Harnessing Engineering Expertise in Industry: Activating Six Sigma themes in a College/Industry Course Development Collaboration

Dr. Mary K. Pilotte, Purdue University, West Lafayette

Mary Pilotte is Associate Professor of Engineering Practice in the School of Engineering Education at Purdue University, West Lafayette, Indiana. She leads the First-Year Engineering instructional operations group, is an instructor for First-Year Engineering and Multidisciplinary coursework, and was recently appointed Director for the undergraduate Interdisciplinary Engineering Studies and Multidisciplinary Engineering program. With over 20 years of industrial work experience, and supportive of her academic roles, Mary actively leads academic outreach to industrial firms to develop in-classroom, project-based, active learning through identification of "real life", in-context problem scenarios.

Pilotte's research interests involve understanding engineering culture, identity, and communication in the context of professional engineering practice. Expanded interests include understanding student benefits associated with in-context active learning, innovative distance learning, and global learning experiences. She holds Bachelor of Science degree in Organizational Leadership and Supervision from Purdue University, an MBA from the Goizueta School of Business, Emory University, Atlanta, Georgia, and a Ph.D. in Engineering Education from Purdue University.

Dr. Rick I Zadoks, Caterpillar Inc.

Rick Zadoks is the Engineering Technical Steward for Engine Dynamics at Caterpillar Inc. He is Caterpillar's representative to Purdue University's School of Engineering Education Industrial Advisory Council and currently serves as the Chair. Before joining Caterpillar, Rick was a professor in Mechanical Engineering at the University of New Mexico (1988-1994) and the University of Texas-El Pas (1994-2000). He received his PhD in Mechanical Engineering from Purdue University, where he served as a Graduate Instructor in the Department of Freshman Engineering.

Dr. Monica Farmer Cox, Purdue University, West Lafayette

Monica F. Cox, Ph.D., is an Associate Professor in the School of Engineering Education at Purdue University, the Inaugural Director of the College of Engineering's Leadership Minor, and the Director of the International Institute of Engineering Education Assessment (i2e2a). In 2013, she became founder and owner of STEMinent LLC, a company focused on STEM education assessment and professional development for stakeholders in K-12 education, higher education, and Corporate America. Her research is focused upon the use of mixed methodologies to explore significant research questions in undergraduate, graduate, and professional engineering education, to integrate concepts from higher education and learning science into engineering education, and to develop and disseminate reliable and valid assessment tools for use across the engineering education continuum.

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Abstract

With over 10,000 Baby Boomers a day retiring from the U.S. workforce, the issue of retaining irreplaceable knowledge capital was at the forefront of strategic initiatives of industrial leaders. In spite of the attention the topic was receiving in industry, little mind space or targeted research within the academy was being focused on the looming issue. In 2011, with urging and support from an Engineering Education Industrial Advisory Council (IAC), a first of its kind course was launched entitled "Harnessing Engineering Expertise in Industry". The graduate course, co-developed and instructed by university faculty and members of the IAC, explored the topic of engineering expertise from an industrial perspective. The objective of this course was to make explicit the concept of expertise in industry, to replicate and/or develop research based approaches for identifying and capturing this expertise, and to consider how these approaches could benefit industrial enterprise. Further, rigorous Engineering Education research practices were put to work underpinning the topical exploration, and enabling the class deliverables which included individually developed, industry facing, research proposals, and formal proposal "pitch" presentations to industry representatives. Beneficial outcomes from developing this course have included: 1) establishing a foundation of college/industry collaborative graduate level course work that supports the concerns of industry facing stakeholders and beyond, and 2) offering engineering education students a unique area of research specialization focused on life-long learning and engineering practice in Industry.

Framed using the so-called "six themes of Six Sigma": genuine focus on the customer; data and fact driven management; processes are where the action is; proactive management; boundary-less collaboration; and drive for perfection-tolerate failure [1], this paper unpacks the collaborative processes and perspectives by which this course was developed and continues to evolve and improve. Authors suggest that collaborative industry/academic efforts may benefit by reflecting upon their work product through the six themes of Six Sigma as an alternative assessment framework to traditional academic assessment approaches.

Introduction

Six Sigma – An improvement mindset

Six Sigma is a quality management system that swept the industrial sector in the 1990's and became indelibly connected to the General Electric (GE) conglomerate and more specifically, their leader, patron, and program promoter - Jack Welsh. The American Society of Quality (ASQ) defines Six Sigma as "A method that provides organizations tools to improve the capability of their business processes. This increase in performance and decrease in process variation lead to defect reduction and improvement in profits, employee morale, and quality of products or services." [2]

Early on, Six Sigma was seen as just another operations focused quality improvement methodology [3]; however, its persistence and proclaimed benefits beyond manufacturing operations [4, 5] into far flung areas including white collar and service industries such as healthcare, necessarily commanded a higher level of deference for its approaches, results, and the culture that flows from practice of the methodologies and tools that are embedded components of its prolonged success. The Six Sigma movement is sometimes framed as more than a statistically oriented intervention framework, rather a managerial mindset required to survive the rigors of churning external business conditions and robust competition [6]. Similarly, others regard Six Sigma as an opportunity to engage the entire organization in improvement and organizational learning [7].

The Six Sigma frameworks and language – while new to some academic constituents, has begun to find its way into academic institutions, as stakeholders from industry begin engaging in academic affairs through more frequent interactions, adjunct instruction, the creation of advisory boards, and purposeful efforts to bring authentic industrial contexts to the classroom. It was just such engagement with industry that lead the School of Engineering Education at Purdue University to collaboratively develop a graduate level Engineering Education course.

Development of an Industry Focused Course

In 2011, Purdue University's School of Engineering Education was encouraged by their Engineering Education Industrial Advisory Council (IAC), to develop a first of its kind course focused on topics important to industrial concerns. Entitled "Harnessing Engineering Expertise in Industry", this graduate course explored the concept of engineering expertise in the workplace. The stated objectives of the course (which continues today), was to: 1) make explicit the concept of expertise in industry; 2) replicate and/or develop research based approaches for identifying and capturing this expertise; and 3) to consider how these approaches could benefit industrial enterprise. The course also embedded rigorous engineering education research practices, enhancing the credibility of the research undertaken, and concurrently supporting the class deliverables which included individual student developed research proposals and execution of "pitch" presentations to industry representatives.

The school, course designers, and the IAC community idealized several beneficial outcomes associated with developing this new course including: 1) establishing a foundation of college/industry collaborative graduate level course work that supported the concerns of industry facing stakeholders and beyond, and 2) offering engineering education students a unique area of research specialization focused on life-long learning and engineering practice in Industry. The creation and assessment of this course however moved beyond the initial objectives idealized. In retrospect, this course development project serves as a means for evaluating one industry/academic partnership through the lens of a Six Sigma orientation, by way of a shared experience.

Review of Literature

A scant number of scholars are reflecting upon how Six Sigma tools and mindsets might be appropriate for use in academic settings, beyond a few who discuss the appropriateness of teaching Six Sigma as instructional content [8]. Hargrove & Burge, and Burtner [9, 10] however have used Six Sigma concepts to review university policies and to help reduce student defections from engineering education programs. In the context of education, a loss of a student from the engineering program examined was seen as a Six Sigma defect of the educational system, requiring attention to improve customer (student) satisfaction. Others [11, 12] have explored and expressed the difficulties of integrating Six Sigma into the fiber of the academic system.

The initial and crucial challenge of Six Sigma deployment in academia is overcoming the intellectual debate over defining the work product, and for whom this product is developed (the customer). Jenike, Kumar, and Holmes [11] suggested a three-tiered framework for implementing Six Sigma within the academy. In this proposed framework they advised that there are tangible actions that can be taken at various levels of university administration. The top "tier one" level reserved for administrators, is suggested to focus on defining customer requirements, while at the lowest "tier three level" representing departments and programs, the focus is idealized as best suited for initiating improvements that serve and sustain (i.e. control) a beneficial customer metric of performance [11]. Specifically, the development of new courses using Six Sigma tools has been identified as an area of opportunity at the departmental/major level of an academic unit.

Framework of Reflection

While some has been written idealizing Six Sigma in the academic setting, there is no study that evaluates the development of a new engineering education course through the lens of Six Sigma's six critical themes [1]:

1. Genuine focus on the customer
2. Data and fact driven management
3. Processes are where the action is
4. Proactive management
5. Boundaryless collaboration
6. Drive for perfection, tolerate failure

These themes, combined with a qualitative method of participant observation, unify to describe the origins and subsequent execution of a graduate level Engineering Education course in Purdue University's School of Engineering Education. The course is entitled "Harnessing Engineering Expertise in Industry".

Theme 1: Genuine focus on the customer

Unlike the wide range of quality improvement systems/programs that have existed across time in the industrial sector, the Six Sigma approach involves a dogged focus on customers and their needs. Defining the customer as the highest order priority in all development/improvement activities within a firm becomes the litmus test to answer if a project should be taken on, and if so, how it should be measured based on customer definitions of improvement within their lived experienced. The ultimate goal of Six Sigma is "the creation of economic wealth for the customer and provider alike" [13]. In the world of Six Sigma, all knees bend at the altar of the customer; all priorities explored, projects defined, and measures of performance analyzed must service the needs of the customer. But who exactly is the customer in a graduate education program?

The difficulty of identifying customer in the academic setting was acknowledged by prior researchers; however, to allow the difficulty of a task to render a task unattainable is inconsistent with the academy's charter to advance the inconceivable. For the case of creating a course focused on industrial themes, the identity of both the customer and provider evolved, merged, and evolved through a series of extensive discussions between the IAC and key stakeholders within the school of Engineering Education. This process of defining a broad and evolved identity associated with "customer" is consistent with experts in the domain of engineering design for new product development.

Ulrich and Epplinger's [14] view of customer expands to include stakeholders who take an active role in defining and delivery of the end product to the end user. Using this definition, adhering to theme one of the Six Sigma critical themes (genuine focus on the customer) dictated careful listening and responsiveness to all those who engaged in the early discussions around the need for a course on the topic of industrial knowledge capture. In this case, those stakeholders included engineering education faculty and department leadership, Ph.D. students at various stages within the program, and industrial advisory committee members, all totaling nearly 25 people. The IAC members represented organizations including large consumer products firms, heavy industrial equipment manufacturers, major airlines, and small consulting firms.

Continuing the comparison of design/development of this course to engineering design activities used in industry, the capture of the so called voice of the customer (VOC) [15] would be a necessary step in defining critical attributes of such an idealized course. Harvesting the VOC includes developing a customer needs list, developing a hierarchical structure for those needs, developing "importances" [15] from which to prioritize those needs, and looking at competitive products aimed at meeting those same customer needs. Such a needs list was developed through a series of open discussions and more formal IAC meetings with the broadly defined customer list mentioned above across nearly three years. The needs included developing a robust research program that supported the needs of industry, and establishing course work that supported Engineering Education graduate students with an interest in a career in industry or in learning how the field of engineering education is applicable in industry. Priority or "importances" were assigned to needs based upon the following criteria: 1) course activities/deliverables which added authenticity and increased student exposure to industry generally, 2) course activities which engaged IAC members as ongoing key stakeholders or industrial subject matter experts (SMES) on themes central to knowledge sharing, and 3) course activities/deliverables that were action oriented, in that they advanced the body of knowledge on the course topic through rigorous research activity, and/or they advanced student research-based interaction opportunities with industrial contacts.

Theme 2: Data and fact driven management

Six Sigma methods dictate the collection and analysis of data to help clarify potential sources of opportunity. It had been made apparent through the numerous stakeholder discussions within the local engineering education community that there was interest and anecdotes to support development of a course around the topic of retaining knowledge capture in the industrial sector. That said, there was little known about what research on the topic already existed within the engineering education domain. Following a data driven Six Sigma protocol demands that two key questions be asked: 1) What data/information is needed to actively analyze the problem? and 2) How can use of that data/information provide the maximum benefit [to the customer]?" [1].

The community of engineering education highly values a wide range of qualitative/quantitative data collection and validated methods that lead to rigorous research analysis. To that end, to answer the question of what data was needed, it seemed that greater understanding of the body of knowledge within the topical domain would be a worthwhile activity preceding advances in defining a new course. The question on the use of data to maximize customer benefit, spoke to the need for a quality research approach to help encourage development of actionable frameworks from course participants (engineering education graduate students) from which solutions for industry could be examined, trialed, and more fully developed.

Serendipitously, at nearly the same time in 2010 that discussions were being held with the IAC and faculty were exploring the opportunity for an industry focused course, a student in the Engineering Education graduate program (author Pilotte) requested an independent study on the topic of knowledge capture in industry, unaware of the prior series of investigative discussions. The independent study (IS) was approved and was executed in part as an extensive literature review. Completed in the summer of 2011, this IS served to provide evidence to both the school and the IAC that while a wide range of research had been conducted outside of engineering, there lacked sufficient data and rigorous research on the topic within the engineering education domain. The IAC and potential students for the course were both encouraged and discouraged by these findings. On a positive note for potential student customers, it became apparent that a course focused on research and discovery along this topic would be both novel and innovative in nature, providing rich ground for Ph.D. thesis topics. On a less optimistic note for the IAC customers, it became clear that a swift remedy to help stave off knowledge loss in the industrial setting was not something that could be readily resolved in the near-term by building upon ready research.

The discoveries (or lack thereof) from the IS became the reinforcement necessary to urge the IAC and faculty group further in development of the course. After a brief course sub-committee meeting in the summer of 2011, the decision was made to launch the inaugural course as an experimental offering that fall, co-taught by one full-time faculty member and one volunteer industry representative from the IAC. The full-time faculty member (author Farmer Cox) was a tenure-track member of the Engineering Education department with an interest in the industrial environment and topics around engineering education, policy, and leadership. Her research explored the preparation of engineering Ph.D. students for careers in academia and industry. Informed from some of her research findings, this course addressed several issues of concern by engineering Ph.D. holders working in nonacademic environments. The co-instructor from the IAC (author Zadoks) came to the course with unique perspectives and benefits non-traditional to most graduate courses. Zadoks had lived a hybrid career that combined both time worked in academic settings as a faculty member, as well as an extensive career in the industrial domain leading high-stakes engineering departments and programs. His experience and exposure across settings (industry/academy) as well as disciplinary domains (engineering/education) offered an advantageous compliment to the engineering education faculty instructing with him.

The course was created as a “temporary course” which expedited its creation within the university’s sometimes slow-to-respond system for course introduction/development. The title of “Harnessing Engineering Expertise in Industry” was assigned to the course. Given limited time for course promotion, the first class filled with 5 students including author Pilotte who agreed to take the course to further develop her IS work, and to serve the other course participants as an emerging topical domain reference.

Theme 3: Processes are where the action is

A key tenant of Six Sigma is the reduction of so called defects by reducing process variability [16]. Process variability can be related to limitations of assets/resources/people who own and manage the processes, as well as a simple lack of process documentation. In firms that adhere to a Six Sigma approach, training on and use of well documented standardized processes is the cultural norm. Mastery of key processes is thought to be an effective way to maintain competitive advantage while delivering value to customers [17]. It was in that light that substantial thought was given to identifying processes that would be both core to skill development in Ph.D. student researchers, and would help build a process mastery mentality into the learning outcomes and deliverables of the new course. Further, if students who completed the course were viewed as even budding “masters” of these processes, it was hoped that it could potentially be seen as a “competitive advantage” for students within the larger Engineering Education Ph.D. program.

One primary deliverable associated with the “Harnessing” course included creation of an industry targeted proposal for funded research. Successful scholars in the academic community come to know how to develop such proposals through tacit learning as they are exposed to proposal writing opportunities over time. Successful proposal writing requires both process knowledge and developed skill to achieve long-term academic success, as one aims for developing a world-class research agenda. Within graduate education, making explicit and following a standard process for developing and presenting such a proposal was viewed by the course stakeholders as a skill set that could enable young scholars to take their research questions into actionable discovery with greater speed and efficiency. Further, mastery of the proposal writing process was actively encouraged over the span of the course in a semester, as students turned in successively improved drafts of their proposal, receiving feedback from both instructors. The feedback from instructors ranged from students’ adherence to a standardized proposal structure, to appropriate methods targeted for the research questions, to strategic positioning of their proposals for an industrial audience.

Identifying and highlighting the importance of this process/skill to the student customer is now viewed as a critical success element of the course. This course deliverable also serves the needs *and actions* of the external industry focused customers, as they seek opportunities to fund research that is focused on helping to solve their most critical problems – critical knowledge loss being one of those issues. In sum, identifying a core process central to scholarly research work and creating a course deliverable served through an appropriate pedagogical approach that helps encourage process mastery, has enabled students in the course to develop a work product that not only encourages action and progress on their individual academic careers, but also offers the opportunity for action by would be industrial sponsors of high-quality engineering education research.

Theme 4: Proactive management

Consideration of Six Sigma theme four (proactive management) is a reminder to retain creativity and responsiveness while valuing the conformity of strong process, and promoting analytical approaches to improve quality [1]. Proactive management in relation to product development is about creating a culture where one constantly reviews current product performance and anticipates the next opportunity for improvement, staying tuned in to dynamic customer demands [13]. This concept of proactive management as "continuous improvement" was embedding early into the development of the Harnessing Engineering Expertise in Industry course, perhaps in part due to the significant role played by industry-based stakeholders.

The first example of proactive management using a continuous improvement approach can be demonstrated in the evolution of the course itself. Mentioned prior, the course began as an exploration of the topic via an independent study course (summer 2010); from there the first full course emerged (fall 2011). After the conclusion of the first course run, several opportunities for improvement were identified including: the addition of industry-focused guest speakers presenting on topics ranging from entrepreneurship to common practices in doing university research with industry; student field trips to industrial sites to meet with key organizational learning personnel; and the institution of a "student/Ph.D. advisor contract" establishing a formal co-commitment should the proposal be picked up and funded by an industrial client. The fall 2012 course was further enhanced once launched, by pre-seeding research questions for enrolled students by soliciting a "hot list" of critical subjects from the IAC. Providing students with the option to select from this short list improved the chances that students' proposal presentations might find willing sponsors for the research.

A second example of proactive management in the design of this course revolves around more strategic and innovative discussions led by the two instructors and joined by key stakeholders. In several brainstorming sessions since its inception, stakeholder participants have critically examined how this single course might evolve into a collection of unique industry related courses, projecting even further into how the idealized collection might translate into a one-of-a-kind value proposition for the Ph.D. students that would consider it as a track for research. Embracing a spirit of innovation, the key stakeholders have leaned into the possibilities of meeting future customer needs. This way of thinking and acting is central toward instilling Six Sigma thinking within the academic setting.

Theme 5: Boundaryless collaboration

Theme five (boundaryless collaboration) is about harnessing the power of improved teamwork, making every effort to eliminate disconnects, destroy barriers, and build synergy across (inside and outside) organizations [1]. The goal to achieve a high degree of teamwork and collaboration is in many ways an effort to eliminate waste and "defective exchanges" between disparate individuals and groups. The degree to which different types of groups come together to work cooperatively is a direct reflection of the importance each group places on the joint effort between them [18]. To that end, the development of the Harnessing Engineering Expertise in Industry course, from its very inception, has represented boundaryless collaboration at its best. In particular, the interactive teamwork represented within this project provides a possible emergent model for academia and industry partners moving forward.

The School of Engineering Education at Purdue University takes seriously opportunities to engage their IAC. The IAC meets formally with members of the school twice a year, and agendas are filled not only with "state of the union" topics, but also include faculty/IAC break-out sessions to debate and discuss key topics and critical processes under review. Throughout the year, individual IAC members meet and engage faculty members in a wide variety of specific research endeavors. Developing an empowered, lively, and collaborative culture within the joint IAC and Engineering Education faculty requires strong leadership on both sides, and a mutual commitment toward the end goal of improving the state of education in the domain of engineering.

Building upon the mutual goal of improving the state of engineering education allows for all parties to think creatively about possible solutions to this very daunting problem. It was just such creativity, coupled with a deep commitment from one of the IAC members, which made possible enlisting instructional support to teach the industry-focused course. It should be noted that this in no way compromised the quality of instruction; quite the contrary, as not only was the IAC member credentialed with a Ph.D. in engineering, but as was noted earlier, had prior classroom experience as a mechanical engineering faculty member.

Shared goals also fuel the collaboration between the engineering education students, faculty, school leadership, and the IAC. Careful course design, which was built in part based on student interest and ongoing feedback/input, has evolved into a self-perpetuating, virtuous cycle of interaction and collaboration. This cycle can be modeled as follows:

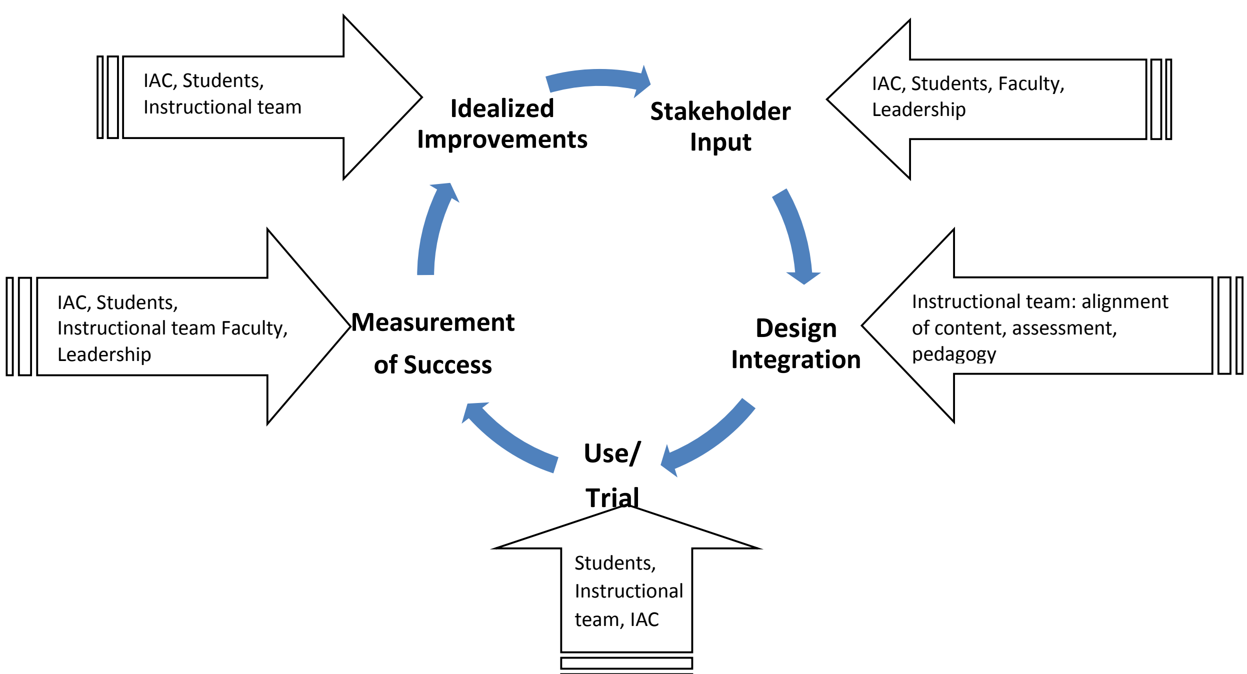

Figure 1 Course development and customer/stakeholder engagement model

Theme 6: Drive for perfection; tolerate failure

No one enjoys experiencing failure; however, embracing a *tolerance* for failure allows one to make choices beyond the safe and sure, develop a willingness to innovate in areas of uncertainty, and reach out to unexpected and new partners. The ultimate statistical goal of Six Sigma is perfection, but perfection is rare in reality. The objective of the sixth critical theme of Six Sigma is to strive for perfection, but accommodate and manage through collapse and disappointment [1].

Up to now, the narrative of this course development and stakeholder engagement may read like the fabled portrait of Six Sigma perfection; however, as always, opportunities for improvement existed. While many significantly beneficial outcomes have materialized from the project, a myriad of unexpected situations have also occurred, often presenting themselves as failures if not defects of an incomplete work-in-process. The most significant failures to date revolve around human resources; that is to say activity associated with students, faculty, and IAC members engaged in the engineering course or Ph.D. program.

As mentioned earlier, there were five enthusiastic Ph.D. students enrolled in the first launch of the Harnessing Engineering Expertise in Industry course in fall 2011. This was followed by five students in fall 2012, and this time, the group even included a student from outside of engineering education who had heard of the course. Many were optimistic about these increases/diversity, and believed they would likely continue into the future. Unfortunately, it was determined that there would be no scheduled class in the fall of 2013 due to competing obligations of the instructors. The break in course offering seemed to have a negative impact on student interest in the course. This was seen in the fall of 2014, when in spite of marketing the course broadly, most students had already planned their fall class line-up and the course failed to fill to the course minimum and was cancelled for that term.

Upon investigation and interviews with students who were thought to be viable course customers, it was revealed that after the course's one year hiatus in 2013, the group of prospective students planning to take the course had advanced in their programs and were no longer able to fit the course into their schedule which now included a healthy dose of research credits. Additionally, the perceived unreliable availability of the course led students whose interests were in industrial topics to redirect their efforts to more prevalent themes that offered a broader course offering (K-12 education; Global Engineering; Technical topical research areas).

Other human resource related failures were smaller in nature but still directly impacted the course and its delivery. In one instance of the course, a key IAC member who had committed heavy participation was assigned a high priority and time consuming project at work and so had to cut back on the commitment to the course. Likewise, the primary faculty was sometimes unable to participate regularly given competing course, administrative, and service responsibilities that did not provide ample time and resources (e.g., course buy outs) for her to devote to an elective graduate course; this left the IAC instructor to increase his portion of the course load. The departure of the faculty member for a sabbatical during the following year left course development and implementation up to other faculty who also had competing demands and responsibilities. Neither of these situations jeopardized the course on whole, but through the lens of Six Sigma can be viewed as defects of the course planning process, and offer opportunities for improvement going forward.

While each process defect is disappointing, they are reminders that development of a course does not end with idealizing the concepts and content to be taught. Content development represents just the beginning of a journey that requires careful attention toward human resource planning and course marketing. Without careful ongoing attention to the customers, including their needs, schedules, and availability, the best designed course will remain unexercised and fall short of its idealized potential.

Conclusion

In this paper, an innovative graduate level engineering education course was outlined. The course, Harnessing Engineering Expertise in Industry, focused on exploring relevant literature and methodological approaches for research tied to the central topics of expertise, knowledge capture/loss, and organizational learning. The course's development was discussed and explored through the novel lens of Six Sigma's six critical themes, relaying details of its origins, subsequent execution, improvements, and failures.

The relative success of this course was made possible through a deliberate and highly collaborative relationship between the school (including the Engineering Education leadership, faculty, and graduate Ph.D. students) and an intensely involved Industrial Advisory Committee. While not offered in the most recent two years, the forward looking plan is to offer the course again in the next academic cycle, migrating it from its temporary number to a permanent one, thereby securing its importance in the Engineering Education program. Through early, purposeful, and reoccurring marketing of the course, it is hoped that the interested student body will once again converge to explore and expand critically important research topics relevant to industry and engineering educators alike.

For other academic organizations hoping to increase industry-based collaborations, it is suggested that when undertaking projects or considering large-scale joint development endeavors, this example may serve as a new model for engaging willing and qualified industry partners. Further, when involved in any educational development process, examining plans, actions, and outcomes through the six themes of Six Sigma can provide a valuable alternative to traditional academic assessment approaches.

Bibliography

1. Pande, P. and L. Holpp, *What is Six Sigma*. 2002, New York: McGraw-Hill. 87.
2. American Society for Quality. *What is Six Sigma?* 2015 [cited 2014 November 20]; Website]. Available from: http://asq.org/learn-about-quality/six-sigma/overview/overview.html.
3. Snee, R.D., *Why should statisticians pay attention to Six Sigma?* Quality Progress, 1999. **32**(9): p. 100-103.
4. Breyfogle, F.W., *Implementing Six Sigma: Smarter Solutions Using Statistical Methods*. 1999, New York: John Wiley & Sons Inc.
5. Chakrabarty, A. and K.C. Tan, *The current state of six sigma application in services.* Managing Service Quality, 2007. **17**(2): p. 194-208.

6. Yilmaz, M.R. and S. Chatterjee, *Six Sigma beyond manufacturing-a concept for robust management.* Quality Management Journal, 2000. **7**(3).
7. Wiklund, H. and P.S. Wiklund, *Widening the Six Sigma concept: an approach to improve organizational learning.* Total Quality Management, 2002. **13**(2): p. 233-239.
8. Rao, K. and K.G. Rao, *Higher management education? should Six Sigma be added to the curriculum?* International Journal of Six Sigma and Competitive Advantage, 2007. **3**(2): p. 156-170.
9. Hargrove, S.K. and L. Burge. *Developing a six sigma methodology for improving retention in engineering education*. in *Frontiers in Education, 2002. FIE 2002. 32nd Annual*. 2002: IEEE.
10. Burtner, J. *the Adaptation of six sigma methodology to the engineering education enterprise*. in *ASEE southeast section conference*. 2004.
11. Jenicke, L.O., A. Kumar, and M.C. Holmes, *A framework for applying Six Sigma improvement methodology in an academic environment.* The TQM Journal, 2008. **20**(5): p. 453-462.
12. Hoerl, R. and G. Bryce. *What influence is the six sigma movement having in universities? What influence should it be having?* in *ASQ six sigma Forum Magazine*. 2004.
13. Breyfogle, F.W., J.M. Cupello, and B. Meadows, *Managing Six Sigma*. 2001 New York: John Wiley & Sons Inc. 272.
14. Ulrich, K.T. and S.D. Eppinger, *Product design and development*. Vol. 4th Edition. 2008, Boston: Irwin McGraw-Hill.
15. Griffin, A. and J.R. Hauser, *The voice of the customer.* Marketing science, 1993. **12**(1): p. 1-27.
16. Klefsjö, B., H. Wiklund, and R.L. Edgeman, *Six Sigma seen as a methodology for total quality management.* Measuring Business Excellence, 2001. **5**(1): p. 31-35.
17. Bandura, A., *Growing Primacy of Human Agency in Adaptation and Change in the Electronic Era.* European Psychologist March, 2002. **7**(1): p. 2-16.
18. Wagner, J.A., *Studies of individualism-collectivism: Effects on cooperation in groups.* Academy of Management Journal, 1995. **38**(1): p. 152-173.