

MEERCat: A Case Study of How Faculty-led Research Initiatives Gave Rise to a Cross-departmental Research Center with Potential to Inform Local Policy

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Work-in-Progress - MEERCat: A Case Study of How Faculty-led Research Initiatives Gave Rise to a Cross-Departmental Research Center with the Potential to Inform Local Policy and Practice

Abstract

This work-in-progress paper presents a case study at a large Midwestern university where two faculty-led initiatives resulted in the creation of a cross-departmental center, the Mechanical Engineering Education Research Center at Purdue University (MEERCat Purdue), with a goal of transitioning engineering education research advances into practice at scale. Other faculty engaged in innovation and research can use this case study to identify strategies to collect data and use the results to inform both the innovation itself and the broader departmental system (i.e., policies and practices) in which it operates. By systematically looking at the larger implications of their local innovation, faculty can create productive research-to-practice cycles that can improve the teaching practice and departmental culture and later inform policy decisions at the department and college level.

Two signature initiatives under the MEERCat umbrella provide useful examples of such data collection and research strategies and connections to inform research-to-practice. In one research project, faculty in the School of Mechanical Engineering transformed the core undergraduate Dynamics course into an Active, Blended, and Collaborative (ABC) learning environment, now known as “Freeform”. As the Dynamics course was taught in an iteratively-refined Freeform learning environment, the rate at which students received the non-passing D, F, and W grades decreased. The Revolutionizing Engineering Departments (RED) project is another faculty-led research effort, which evaluates the cultural factors that influence student academic and professional outcomes and engages faculty, staff, and students in conversations that span the pedagogical-to-departmental policy spectrum. The approaches adopted in the Freeform and RED projects are detailed in this paper, with a special emphasis on data collection, research, and specific partnerships that enable department-level policy and practice discussions to take place.

MEERCat’s mission is to put results from the research studies into large-scale practice. The center allows the Freeform and RED projects to work in parallel to align data collection and implementation efforts and to leverage the network of other researchers and professionals on our campus, including our Institutional Research Office and Center for Instructional Excellence. Since its establishment, MEERCat has received visibility across the University and has demonstrated the potential to inform practice both in the School of Mechanical Engineering and across other Schools in the College of Engineering. This paper describes the process of how a faculty-driven pedagogical innovation and research around departmental culture laid the foundation for a University-level research center that has begun to show the potential to inform teaching and learning in the School of Mechanical Engineering.

Introduction

Science, Technology, Engineering and Mathematics (STEM) educators continue to emphasize the need to develop an academic climate that supports systematic innovation and change in engineering education [1]. Change strategies in undergraduate education may be categorized by their approach to transformation and by the impact they produce [2]. Transformations that impact an entire environment arise from far-reaching policy adjustments or from developing a shared vision of the desired change, which are referred to as top-down or bottom-up approaches, respectively. However, top-down approaches to change have been demonstrated to be far less effective than bottom-up approaches [3]. To successfully implement organizational change, it is necessary for all of the stakeholders to collectively work towards developing a shared vision to transform an institution or department [4, 5]. One way this can be achieved is by building an academic climate that allows faculty to use the results from educational research to pedagogically reform undergraduate STEM education.

This paper describes two cross-departmental, faculty-led engineering education research projects that are working towards building research evidence that can be applied to instructional practice. Both of the projects emerged from a first-of-its-kind partnership between the School of Engineering Education and the School of Mechanical Engineering at Purdue University (West Lafayette). Initial results from both of these NSF-funded research projects provided visibility at the department and college levels, which resulted in the formation of the Mechanical Engineering Education Research Center at Purdue University (MEERCat Purdue). The vision of MEERCat is to bridge the gap between research and practice by using the results obtained from research projects to inform course-level and department-level change. Narratives about the two research projects are presented below, followed by a brief discussion of their role in the formation of MEERCat and its implications for the research-to-practice transition at the department level.

Foundational Research Project 1 - Freeform

Recognizing the need to adopt a new research-based understanding of how engineering undergraduate students learn, instructors in the School of Mechanical Engineering at Purdue University redesigned a sophomore-level Dynamics course into an Active, Blended, and Collaborative (ABC) learning environment called Freeform [6]. The instructors developed multiple learning resources for the students including a hybrid lecturebook, an online repository of video based homework solutions, videos of lecture examples and visualizing mechanics principles, an online discussion forum, and tutorial rooms. The lecturebook contains concepts, equations, and examples that are taught in the class, alongside sufficient white space for the students to take notes on the lectures themselves. Online, the course blog hosts example and solution videos, discussion forums, and detailed homework sets. Lecture example videos detail solution steps for the problems in the lecturebook, which are also the problems covered in class, and they can prove especially helpful to students when solving homework questions. Homework solution videos can help answer questions after submission. The Visualizing Mechanics videos help students who find it hard to visualize the Dynamics concepts, as most of the topics covered by the videos involve moving objects. The discussion forum is organized by individual

homework problems and allows students to have peer-to-peer interaction and clarify queries throughout the course.

Between 2008 and 2014, as the Dynamics course was taught in the iteratively-refined Freeform learning environment, we observed a drop in the rate at which students received the non-passing grades of D, F, and W [7]. These initial positive results provided the motivation for a research collaboration between the School of Engineering Education and School of Mechanical Engineering, which gave rise to an NSF-funded research project in 2015 to study the Freeform environment. Currently, the study is examining multiple research questions that include the patterns of the students' engagement with the various Freeform learning resources and their influence on the students' performance; the differences in student engagement based on their backgrounds; the attitudes and emotions of students and faculty towards the Freeform environment as compared to a traditionally-structured course; and the role of instructor, engineering discipline, and institution on the students' academic performance.

The Freeform research team collects a large amount of data and collectively analyzes it to address these complex research questions. Multiple forms of quantitative and qualitative data are collected, including information about the students' ethnicity, gender, international status, major, GPA, and previous course grades at Purdue University. All relevant student data are collected every semester and updated in a master data spreadsheet. Other forms of data include semi-structured interviews, gradebooks obtained from the instructors, video-recorded observations of the instructors' teaching behaviors, and tracking of the students' blog usage. The burden of collecting and organizing this immense amount of data is made easier through the Freeform team's collaboration with other offices at Purdue University. The Office of Institutional Research, Assessment, and Effectiveness (OIRAE), for example, assists the team in collecting institutional data on student registration, background, and performance. Likewise, the Center for Instructional Excellence (CIE) assists in onboarding new faculty members to a student-centered learning environment.

Results from the first two years of the Freeform research project illustrate the role of the instructors in shaping the students' academic performance [8], the impact of learning in the Freeform environment on future courses at Purdue, and the actions that instructors take in a typical Freeform classroom [9]. The results allow the team to provide valuable insights and feedback to Freeform instructors, which could improve the overall learning experience of students in the course. The positive results from the project have led to ongoing discussions of introducing the Freeform learning environment to other core courses in the School of Mechanical Engineering.

Research Project 2 - REvolutionizing engineering and computer science Departments (RED)

A MEERCat faculty member who has a joint appointment in the School of Engineering Education and the School of Mechanical Engineering interviewed a dozen faculty members about their opinions, beliefs, attitudes and the functioning of the School of Mechanical Engineering. The data informed a funded proposal under the RED program, which was initiated by the NSF to provide resources to specific departments in need of significant cultural,

operational, and productivity shifts to enable improvements in student “professional formation” (NSF uses the term “professional formation” to describe the process by which people become engineers and computing professionals, and this is a lifelong process). RED awards support research and programmatic developments during the brief but crucial period of the professional formation during undergraduate study, especially in the middle years of the curriculum. RED projects focus on Professional Formation of Engineering Outcomes (PFEOs) that are essential for thriving engineers in a modern economy, including communication, teamwork, project management, and creativity.

The RED project focuses on two types of research questions: (i) engineering education research questions, which largely examine how department members (faculty, staff, students) work together to achieve excellent educational outcomes (especially at a large scale), and (ii) how does cultural change happen in a large, complex academic organization? Together, these research questions frame the challenges of understanding the departmental culture, especially faculty culture and how it shapes the educational outcomes that students achieve. To address the challenges of conducting ethnographic and social science research in an engineering department, the Principle Investigator (PI) formed a team of administrators, engineering education researchers, a change agent, and two anthropologists, as well as several graduate and undergraduate student researchers.

The project uses both qualitative and quantitative approaches to reveal the underlying features of the departmental culture and its connection to student PFOs. Our sampling frame included all of the members of the department community (that is, all students, staff, and faculty affiliated with the department), as well as a small number of faculty and staff outside of the department (e.g., representatives from the Purdue Center for Career Opportunities). The team collected data through interviews, focus groups, observations, surveys, and “deep hanging out” [10] in many settings and locations within the department. The RED project, which is fundamentally a collaboration between engineering education researchers and engineering department members, also leverages relationships with other university offices such as CIE, OIRAE, and the Provost. Further, the team works with other RED sites across the US to share experiences, research results, and ideas about how change happens in different academic settings.

To date, the findings from the RED project have focused on two main areas. The first is the characterization of the departmental culture, inclusive of the perspectives of faculty, staff, and students, showing fairly extraordinary time pressures extant for each group. While their work is very different, each group experiences intense time pressures to be productive, efficient, and above all else rigorous and accurate in their work. The narratives conveyed to our research team form the basis for on-going conversations about workload management across the department, including faculty and staff roles and the distribution of effort. The second key finding concerns the change strategy employed as part of the research grant. The RED team formed teams of faculty, staff, and students to focus on a specific problem or opportunity, trained them in a strategy discipline, and facilitated each team throughout their work. Some of these change efforts succeeded more than others, but a key observation is that teams that were predominantly composed of staff seemed to be more productive than teams mostly composed of faculty. The team continues to consider and document how this observation relates to the current status quo in the department and the future prospects and strategies for change.

MEERCat Purdue

The unique partnerships between the two Schools of Engineering at Purdue University laid the foundation for the formation of MEERCat. PIs and co-PIs of both the Freeform and RED projects have observed the potential for the datasets collected to complement each other and address a variety of interrelated research questions. As shown in Figure 1, the RED project works at the macro level understanding the students' experiences in the School of Mechanical Engineering, and the Freeform project takes a micro level deep dive into the students' experiences in a single course that has applied the Freeform learning environment.

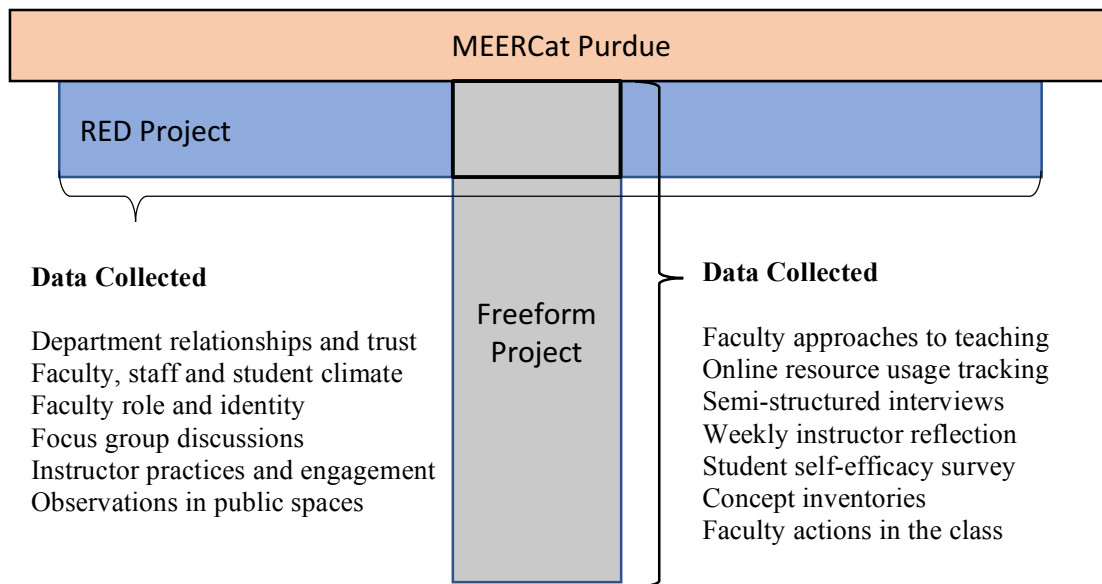


Figure 1 – Visual representation of MEERCat with respect to the two research projects

Both of the research projects have some level of intersection, as the data collected in both of the projects are complementary. For example, the semi-structured interview data collected from students in the Freeform project complement the student focus group data collected in the RED project. Both of these data contribute to our understanding of the help-seeking behaviors of students in their sophomore year and their resource usage preferences to succeed in the program. This led the two Schools to establish an umbrella to encompass each of these cross-departmental research projects, and hopefully a number of others in the future, with an aim to align the data collection and research-to-practice implementation efforts. MEERCat was launched in 2017, and the Center provides a platform for faculty to engage in discussions that take the results from local research and translate them into practice. MEERCat's mission is to enable the holistic formation of mechanical engineers by bridging research and practice. The Center brings together faculty from both of the schools who can cohesively work with each other, and provide a student-centric mechanical engineering education experience to all of the students. The Center also collaborates with the Provost's office and others to support instructional development efforts across the university.

Implications for Research-to-Practice

In the first year of its establishment, MEERCat has demonstrated the potential to enact research-to-practice at the department level. One important example is the wide-spread adoption of Gradescope, a third-party software used to grade homework online. Gradescope was first used as a research tool to quickly grade the Dynamics concept inventory, which was administered to the students as a pre- and post-test. The assessment of instructors' actions based on video observations in the Dynamics classroom informed us that about 10% of the class time over the semester was used for administrative tasks, mostly through the collection and distribution of homework assignments [9]. This insight inspired instructors across the course to adopt Gradescope for their homework assignments, which also allows students to upload and receive feedback on their homework online. This contributed to the reduction of time spent on administrative tasks that can instead be utilized for other instructional purposes. The adoption of Gradescope eased the process of submitting and receiving homework for the more than five hundred students every year.

While analyzing the semi-structured interviews collected from the students, one member from the research team observed that many students were critical about the answers posted on the discussion forum. With over 400 students using the discussion forum every semester, there were multiple posts from students who were responding to the same question posted by their peers. For example, one student mentioned: *"It's pretty common for a student to say something and then another student to be like, "Well, I got this" and another student to be like, "Well, I got this". Now you have three options. You came to the blog because you were confused and now you have three options. It doesn't help me"*. This often confused the students especially when they were looking for the most useful response. This insight was provided as feedback to the lead instructor as a suggestion for changes to be made in the future semesters. The lead instructor then incorporated a like and dislike voting option for the comments posted on the discussion forum. This allowed students to vote their preference for the comments posted on the discussion forum based on their perceived value. Students can now identify the posts that have the highest number of likes and use that information to decide which are most useful, thus improving the efficiency and value of using the discussion forum.

Another early example of MEERCat's on-going research-to-practice cycle is the integration of scalable teaming experiences to our large-enrollment courses, as enabled by CATME (what began as the "Comprehensive Assessment of Team Member Effectiveness"). CATME is a web-based tool that enables instructors to implement best practices in managing student teams [11]. The RED team has worked with capstone design instructors, whose collective enrollment is nearly 400 students per year, to implement a scalable solution to team formation and peer review for capstone design teams. The overarching goal is to institutionalize the use of CATME for teaming within the department, and this initial foray into capstone design has been enthusiastically supported by the capstone instructors. They support CATME not only because it provides an efficient platform for team formation and peer evaluation, but also because when integrated throughout the curriculum, it provides a timeline of student professional formation as a teammate and leader. Students have a more formal way to understand their ability to function effectively in a team environment, and the department has a better way to track these crucial student PFOs for accreditation purposes.

The intersection of the results from the Freeform and RED projects has helped us understand students' help-seeking behaviors in the Dynamics course specifically and the School of Mechanical Engineering in general. As described in a forthcoming paper, we observed that students first preferred to use the learning resources provided in the course, then resorted to their peers to seek help, and at the end reached out to the instructor for support. This information is valuable as the School of Mechanical Engineering can now provide additional learning resources to students and can provide more targeted support with continuous opportunities to work with their peers. In fact, the Freeform research team has started the process to recruit undergraduate students who will work with the instructors to develop more Visualizing Mechanics videos, which would be directed at supporting students in their understanding of Dynamics concepts.

MEERCat has also provided a platform for the faculty to engage in thoughtful discussions that might contribute to improving the learning experience of students in the School of Mechanical Engineering. This was visible when the faculty voiced their opinion during a discussion on curriculum changes at a recent faculty meeting. The original proposal wanted to eliminate a free elective in the curriculum, which would have negatively impacted the students' experiences by limiting course choice. Alternatively, MEERCat faculty recommended keeping the free elective and removing a technical elective instead. This counter-proposal still met the original objectives but also maintained course flexibility. The collaboration between the Schools of Engineering Education and Mechanical Engineering influenced this forward-thinking change, which will positively impact mechanical engineering students for years to come.

As most of the research-to-practice examples presented above are directed mainly through the two core research projects, it is important to note that MEERCat was established recently (early summer 2017). However, MEERCat has already begun to gradually change the culture in the School of Mechanical Engineering, which is evident as most of the research-to-practice examples mentioned above were implemented after the establishment of MEERCat. The establishment of MEERCat has been the catalyst for the two research projects to look at the many practical implications of their research and shepherd the various research-to-practice activities. We believe this change in the culture will lay the foundation for additional conversations among the faculty in School of Mechanical Engineering and with the faculty in the School of Engineering Education, to continuously improve the learning experience of students from matriculation to graduation.

Conclusion

This work-in-progress paper presented narratives about two cross-departmental research projects, which combined to catalyze the development of a department level research center. The paper highlighted the role of faculty in the establishment of MEERCat and how faculty-led research projects can contribute to informing both policy and practice at the department level. The narratives provided details on the history behind the development of these research projects, the large data collection efforts involved, and the collaborations inside the University that help the projects function smoothly. Faculty who engage in course innovation or education research can use this paper as a case study of how to get actively and collectively involved in influencing department-level practices at their respective institutions.

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