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Abstract

Published research has provided a robust set of documented tools and techniques for transforming individual engineering courses in ways that use evidence-based instructional practices. Many engineering faculty are already aware of these practices and would like to use them. However, they still face significant implementation barriers. The E^2R2P effort addresses the question: How can successes in engineering education research translate into widespread instructional practice?

This poster session will describe hard-won lessons the E^2R2P team has learned as it begins its third year attempting such curricular change.

Lesson 1: "Wonder workshops" and visible course redesigns don't produce curricular change.
Lesson 2: Focus on the larger engineering education system, rather than its isolated parts.
Lesson 3: Insurmountable time barriers prevent faculty from adopting RBIS.
Lesson 4: Universities, industry, and other stakeholders working in isolation can't do much more to help engineering faculty address these problems.
Lesson 5: Changing the curriculum requires a larger community of shared concern and practice.
Lesson 6: Bring in partners and expertise in cross-boundary, multidisciplinary way.
Lesson 7: Work together to address a shared concern: Decreasing ramp up time to competent workplace performance.
Lesson 8: Make the effort to grow the contact network to address this opportunity.
Lesson 9: Use a common engineering model to create a venue for collaborative problem identification and root cause analysis.
Lesson 10: Talk about what fresh out engineers are ***doing*** on the job, along with its monetary and nonmonetary consequences.
Lesson 11: Collaborate on interpreting the problem identification and root cause analysis data.
Lesson 12: Work together to specify corrective actions that remove barriers to RBIS adoption.

Our Story

> *"You can always tell who the pioneers are because they have arrows in their backs..."*
> — anonymous

The E^2R2P team seeks to increase the number of engineering faculty using research-based instructional strategies (RBIS) in their teaching practice. This would improve learning and promote skill transfer to the engineering workplace. Our work to attain this goal puts us in the position of being innovators who create ideas and product innovators who try to construct a working model to bring those ideas to the market—albeit a market of academics. As product innovators, the team has had the opportunity to collect a variety of arrows in their backs, which forms the basis of the "lessons learned" that follow.

The team initially thought that a series of "wonder workshops" coupled with the "visible redesign" of an existing engineering course would help faculty adopt RBIS. They didn't (Lesson 1). We then realized that:

- We needed to focus on the larger engineering education system, rather than its isolated parts (Lesson 2).
- Faculty who opt to try research-based instructional strategies (RBIS) in their courses often run into insurmountable time barriers that prevent them from adopting these strategies (Lesson 3).
- Universities, industry, and other stakeholders working in isolation can't do much more to help engineering faculty address these problems (Lesson 4).
- It would take a larger community of shared concern and practice to bring the necessary smarts, will, and resources to the table in ways that could remove barriers to adopting RBIS (Lesson 5).

Feeling the sting of these initial arrows, we began doing other things instead. We:

- Brought in new partners and expertise (Lesson 6).
- Started working with industry and academic stakeholders to address a shared concern: decreasing the time it takes for newly graduated and hired "fresh out" engineers to reach competent levels of performance in the workplace (Lesson 7).
- Began building a contact network to create a venue for concerned parties to address this opportunity (Lesson 8).
- Applied a common engineering model to create a venue to talk about problem identification and root cause analysis (Lesson 9).
- Started talking about what fresh outs are and aren't doing on the job--along with its monetary and non-monetary consequences (Lesson 10).
- Inviting the people who'd spoken with us to help us interpret the data we collected (Lesson 11).
- Finding new ways to work together to specify corrective actions that will remove barriers to adopting RBIS (Lesson 12).

Lessons Learned

A description of the lessons we've learned follows.

Lesson 1: "Wonder workshops" and "visible course redesigns" don't produce curricular change.

As depicted in Figure 1, the initial E^2R2P concept was that a Sounding Board of potential adopters in the engineering faculty would make decisions to employ more research-based instructional practices in their teaching if they had participated in redesigning courses to use them. Sounding Board members came from the colleges of engineering, business and economics, education, and arts and sciences. The Sounding Board would participate in a series of workshops to build skills in using RBIS such as problem-based and active learning [1-3]. The Sounding Board would also provide input and feedback guiding the redesign of an engineering course in the Test Bed. Six members of the engineering faculty attended the first meeting of the Sounding Board. One member from the engineering faculty attended the subsequent meeting. Subsequent informal conversations provided anecdotal data indicating that faculty have other more pressing demands on their time—even when the researchers buy the first round of appetizers at a local restaurant. The Sounding Board concept proved inherently unsustainable.

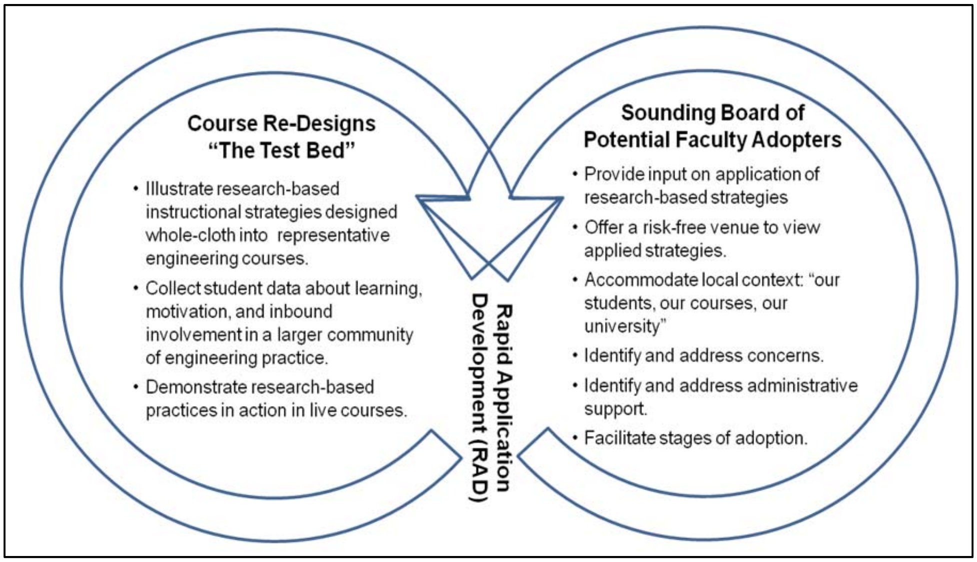

Figure 1: E^2R2P Test Bed and Sounding Board

After the Sounding Board folded, the researchers continued with the redesign of a senior-level Thermal and Fluids Systems Design (ME 424) course that provides an application-oriented approach to thermal and fluid science concepts using a systems design format. Evidence-based redesign efforts included:

- *A focus on project- and problem-based instruction*. The course traditionally used a lecture-based format with a project at the end of the semester. In the revised course, students worked in teams to complete two authentic engineering projects: (1) piping design of the cooling water for air handling units in a small building using a hardy cross solution method, and (2) the design and fabrication of a miniature wind turbine.
- *Project assessment rubrics to measure authentic engineering performances*. Various researchers have reported authentic learning outcomes in engineering courses that they measured using rubrics [4-6]. The American Society of Civil Engineers has developed

rubrics for assessing their 21st century body of knowledge [7]. The researchers created a preliminary Design Review (PDR) that they administered halfway through the course to assess the ability of each student team to formulate an engineering problem from the given information. This included developing a schedule, identifying design requirements, and evaluating concepts. The researchers also created a Critical Design Review (CDR) rubric they administered at the end of the course to evaluate students' ability to generate an engineering solution from the evaluation performed in the PDR phase. Each student team was assessed on their ability to link engineering requirements to modeling results, a final design and ultimately a reporting document for a technical audience.

- *Survey of student knowledge sharing*. The research team adapted a validated survey created by Tohidinia and Mosakhani [8] to measure student knowledge sharing. Forty-four Likert scale items asked participants to rate their ability to engage with other students and characterize the nature of any engineering relationships they have developed. Exploratory survey results from 57 students appear worthy of further investigation. On the whole, students entering the course have positive attitudes about sharing knowledge, and they feel that their ability to share knowledge lies within their personal ability to control. Consequently, they intend to share their knowledge with other students. However, Tohidinia and Mosakhani [8] contend that knowledge sharing involves both knowledge collection and donation. Entering students seem more willing to collect knowledge from their peers than donate to it. This situation represents a potential opportunity to target learning activities towards building knowledge sharing skills and confidence.
- *Survey of the motivational design of the assignments themselves.* Keller [9-12] contends that effective instruction employs a motivational design that (1) attracts and maintains student *attention*; (2) demonstrates the *relevance* of what students learn to important personal goals; (3) provides adequate demonstrations, coaching (including error detection and correction), and feedback so students feel *confident* in applying what they have learned; and (4) produces *satisfaction* with the learning experience. Forty-six students completed the survey for the pipe network (81% response rate); forty-four students completed the survey for the wind turbine (77% response rate). Results indicated opportunities to improve the instruction for these projects in ways that would attain and maintain attention and show the relevance of the piping design project.

While the researchers redesigned the course to employ more RBIS, the revision of this single course did not lead to subsequent revisions of others within the department or across the College of Engineering. This situation led the researchers to conclude that engineering faculty do not have the time to watch or participate in the redesign of other people's courses—even when these redesigns involve evidence-based strategies they could potentially use in their own courses. The team also realized that their redesign efforts involved the course instructor, two instructional designers, and one graduate student in support roles. Most engineering faculty do not have access to such resources. Like the Sounding Board, the Test Bed concept proved inherently unsustainable.

Lesson 2: Focus on the larger engineering education system, rather than its isolated parts.

It's typical to see reports of redesigned, one-off courses in the professional engineering education literature. The redesigned courses often contain a variety of RBIS that improve classroom learning and promote skill transfer to the engineering workplace. It's less common to see reports of curricula redesigned across an entire engineering department. It's exceedingly rare to see reports of curricular change that spans multiple departments at the level of a college of engineering within a university. Indeed, a discussion of such curricular level change was the focus of ASEE's 2012 plenary session.

Senge [13] contends that subsystem solutions don't produce systemic change. Any system (including a college of engineering) facing potential change will "push back" in the form of compensating feedback. He also observes that there are points of leverage that, while often nonobvious, can change the direction of an entire system. The problem of finding and using such subtle leverage points becomes more problematic because the way that people design and operate organizations makes it hard to see important interactions among their components. He mentions "rigid internal divisions that inhibit inquiry across divisional boundaries". In companies, these divisions often occur in the form of silos among marketing, manufacturing, and research. In engineering education, divisions occur within and among a larger cast of stakeholders affecting any engineering college, some of whom appear in Table 1.

• University leadership o Presidents o Vice Presidents o Deans o Department chairs • Students • Faculty	• Alumni • ABET • State Boards of Education • Industry • Legislators • Advisory Boards • Professional Organizations • Other Universities

Table 1: Engineering Education Stakeholders

The E^2R2P team realized that our initial efforts largely targeted revising one-off courses and isolated workshops. We ignored the larger system, including potential stakeholders in university leadership, industry, and professional organizations. In focusing on a bottom-up approach for creating change "by and for the faculty," we found that we needed the help of others in and outside academe who could participate in making and sustaining the change. In hindsight, our subsystem solution seemed better at collecting arrows than producing curricular change across one university's larger engineering education system.

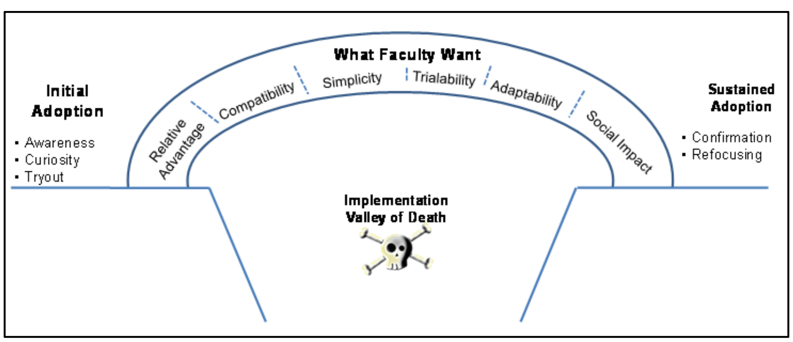

Figure 2: Change process requires passing through the implementation valley of death to provide what faculty want.

Lesson 3: Insurmountable time barriers prevent faculty from adopting RBIS.

People who adopt changes in their personal and professional lives work through a series of phases [14, 15]. Initial phases involve being aware of something different and curious about it. These initial phases may lead to a decision to try out something new, say an RBIS in an engineering course. Faculty reach this phase in the change process first completing “thought experiments” where they mentally try out the use of RBIS in their courses, visualizing how the changes might work—or not. After the mental try out, they may choose to try the RBIS in one or more courses. After reaching this point of these mental and hands-on try-outs, faculty make decisions about whether to keep on doing something different or to return to their previous ways of doing things. Faculty may see the tryout as successful, confirming their decision to use the RBIS. After using the RBIS for a while, faculty may even refocus on implementing new RBIS or other things in their teaching practice [16].

Henderson [17] notes that physics faculty are largely aware of 24 different RBIS, reporting that only 12% of survey respondents reported no knowledge of them. Another 16% of faculty are aware of these practices and have not tried using them. Another 23% of faculty try using these strategies and then discontinue their use after using them. Of the faculty who have tried these strategies, 1/3 don’t currently use them, 1/3 are low users who may employ 1-2 strategies, and 1/3 are high users who employ three or more strategies. These findings beg the question: How do engineering educators interested in curricular change that supports the use of RBIS span a valley of death that occurs when faculty try out these practices? Henderson reports that a “lack of time as the biggest impediment to using more RBISs” (p. 020104-3).

Henderson reports ten individual and situational characteristics facilitate the transition from a one-time tryer to a confirmed adopter. However, adoption is complex and there are more factors at work. Rogers [14] and Dormant [15] advise that characteristics associated with the change itself can work to accelerate, delay, or preclude its adoption. Seen through this perspective, the challenge becomes one of how to build the characteristics that appear in Table 2 into RBIS themselves in ways that address the overall “lack of time” that precludes greater faculty adoption.

Lesson 4: Universities, industry, and other stakeholders working in isolation can’t do much more to help engineering faculty address these problems.

Traditional silos in engineering tend to separate learning in the university from doing in the engineering workplace. The role of the university is to teach, and students are supposed to learn. Upon graduation, students begin working, where they are supposed to perform their jobs in ways that help their organizations meet business goals.

Such silos mean that academics often work in academic circles. Engineering faculty may seek advice about how to use RBIS from other academics. Deans and department chairs may feel uncomfortable acting as change agents promoting the use of RBIS across the different departments within their colleges. Promotion and tenure polices based on student evaluations and peer-reviewed publications may be misaligned with the introduction of RBIS, which could produce short-term decreases in student ratings and declines in submitted manuscripts.

Adoption Characteristic	Definition	Application	Example
Relative Advantage	The change is better than living with any new or old alternatives. The change is better than the one it replaces.	Faculty see an RBIS as better than the existing teaching strategy it replaces. An RBIS offering relative advantage answers the question of “what’s in it for me?” at a personal (rather than organizational) level.	A promotion and tenure committee views the use of RBIS in an assistant professor’s philosophy of teaching and learning as a factor warranting tenure.
Compatibility	The change is consistent with existing values, past experiences, and needs.	Faculty are more likely to adopt RBIS that are compatible with what they have done in the past as well as with their values, beliefs, and perceived needs.	An associate professor with prior industry experience wants to include “real-world” engineering projects in a course.
Simplicity	The change is both easy to understand and use.	The more simple an RBIS is and the easier it is to use, the more likely faculty will use it. The more complex an RBIS is and the harder it is to use, the less likely faculty will adopt it.	An assistant professor who wants to bring a practicing engineer to her class to talk about a “day in the life” contacts him directly using an online repository of vetted speakers willing to talk to classes for free.
Trialable	People can experiment with the change on a limited basis without experiencing any overwhelming adverse consequences.	Faculty can try the RBIS (or parts of it) in ways that are safe for themselves and students in their courses.	An associate professor flips one lesson in a course, making the lecture (homework) available before the course and using class time to provide coaching and feedback as students work in teams to answer a series of design questions. The professor flips more lessons over time.
Adaptable	People can adapt the change to fit their specific situations.	Faculty can tweak the RBIS (or parts of it) to fit it into existing or new courses or to accommodate a new group of students or technical content.	A lecturer with industry experience but little teaching experience uses a think/pair/share activity in a large lecture course.
Observable	The change produces desirable consequences for others who adopt it and doesn’t produce any unwanted consequences in their relationships with other people.	Faculty can observe positive consequences about other engineering faculty who’ve used and adopted RBIS in their teaching practice—without losing standing and respect from faculty colleagues, university administration, funding agencies, and students.	An assistant professor receives release time to sit in on classes that master instructors teach and the opportunity to sit with each after the course is over to discuss strategies, techniques, and the advantages and disadvantages of using them.

Table 2: Characteristics of change that lead to adoption

Silos may also preclude industry from taking a larger role in shaping the academic environment. Granted, engineering companies often support universities in the forms of internships and cooperative learning experiences. Industry may provide scholarships. Industry representatives may sit on engineering college advisory boards. While these forms of support are part of curricular reform, they also remain subsystem solutions if industry and academics remain working independently.

While internships, cooperative education, engineering practice programs, and similar efforts make these boundaries between academics and industry more porous, more needs to be done. Neither university leaders nor industry executives have the budgets or resources to provide support to engineering faculty in ways that would ensure that RBIS possessed characteristics that led to wider faculty adoption.

Lesson 5: Changing the curriculum requires a larger community of shared concern and practice.

The original E^2R2P concept drew on Wenger et al. [18-20] in cultivating the work of communities of practice (CoPs). These CoPs are "groups of people informally bound together by shared expertise and a passion for joint enterprise…people in communities of practice share their experiences and knowledge in free-flowing, creative ways that foster new approaches to problems" [19]. Unlike formal teams created by managers, members of a CoP are informal and self-organizing, with members selecting themselves based on their passions, commitments, and identification with the group's expertise; the CoP will last as long as there is interest in maintaining the group and its ability to develop members' capabilities to build and exchange relevant knowledge.

A Sounding Board overseeing course revisions in the Test Bed would act as a CoP. However, hindsight later revealed that this CoP comprised of faculty and a liaison to the engineering dean's office was simply too small and lacked the resources necessary to be sustainable—let alone produce curricular change across the college of engineering. Faculty working together to explore RBIS simply lack the wherewithal to ensure these changes to instructional practice possess characteristics that lead to their widespread adoption.

Lesson 6: Bring in partners and expertise in cross-boundary, multidisciplinary way.

The collapse of the Sounding Board and Test Bed concepts made the E^2R2P team realize that faculty-focused efforts to change the engineering curriculum were problematic. The team initially thought that a liaison to the dean's office could provide sufficient support for change. However, our re-reading of the change literature revealed our initial faith in change being driven from the bottom of the organization (a.k.a. "by and for the faculty") was misplaced. Conner [21] notes that major "change will not occur unless the appropriate sponsors demonstrate sufficient commitment…Sponsorship takes far more than ideas and rhetoric; it requires the ability and willingness to apply the meaningful rewards and pressure that produce the desired results. And sponsorship in changing engineering education curricula is more complex. Sponsors could include deans, department chairs, advisory boards, engineering firms, and others. Given our realization that we needed to adopt a systemic approach to changing instructional practice, we began working with a variety of sponsors. The dean of the college of engineering offered to support our work. We met with interested department chairs. They offered access to their respective advisory boards comprised of representatives from local engineering firms.

In addition to including potential sponsors from university leadership and industry, the team also realized that we needed to bring in additional expertise in qualitative research methods and business communications. We began finding allies in administrators, deans, department chairs, faculty, engineers and others who care about student learning and its transfer to subsequent courses and the engineering workplace.

Lesson 7: Work together to address a shared concern: Decreasing ramp up time to competent workplace performance.

To remove barriers to adopting RBIS, the E^2R2P team had realized that it needed to involve stakeholders throughout the system to make a systemic change. Working systemically required a larger CoP that cut across traditional academic and industry silos. This larger CoP would theoretically possess the wherewithal to promote the adoption of RBIS by reducing the time that faculty would need to spend adopting them. This larger CoP could work together to find ways to ensure that RBIS possessed the characteristics that promoted their faculty adoption, rather than hindered it.

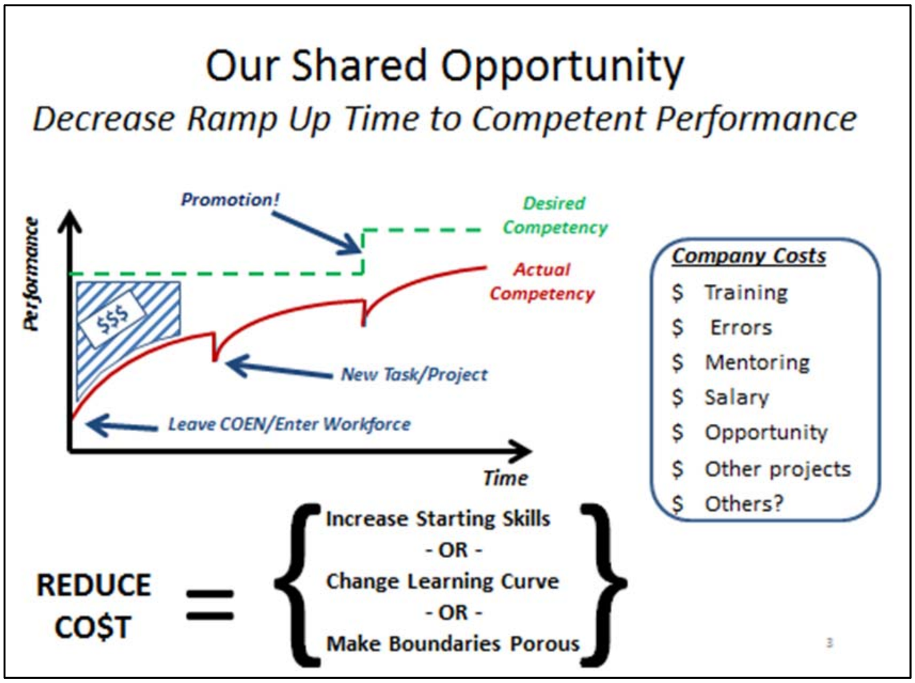

Figure 3: A shared opportunity to decrease ramp up time to competent performance in the engineering workplace

The question became what shared concern could form the basis of this larger CoP. Conceivably, the concern could be anything that significantly affected academics and industry alike, such as sustaining innovation, seizing global markets, or creating new engineering approaches that worked with agile project management strategies. The team chose a different shared concern: how to decrease the time that newly graduated and hired "fresh out" engineers need to reach competent levels of performance in the engineering workplace. For academics, ramp-up time to competent workplace performance could become a competitive differentiator among engineering programs. Students investigating engineering degree programs might prefer those that produce graduates who require less time to come up to speed on the job. Likewise, engineering firms looking to hire the best talent in ways that minimize costs and maximize revenue might prefer to hire graduates of such programs. As depicted in Figure 3, decreasing time to competent performance means decreasing costs associated with employee orientation and onboarding. Decreasing ramp up time also means getting employees who help the organization meet its business goals sooner. Ultimately, such cost reduction depends on increasing freshouts' starting skills, changing their learning curve, or making the boundaries between academic and industry experiences more porous.

Lesson 8: Make the effort to grow the contact network to address this opportunity.

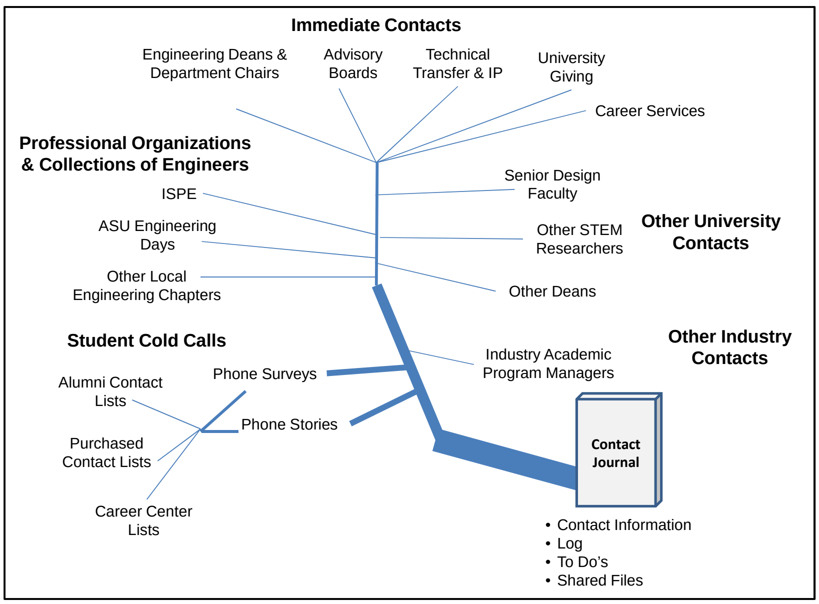

Figure 4: Contacts to grow the community of shared concern and practice

Getting opportunities to grow a larger community of shared concern and engineering practice that wants to decrease ramp up time to competent requires industry contacts. Collecting data to help guide these efforts requires people who can say "yes" to focus groups, interviews, and surveys. It requires people that can authorize release of extant data. Most academics may not know many engineering managers high enough on their organizational food chains to take engineers off billable project work and put them on internal overhead to participate in focus groups.

It takes time to grow the contact network that can bring academics and industry stakeholders into a larger community of shared concern and practice. As depicted in Figure 4, the E^2R2P team has grown immediate contacts by meeting with engineering deans and department chairs, advisory boards, university technical transfer and intellectual property personnel, university giving directors, and career services. The team has also contacted other university contacts, including engineering senior design faculty, other STEM researchers, and other deans in the Arts and Sciences and Business Colleges.

The team has also begun contacting professional organizations to administer an engineering practices survey at their meetings. The team administered this data at an August meeting of the Idaho society of professional engineers and will return during a February meeting to discuss the results. The team will contact other professional engineering organizations to try to make similar arrangements.

To manage the communication stream with the growing network of contacts, the team now uses a "contacts journal" software (Contacts Journal, iPad Edition v.3.2.1. from zaal LLC). This commercially available product acts as a shareable repository for contact information, contact logs, "to do" lists, and document files the team has sent.

The team's plans for expanding the E^2R2P effort involve recruiting and paying undergraduate engineering students to use contact lists provided by the alumni association, the career center, and other mailing list providers to place calls to practicing engineers in the workplace to collect data. One source of data would be administering a short phone survey about engineering practice in the workplace. Another source of data would be conducting an online phone interview to collect incidents of successful and unsuccessful workplace performance and the root causes of nonperformance. Each of these interactions would conclude with a request to ask the participant's supervisor or manager the same questions. This modified Delphi technique will further grow the contact network of both practicing engineers as well as higher-level managers.

Lesson 9: Use a common engineering model to create a venue for collaborative problem identification and root cause analysis.

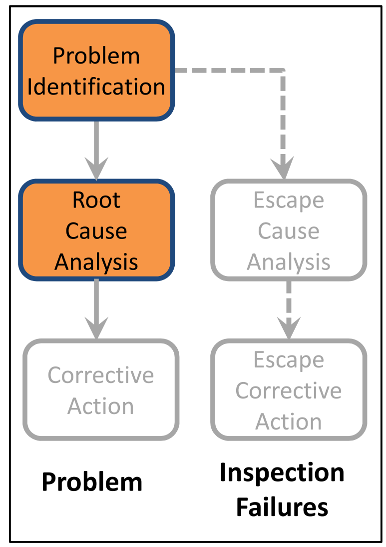

Figure 5: Education engineering for engineering education

From a cognitive standpoint, curricular change is about solving a messy, ill-structured problem. According to Foshay, Silber, and Stelnicki [22] ill-structured problems are the most complex problems people try to solve. The goal state isn't clear, and the initial state and constraints may be unknown when people start trying to solve these problems. People who try to solve ill-structured problems need to recall and assemble what they know in novel ways to solve the problem—as they are working on it. Compounding this situation is the fact that a systemic approach to changing the engineering curriculum to employ RBIS involves ill-structured problem solving across a community of shared concern and practice. While members of this CoP share a concern for decreasing ramp up time to competent performance in the engineering workplace, their perspectives on how to do this may be quite different.

Different disciplines employ their own solving models for solving ill-structured problems. Performance improvement practitioners have used their own models [23-26], and they use them to seize opportunities to decrease ramp up time to competent job performance in a variety of workplace settings [27, 28]. However, performance improvement practitioners and their models use their own terminology, and there is no reason for academics or engineers to learn or use it.

Acting on advice from our NSF program manager, the E^2R2P team opted to use an engineering model [29] depicted in Figure 5 to improve engineering education. Our current research agenda focuses on problem identification and root cause analysis to answer the following questions:

1. What are newly graduated and hired “fresh out” engineers doing/not doing in the workplace that they should?
2. What are the consequences of performance/non-performance in the workplace?
3. What workplace competencies should fresh outs possess?
4. In what workplace contexts do fresh outs apply the competencies?
5. What are the root causes of workplace nonperformance?

Lesson 10: Talk about what fresh out engineers are *doing* on the job, along with its monetary and nonmonetary consequences.

Incident Card **Name:** ________________

Describe an incident in the workplace that occurred within the first six months to three years after a newly graduated engineer first starts working.

Does this incident reflect (check one):

☐Where the new engineer successfully performed a job task?

☐Where the new engineer was unsuccessful in performing a job task?

What were the general circumstances leading up to this incident?

Specify exactly what the new engineer was trying to do on the job.

How did this incident affect the goals of your project, department, or company?

How long had the new engineer been on the job when this incident occurred?

Figure 6: Critical incident card for a manager

Answering the team’s research questions meant avoiding common pitfalls and finding ways to collect trustworthy and useful data. The team decided that it wanted to avoid conversations within the community of shared concern and practice about “knowledge” and potential topics for courses and lessons. From a pragmatic standpoint, there is no way to address all of the topics that appear on these continuously growing lists. At best, these conversations tend to produce lectures and learning activities associated lower levels of Bloom’s taxonomy. The addition of such topics does little to promote learning within a given course, let alone promote transfer to subsequent courses or the engineering workplace.

To avoid this pitfall, the E^2R2P team opted to use workplace performance as a gold standard for specifying competencies and contexts that promote skill transfer. Instead, of talking about knowledge and topics, the team opted to talk about what fresh out engineers are ***doing*** on the job. To collect such data in a rigorous fashion, the team drew upon the critical incident method [30-32]. We facilitate focus groups comprised of 3 – 6 participants who are either.

- Engineering managers, engineering leads, HR personnel, and technical scientists who work with fresh out engineers.
- Fresh out engineers.

During a typical session, participants:

1. Complete 2-page engineering practices survey.
2. Generate incident cards (as depicted in Figure 6) describing successful workplace performances and share them with the group.
3. Generate incident cards describing unsuccessful workplace performances and share them with the group.
4. Create categories describing the incidents.
5. Assign each incident to a category.
6. Rank the categories in terms of their overall importance.

Qualitative analysis of these data will produce industry-derived workplace competencies and their corresponding contexts, answering research questions 1-4.

To investigate root causes of nonperformance in the engineering workplace (RQ 5), the team drew on the work of a variety of theorists to create a troubleshooting model that identifies environmental and personal factors. Most of the model arises from the work of workplace performance improvement theorists [33-35]. The addition of flexibility and resilience arises from more recent work investigating expertise, wisdom, and sustainability [36-38].

	Information	Tools	Motivation
ENVIRONMENT	• **Data** • **Expectations** • **Feedback** • **Standard Operating Procedures**	• **Resources** • **Software** • **Tools** • **Support**	• **Incentives** • **Rewards** • **Consequences**
PERSON	• **Knowledge** • **Skills**	• **Physical Capacity** • **Mental Capacity** • **Flexibility** • **Resilience**	• **Motives** • **Affect** • **Work Habits** • **Drive**

Figure 7: Root cause analysis model for troubleshooting instances of unsuccessful performance.

To provide these data, focus group participants first select the incident cards they've written describing unsuccessful performances. Participants then place each incident card describing an unsuccessful performance into a cell of the root cause analysis model that appears in Figure 7.

Lesson 11: Collaborate on interpreting the problem identification and root cause analysis data.

After each focus group, the E^2R2P team asks the company sponsor who approved the focus group and the focus group participants whether they are interested in a follow up discussion about:

- The aggregated results of their focus group.
- How their focus group results compared to others.
- Their interpretations of the results.

The team hopes that this collaboration in collecting and then analyzing problem identification and root cause analysis data works to build shared concern within a larger community of engineering practice. To date, everyone has been interested in participating in these follow-up discussions.

Lesson 12: Work together to specify corrective actions that remove barriers to RBIS adoption.

Combined with the E^2R2P team's outreach activities at local professional organizations and other efforts to grow our contact network, we see this collaboration in problem identification and root cause analysis as a foundation for future collaborations about shared corrective action. The team hopes that the community of shared practice and concern is large enough at this time to work together to find innovative and effective ways to:

- Build characteristics into RBIS that will make more engineering faculty want to try them out.
- Decrease the time pressures that prohibit faculty from adopting RBIS in their teaching practices.
- Remove other barriers in academic and workplace settings that increase ramp up time to competent performance.
- Remove the silos between academics, industry, practicing engineers, and other stakeholders in ways that provide systemic solutions promoting curricular change.

Conclusion

In the marketplace, "first movers" follow "product pioneers" and "innovators" [39]. They have a 47% failure rate. Together, innovators, product pioneers, and first movers collect the arrows in the backs for the "fast followers" who come afterwards. These later settlers experience failure rates of 8 percent. As academics, rather than entrepreneurs, the E^2R2P team is delighted and honored to have collected the arrows in our backs that form the basis of this story about the lessons we've learned. We hope that others trying to improve the engineering education curriculum in ways that improve learning and its transfer to subsequent courses and the engineering workplace find our tale informing.

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