultural change."[7]

Funded RED projects

In 2015, the first cohort of six RED projects were funded at Arizona State University (ASU), Colorado State University (CSU), Oregon State University (OSU), Purdue University, University of North Carolina, Charlotte (UNCC) and the University of San Diego (USD). In 2016, the second cohort of seven more projects were funded at Boise State University, Iowa State University, Rowan University, University of Illinois, University of New Mexico, University of Texas at El Paso, and Virginia Tech. In addition, NSF funded researchers at Rose-Hulman and the University of Washington (called REvolutionizing engineering and computer science Departments Participatory Action Research REDPAR) to facilitate communication and collaboration among the RED teams and to study the processes followed by RED teams.

All projects that were funded in the first two rounds of the RED program are listed in Table 1 including cohort, title, institution, and department. All are public universities except for USD. Brief summaries of some of these projects and references to other published work are included in the discussion below.

Table 1 Funded RED Programs from Cohorts 1 and 2.

Cohort	Title	Institution	Department
1	*Additive Innovation: An Educational Ecosystem of Making & Risk Taking*	Arizona State University	Engineering
1	*Revolutionizing Roles to Reimagine Integrated Systems of Engineering Formation*	Colorado State University	Electrical and Computer Engineering (ECE)
1	*Shifting Department Culture to Re-situate Learning and Instruction*	Oregon State University	Chemical, Biological & Environmental Engineering
1	*An Engineering Education Skunkworks to Spark Departmental Revolution*	Purdue University	Mechanical Engineering (ME)
1	*The Connected Learner: Design Patterns for Transforming Computing and Informatics Education*	University of North Carolina, Charlotte	Computer Science (CS)
1	*Developing Changemaking Engineers*	University of San Diego	School of Engineering
2	*Computer Science Professionals Hatchery*	Boise State University	CS
2	*Reinventing the Instructional and Departmental Enterprise to Advance the Professional Formation of Electrical and Computer Engineers*	Iowa State University	ECE
2	*Rethinking Engineering Diversity, Transforming Engineering Diversity*	Rowan University	Civil & Environmental Engineering
2	*Defining the Frontiers of Bioengineering Education at Illinois & Beyond*	University of Illinois at Urbana-Champaign	Bioengineering
2	*Formation of Accomplished Chemical Engineers for Transforming Society*	University of New Mexico	Chem & Bio Engineering
2	*A Model of Change for Preparing a New Generation for Professional Practice in Computer Science*	University of Texas at El Paso	CS
2	*Radically Re-designing the Fan-in and Fan-out of an Electrical and Computer Engineering Department*	Virginia Tech	ECE

Cohort 1

At Arizona State University, the RED team is taking a systems approach to better understand the educational ecosystem and to support faculty to realize a mindset of additive innovation [8] and pedagogical risk-taking in their classrooms [9]. The team is taking a multi-pronged approach that includes understanding the engineering program's current culture through experience-centered narrative research [10], developing an instrument to assess pedagogical risk-taking, developing an understanding of making in the engineering classroom, and tracing impacts of the RED project on other institutions. The team has also developed a conceptual framework that leverages previous work in organizational change theory, higher education, and STEM teaching practices [4, 11, 12, 13, 14, 15, 16] to screen potential faculty interventions to increase the likelihood of success. This framework has facilitated the emergence of faculty-driven affinity groups that will serve as one vehicle for increasing pedagogical risk-taking among faculty. This framework, and examples from our experiences applying the framework, will be presented in this session [17].

At Colorado State University (CSU) the RED team is redefining what it means to teach and learn in the Department of Electrical and Computer Engineering (ECE). Approaching the degree from a holistic perspective, they no longer view the ECE program as a set of disparate courses taught by autonomous faculty in "silos," but as an integrated system that fosters collaboration. They are, in effect, throwing away courses to overcome the challenges of the current engineering educational system, yet their vision can be realized within the structural barriers inherent in higher education. CSU's new pedagogical and organizational model emphasizes knowledge integration and interweaves thematic content threads (creativity, foundations, and professionalism) throughout the curriculum. While ECE material is known for being extremely abstract and mathematically intense, multifaceted faculty teams are working collaboratively to help students connect the dots between topics and demonstrate *why* their knowledge is relevant to the world outside the classroom. Embarking on a range of initiatives to cultivate a student-centric culture that embraces people of all backgrounds, the CSU RED team is drawing on the latest technologies and active learning methods to help students explore their passions and experience the excitement of engineering. More information on this project is available [18, 19, 20, 21, 22, 23, 24, 25, 26].

At Oregon State University the RED team is transforming a School of Chemical, Biological, and Environmental Engineering (CBEE) through creation of a community and culture of inclusion and a shift in student learning from sequestered activities to more realistic and consequential work [27]. While CBEE has already implemented innovative curricula with a rich array of co-curricular activities, the professional development of engineers operates within the larger culture of engineering as practiced in industry. OSU has proposed that this larger context must be attended to, including improved inclusion from under-represented groups. Project activities address course design, pedagogies, faculty/staff/graduate student culture [28], and undergraduate student culture [29]. The team proposes that if efforts are to affect lasting change, simultaneous resituating and renegotiating these multiple components must occur. Activity theories provide both an explanation for the ongoing existence of departmental norms and practices and a framework for inducing and situating change. Indeed, it has been argued that a situative approach is needed to address the complex professional development of engineers. Project implementation focuses on: development of a faculty/staff working group advancing equity and inclusion,

curricular reform in a studio-based model that utilizes Model- and Design- Eliciting Activities to reflect the real work of engineers, student "Pods" as self-assembling communities of experience, and changing departmental policies and procedures to better value and reward faculty/staff efforts in support of this work.

At Purdue University, the RED team is attacking fundamental issues of emotion, trust, and relationships within the Mechanical Engineering program, all within the context of large scale. This team is forming a new organization called re|course to function as a skunkworks for engineering education. The research includes a departmental ethnography derived from interviews with faculty, staff, and students, departmental brochures and other documents, and in-person observations within public spaces. re|course is a research-to-practice incubator that provides an organizational structure and support resources to teams of faculty, staff, and students engaged in making change in the ME program. Key research and re|course efforts focus on attitudes and beliefs about teaching and learning, relationships among faculty, staff, and students, scalable assessment and feedback for students, and other dimensions of the student experience. Notably, the curriculum itself is not the focus of any on-going research or re|course effort, and this is recognition that the curriculum is one non-relationship-driven part of the total student experience and the broader departmental culture. Recent work has been reported [30, 31].

At the University of San Diego, the RED team, including the Dean and Chairs of Electrical, Industrial and Mechanical Engineering, is developing Changemaking Engineers. The project aims to prepare students to innovate engineering solutions within a contextual framework that embeds humanitarian, sustainable and social justice approaches with technical engineering skills. This requires an enhanced curriculum with a focus on student teamwork, a greater consideration of social and economic factors, improved communication with diverse constituents, and reflection on an ethical understanding of their decisions and solutions. Effective faculty members need to mirror these values and skills in their instruction and mentoring. This research will produce and disseminate a model for redefining the "engineering canon". The model provides a template for change for similar institution types and creates a platform for change that moves away from narrowly-constructed and techno-centric epistemological approaches. Activities developed to support this project include a "speed networking" event with faculty from across campus and collaboration with industry partners to broadening ownership of engineering education [32].

Cohort 2

At Boise State University, the RED team is creating a Computer Science Professionals Hatchery that incorporates ethics and social justice in agile, vertically integrated Hatchery Units to promote a more inclusive culture and prepare students to work effectively on software development teams and be advocates for change in their future careers. Hatchery Units are one credit courses that are designed to address gaps in students' technical knowledge identified by local industry, infuse ethics and social justice in the undergraduate computer science curriculum, and build communities of practice while providing a more streamlined integration experience for transfer students to the program. Guided by Rawl's [33] theory of social justice, the team will work with students and faculty to create an environment that is welcoming and supportive for all undergraduate CS students and encourage graduates of the program to work to promote these values as future computer science professionals. The development of these values will be

promoted by building communities of practice [34] via capstone design experiences that involve students over all four years of their undergraduate career. The combination of these initiatives and activities will result in graduates better prepared to be computer science professionals and agents for positive change.

At Iowa State University, the RED team is involving students, faculty, practicing engineers and others in collaborative, inquiry-driven processes. Faculty are reshaping core courses in the middle years using evidence-based pedagogical strategies and working together to enhance their understanding and integration of these strategies in courses. A key addition to these courses is a socio-technical context that goes beyond the hardware and software toward responsible development of ECE technologies [26]. The change process is being driven by a novel cross-functional, collaborative instructional model for course design and professional formation, called X-teams. An X-team is comprised of process as well as content experts and uses pedagogical approaches that promote design thinking by faculty and students, systems thinking, leadership, socio-technical mindsets, and inclusion. X-teams are also serving as change agents for the rest of the department through communities of practice referred to as Y-circles. Y-circles, comprised of X-team members, faculty, staff, and undergraduate and graduate students in the department, are beginning a process of discovery and inquiry to bridge the engineering education research-to-practice gap and contribute to an organizational culture that fosters and sustains innovations [35]. A key goal for the RED project is to broaden the participation of underrepresented students, especially undergraduate women, in ECE. The project is being conducted in concert with an NSF S-STEM grant also emphasizing inclusive teaching practices and learning experiences [36]. Among the two cohorts of RED projects, there are three ECE departments, which are working together to share information [26, 37].

At Rowan University, the RED team is known as REDTED. REDTED stands for Rethinking Engineering Diversity, Transforming Engineering Diversity. REDTED has short term goals that include an increase in social and cultural capital by developing more inclusive curriculum and admission standards. The program has long term goals that include increased recruitment and retention of students as well as propagation of program elements to other institutions. A major goal REDTED aims to accomplish is increasing underrepresented minority student representation in the Civil and Environmental Engineering Department by fifty percent and retain ninety-five percent of all students. In order to increase student diversity, REDTED is looking to change admission criteria for first year and transfer students to promote diversity, enhance perception and understanding of diversity among students, faculty, and administrators, develop a mentoring program to service first year and transfer students, adopt inclusive, system-based curriculum material in all courses, develop students' engineering identity by showcasing diverse professionals, and develop a model for recruitment and retention of diverse students. Along with changing recruitment and retention practices, REDTED also intends to change faculty evaluation practices and reward faculty that implement inclusive practices in their curriculum. This is done through working directly with faculty and addressing their needs in developing inclusive curriculum. More information about this project is available [38, 39, 40].

At Virginia Tech, the RED team is transforming the Bradley Department of Electrical and Computer Engineering so that it attracts a more diverse range of students and prepares them for a wider variety of careers. The transformation is based upon changing the department from having

two separate curricular paths, electrical engineering and computer engineering, to having multiple pathways that enable students to choose from a variety of concentrations. Students will also have greater opportunities for open-ended design experiences throughout all four years of the program, including projects that will serve as outreach opportunities to K-12 students in underserved communities. A key aspect of the project is using threshold concepts—concepts that are integrative and transformative, and that are the basis for "thinking like an engineer"—as a lens for faculty, students, and alumni to engage in a participatory design process for changing departmental culture. More information about this project is available. [37, 41]

RED Community

REDCON

The language in the NSF solicitation is unambiguous: "the awardees of this program will create knowledge concerning sustainable change in engineering and computer science education that can be scaled and adopted nationally across a wide variety of academic institutions" [42]. To promote the "scaled and adopted" outcome, NSF envisioned the awardees acting as a consortium to work together to leverage and maximize the outcomes of their individual work. This consortium-level work, now known as REDCON, is facilitated by an NSF-funded collaboration between Rose-Hulman Institute of Technology and University of Washington (known as REDPAR: RED Participatory Action Research). The explicit outcomes of REDCON focus on creating cross-institution collaboration, investigating best practices in making change in engineering and computer science, and promoting the individual work of the awardee teams. REDCON activities include regular conference calls (planned and hosted by REDPAR), outreach to the community (e.g. a five-team panel discussion at FIE 2016 [43]), and individual collaborations among awardee teams (e.g. team members from ASU, Purdue, and University of Washington collaborating on a research project to share at ASEE 2017 [44]). In several years, REDCON will have amassed an incredible library of presentations, publications, and case studies relating to change in engineering education (e.g. [25, 30, 45, 46]), and members will be able to act as consultants or coordinators for other institutions wishing to create the same level of cultural and curricular change needed for transformation. In these ways, REDCON is and will be serving the original goal NSF stated to facilitate scaling and adoption of change across the broader community.

REDPAR

REDPAR is an NSF-funded project acting in concert with the RED awardee teams. The work of REDPAR has two main focus points. First, the REDPAR team provides support and coordination for the teams and the teams' members through consulting, on-site visits, and professional development workshops. These activities are guided by the research in organizational change, particularly with respect to higher education [4, 47, 48]. Second, the REDPAR team investigates the academic change process via a participatory action research approach, working with the REDCON team members to co-produce knowledge through cross-team analysis. Data collected from focus groups, document analysis, observations, and informal discussions guide decisions regarding the support structures and experiences REDPAR provides. The larger consortium-wide research shares particular success strategies, common challenges, novel approaches, and institutional parameters that promote or hold back change efforts. Initial dissemination of this work has suggested the community has a considerable interest in the results of this work [43, 49, 50].

Webinar
A nice example of an extension of REDCON activities that was not initially planned is the three-part webinar series "Developing a competitive NSF RED proposal" held in October 2016 [51]. In 2016, during the PI meeting for RED, the first cohort of RED teams collectively developed the idea of creating value for the NSF RED program by outreach to the applicant pool, with the idea of helping decode and frame the more challenging aspects of the RED solicitation. With leadership from one team in particular, the webinar series quickly developed, with contributions from members of both cohorts and the involvement of outside expertise. Three sessions were hosted: 1) What is revolutionary, 2) Assembling a winning RED team, and 3) Change model required. The series was attended by 190 unique registrants, touching institutions from across the scope of engineering education. The five hours of content produced from this series remain archived on academicchange.org as a resource to future potential awardees. This work was accomplished through collaborative activities promoted by the consortium model.

ASEE Special Session Outline
This special session will begin with an introduction from a former RED program officer. Then seven of the RED teams (Cohort 1: Arizona State, Colorado State, Oregon State, Purdue, and USD and Cohort 2: Iowa State and Boise State) and the REDPAR team will present highlights from their projects. The RED webinar will be summarized with contact information provided. Then session attendees will engage with RED team members in an interactive format to learn more about the projects, gain insight into how they might prepare their own RED proposals should the RED program continue, see how these projects are changing the landscape of engineering education across the U.S., and consider approaches for applying lessons to their own institutions to enact change.

Acknowledgements - This work has been sponsored by the United States National Science Foundation (NSF) under Grants 15400721, 1519467, 1519412, 1519453, 1519339, 1519438, 1519160, 1623125, 1623189, 1623053, 1623190, 1623105, 1623141, and 1623067.

References

1 Froyd, J. E., "The Engineering Education Coalitions Program," in *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*, Washington, DC: National Academies Press, 2005.
2 Borrego, M. "Development of Engineering Education as a Rigorous Discipline: A Study of the Publication Patterns of Four Coalitions," *Journal of Engineering Education*, 96, pp. 5–18, 2007.
3 Spalter-Roth, R., N. Fortenberry, and B. Lovitts, *What Sociologists Know About the Acceptance and Diffusion of Innovation: The Case of Engineering Education*, Washington, DC: American Sociological Association, 2007.
4 Henderson, C., A. Beach, and N. Finkelstein, "Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature," *Journal of Research in Science Teaching*, 48, pp. 952–984, 2011. doi:10.1002/tea.20439.
5 Jamieson, L.H. and J. R. Lohmann, *Innovation with Impact: Creating a Culture for Scholarly and Systematic Innovation in Engineering Education*, Washington, DC: ASEE, 2012.
6 See https://www.nsf.gov/pubs/2014/nsf14602/nsf14602.htm
7 Douglas, E., private communication, January 31, 2017.
8 Jordan, S. and M. Lande, "Additive innovation in design thinking and making," *International Journal of Engineering Education*, 32(3B), pp. 1438-1444, 2016.
9 McKenna, A., N. Kellam, M. Lande, S. Brunhaver, S. Jordan, J. Bekki, A. Carberry, and J. London, "Instigating a Revolution of Additive Innovation: An Educational Ecosystem of Making and Risk Taking," *2016 ASEE Annual Conference & Exposition*, New Orleans, LA, June 2016.

10 Kellam, N., B. Coley, and A. Boklage, "Story of change—Using experience-based critical event narrative analysis to understand an engineering program's culture," *Proceedings of the 7th Research in Engineering Education Symposium (REES)*, Bogota, Colombia, July 2017.
11 Wergin, J. F. "Beyond carrots and sticks: What really motivates faculty," *Liberal Education*, 87(1), 2001.
12 Bolman, L. G. and T. E. Deal, "Leadership and management effectiveness: A multi-frame, multi-sector analysis," *Human Resource Management 1*, 30(4), pp. 509–34, 1991.
13 Borrego, M. and C. Henderson, "Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies," *Journal of Engineering Education*, 103(2), pp. 220-252, 2014.
14 Denison, D. R. and A. K. Mishra, "Toward a theory of organizational culture and effectiveness," *Organization Science*, 6(2), pp. 204–23, 1995.
15 Gallos, J. V. (ed.) *Organization development: A Jossey-Bass Reader*, San Francisco, Jossey-Bass, 2006.
16 Terenzini, P. T. and R. D. Reason, "Parsing the first year of college: A conceptual framework for studying college impacts," in *Association for the Study of Higher Education*, Philadelphia, 2005.
17 Bekki, J. M., A. Ayela-Uwangue, S. Brunhaver, N. N. Kellam, and M. Lande, "I Want to Try That Too! Development of a Conceptual Framework for Interventions that Encourage Pedagogical Risk-Taking Among Faculty," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
18 Notaros, B. N., P.S. Athalye, and A.A. Maciejewski, "Using Conceptual Questions to Assess Class Pre-Work and Enhance Student Engagement in Electromagnetics Learning Studio Modules," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
19 Notaros, B. N., S.B. Manic, and A.A. Maciejewski, "Introducing MATLAB-Based Instruction and Learning in the Creativity Thread of a Novel Integrated Approach to ECE Education," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
20 Chen, T. W., A. A. Maciejewski, B.M. Notaros, A. Pezeshki, and M. D. Reese, "Mastering the Core Competencies of Electrical Engineering through Knowledge Integration," *2016 ASEE Annual Conference & Exposition*, New Orleans, LA, June 2016.
21 Chen, T. W., B. M. Notaros, A. Pezeshki, S. Roy, A. A. Maciejewski, and M. D. Reese, "Knowledge Integration to Understand Why," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
22 Liu, Y., A. Pezeshki, S. Roy, B. M. Notaros, T. W. Chen, and A. A. Maciejewski, "Why Math Matters: Demonstrating the Relevance of Mathematics in ECE Education," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
23 Maciejewski, A. A., Z. Byrne, T.W. Chen, A. Cook, G. Dangelmayr, M. A. de Miranda, A. Leland, B.M. Notaros, M. D. Reese, A. Rosales, T. J. Siller, and J. Weston, "Revolutionizing Engineering Departments at Colorado State University and Beyond," *AAAS/NSF Envisioning the Future of Undergraduate STEM Education: Research and Practice*, Washington, DC, April 2016.
24 Maciejewski, A. A., T. W. Chen, Z. Byrne, M. A. de Miranda, L. B. Sample McMeeking, B. M. Notaros, A. Pezeshki, S. Roy, A. Leland, M.D. Reese, A. Rosales, T.J. Siller, R. Toftness, and O. Notaros, "A Holistic Approach to Transforming Undergraduate Electrical Engineering Education" accepted to appear in *IEEE Access, Special Section on Innovations in Electrical and Computer Engineering Education.*
25 Rosales, A., A. Leland, O. Notaros, R. Toftness, T. Siller, M. de Miranda, A. Cook, M. D. Reese, Z. Byrne, J. Weston, and A. A. Maciejewski, "Preliminary Work on Weaving Professionalism Throughout the Engineering Curriculum," *2016 ASEE Annual Conference & Exposition*, New Orleans, LA, June 2016.
26 Rover, D., M. Mina, D. Jacobson, P. Jones, J. Zambreno, A. A. Maciejewski, T. W. Chen, Z. S. Byrne, M. A de Miranda, L. B. Sample McMeeking, B. M. Notaros, A. H. Rosales, T. J. Siller, M. Reese, A. Leland, L. McNair, T. Martin, and M. Wisnioski, "Impacting Society through the Responsible Development of Technologies and Systems," special session on Catalyzing Collaborative Conversations, *2016 IEEE Frontiers in Education (FIE) Conference (FIE)*, Erie, PA, October 2016.
27 Sweeney, J. D., M. Bothwell, D. Montfort, S. Nolen, S. Davis, and M. Koretsky, "Re-Situating Community and Learning in an Engineering School," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
28 Sweeney, J. D., M. Bothwell, D. Montfort, S. Nolen, S. Davis, and M. Koretsky, "Motivating and Engaging Faculty in Cultural and Curricular Transformation of a Multidisciplinary Engineering School," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
29 Colcer, L., D. Montfort, and C. Smith, "Problems of our own Devising: Individuals' Challenges in Enacting Systemic Changes to Increase the Inclusivity of Engineering Departments," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.

30 Berger, E. J., R. Senkpeil, E. Briody, and E. Morrison, "Work in Progress: A Pedagogical Borderland? Comparing Student and Faculty Attitudes and Actions About Teaching and Learning," *2016 ASEE Annual Conference & Exposition*, New Orleans, LA, June 2016.
31 Senkpeil, R. and E. J. Berger, "Impact of Non-Cognitive Factors on First Year Performance," *2016 ASEE Annual Conference & Exposition*, New Orleans, LA, June 2016.
32 Roberts, C., R. Olson, S. Lord, M. Camacho, M. Huang, and L. Perry, "WIP: Developing Changemaking Engineers (Year 2)," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
33 Rawls, J., *A Theory of Justice* (Rev. ed). Cambridge, Mass: Belknap Press of Harvard University Press, 1999.
34 Wenger, E., *Communities of practice: learning, meaning, and identity*, Cambridge, U.K.; Cambridge University Press, 1998.
35 Rover, D., M. Mina, J. Zambreno, D. Jacobson, P. Jones, A. Khokhar, L. Larson, S. McKilligan, S. Rodriguez, and M. Shelley, "Riding the Wave of Change in Electrical and Computer Engineering," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
36 Rover, D., J. Zambreno, M. Mina, P. Jones and L. L. Chrystal, "Evidence-based planning to broaden the participation of women in electrical and computer engineering," *2016 IEEE Frontiers in Education (FIE) Conference (FIE)*, Erie, PA, October 2016.
37 Rover, D., A. Maciejewski, and L. McNair, "Revolutionizing Electrical and Computer Engineering Departments," Electrical and Computer Engineering (ECE) Division special session, *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
38 Sukumaran, B., H. Hartman, S. Farrell, R. Dusseau, K. Jahan, P. Bhavsar, and T. Forin, "Rethinking Engineering Diversity, Transforming Engineering Diversity," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
39 Liedtka-Bizuga, G., T. Forin, B. Sukumaran, R. Martin, D. Leverick, and B. Varghese, "WIP Developing a Peer Mentoring Program with Insight from Students," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
40 Farrell, S., R. Dusseau, and T. Forin, T., "WIP Developing Multiple Strategies for an Inclusive Curriculum in Civil Engineering," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
41 Virginia Tech, "Faculty receive grant to transform undergraduate engineering education," https://vtnews.vt.edu/articles/2016/07/icat-engineeringeducation.html (last accessed 25 January 2017).
42 National Science Foundation, *IUSE/Professional formation of engineers: Revolutionizing engineering and computer science departments (IUSE/PFE: RED) solicitation* 17-501, 2016. https://www.nsf.gov/pubs/2017/nsf17501/nsf17501.htm
43 Ingram, E. L. "Panel: Changing your department: Examples from Revolutionizing Engineering Departments," Frontiers in Education (FIE) Conference, Erie, PA, October 2016.
44 London, J., E. Berger, C. Margherio, E. Litzler, J. Branstad, J. "The RED Teams as Institutional Mentors: Advice from the First Year of the "Revolution," *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.
45 McKenna, A. F., N. N. Kellam, M. Lande, S. R. Brunhaver, S. S. Jordan, J. M. Bekki, A. R. Carberry, and J. S. London. "Instigating a revolution of additive innovation: An educational ecosystem of making and risk taking," *2016 ASEE Annual Conference & Exposition*, New Orleans, LA, June 2016. https://peer.asee.org/27315
46 Koretsky, M., M. K. Bothwell, S. B. Nolan, D. Montfort, and J. D. Sweeney, "Shifting departmental culture to re-situate learning," *2016 ASEE Annual Conference & Exposition*, New Orleans, LA, June 2016. https://peer.asee.org/26183
47 Foote, K., A. Knaub, C. Henderson, M. Dancy, and R. J. Beichner, "Enabling and challenging factors in institutional reform: The case of SCALE-UP," *Physical Review Physics Education Research*, 12, pp. 010103, 2016. doi: 10.1103/PhysRevPhysEducRes.12.010103
48 Lester, J. and A. Kezar, "Faculty grassroots leadership: making the invisible visible," *Journal of the Professoriate*, 6, pp. 98-129, 2012.
49 Litzler, E. and C. Margherio, "Research results on the process of beginning academic change," *Women in Engineering ProActive Network (WEPAN) Annual Meeting*, Broomfield, CO, June 2016.
50 Ingram, E. L., E. Litzler, C. Margherio, and J.M. Williams, "Learning to Make Change by Revolutionizing Departments: Initial Team Experiences," *2017 ASEE Annual Conference & Exposition*, Columbus OH, June 2017.
51 Camacho, M. M., S. M. Lord, N. N. Kellam, and J. M. Williams, "Institutional Mentoring to Incite a Revolution through NSF's RED Program", *2017 ASEE Annual Conference & Exposition*, Columbus, OH, June 2017.