122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #13481

Engineering Bait-and-Switch: K-12 Recruitment Strategies Meet University Curricula and Culture

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Abstract

This paper uses the metaphor of engineering bait-and-switch to characterize the misalignment between educational approaches of major K-12 engineering initiatives and traditional higher-education engineering programs. We argue that this misalignment is the result of divergent underlying educational logics. While K-12 engineering education is notably inclusive, "baiting" student interest with context-driven, open-ended problem solving, higher engineering education "switches" toward an exclusive, abstract fundamentals-first approach. The paper begins by contextualizing engineering education as a political and economic issue in the US. Next, we describe K-12 programs and elaborate how they typically employ a logic of engagement. Then we describe university programs and elaborate how they employ a logic of exclusion. Finally, we review a program at our institution that seeks to resolve the underlying misalignment of engineering bait-and-switch, highlighting some of the ways it achieves engagement and avoids exclusion.

Introduction

Even a cursory review of K-12 engineering initiatives in the US suggests they differ greatly from the prevailing educational approach represented within most traditional engineering higher education programs. This paper argues that this difference in approach reflects a foundational misalignment in educational philosophies resulting in what might provocatively be characterized as "bait-and-switch." The bait-and-switch characterization reflects a mismatch between the *engagement logics* embedded in most K-12 engineering education and the *exclusionary logics* underlying most university engineering education. While we acknowledge from the start that university engineering programs are increasingly emphasizing student engagement, the rapid expansion of K-12 engineering programs has outpaced reforms in higher education around engagement, thereby magnifying the problems associated with engineering bait-and-switch explored in this paper.

In popular vernacular, bait-and-switch is often associated with fraud or trickery in retail and lawmaking. Something is proposed one way that appears attractive (i.e., the bait), but upon reveal (i.e., the switch) the offering turns out to be much less attractive. As a straightforward example, a television commercial may advertise a desirable car at a great price, but when the prospective customer arrives at the dealership she learns the advertised car is no longer available, although a similar car is available but at a less attractive price. This paper suggests that differences between K-12 and university engineering programs show a similar pattern, even if not resulting from anyone's intentional effort to deceive. Hence, we employ bait-and-switch more as a metaphor for conveying students' experience of disappointment than to insinuate malicious intent.[(i)]

In K-12 engineering programs, the overwhelming curricular emphasis is on engaging, design-based classroom activities: open-ended, hands-on projects requiring creative synthesis across multiple domains of knowledge on the part of the student.[1] In university engineering programs, students confront an educational philosophy that can be characterized as exclusionary and built upon a "fundamentals first" approach to learning:[2] analytically rigorous, rote learning of basic principles in math and science (e.g., calculus, chemistry, physics) followed by engineering sciences (e.g. statics, fluid dynamics) followed by engineering analysis (e.g., control of dynamic systems, mass transfer). In this logic, students spend the majority of their time learning a long sequence of engineering "fundamentals" before they are deemed competent to engage in creative design problem solving in their final-year capstone projects.[3] This approach is understood as "exclusionary" not in the sense of being elitist but in the more general sense of seeking to keep out that which does not belong, including those persons (or those facets of persons) not in line with the dominant decontextualized, narrowly technical-analytic way of problem solving within engineering. Lectures and focused problem sets remain the mainstay educational modalities within university engineering education, even as wide-ranging educational experimentation highlights the possibilities for and effectiveness of alternative approaches.

Many university engineering students who earlier participated in K-12 engineering programs are disappointed when they see open-ended, hands-on, design-centric problems evaporate as they transition into college. Pedagogies of (hands-on) engagement are replaced with pedagogies of (disembodied) fundamentals first, and the enthusiasm surrounding their recruitment into engineering is replaced by the need to prove one "has what it takes" to be an engineer[4]—both the personal and intellectual discipline purportedly required to "cut it" in engineering. We call this phenomenon "engineering bait-and-switch": K-12 students are baited to engineering with engaging design activities but then disappointed by the perceived switch as they enter university programs requiring mastery of a range of analytics skill sets before entering the world of hands-on, creative, synthetic design in the (far distant) final year of their education.

This paper uses engineering bait-and-switch as a metaphor for characterizing the underlying educational logics associated with major K-12 engineering initiatives and traditional engineering programs in higher education and to suggest that differences between them are likely to exacerbate retention problems within engineering higher education. The paper is less concerned with content asymmetry between educational levels—we recognize that content appropriate to age changes as students move up from pre-primary and primary, through secondary, and on to higher education and that this necessarily impacts how engineering can effectively be taught at different levels.[5] We are more concerned with how the misalignment between K-12 and university engineering programs epitomizes broader struggles over representations of *what engineering work actually entails* and devising educational programs to prepare for it. Ultimately, we take the successes of K-12 engineering programs in baiting students—and the

[(i)] This qualification notwithstanding, we do claim that some of the major players in engineering recruitment, at all levels, knowingly and deliberately convey a highly selective, "glossy" image of both engineering education and engineering professional practice. Such selective representation, however, is not unique to engineering.

aligned university-level initiatives around student engagement and design—to offer viable strategies for engineering educational transformation at the university level. In this light, we briefly introduce one such initiative, the Programs in Design and Innovation (PDI) at the Rensselaer Polytechnic Institute and describe how it counteracts the logics of exclusion prevalent within other programs, including at Rensselaer.

Education Policy and US Competitiveness: The Recruitment Imperative

The importance of understanding and addressing engineering bait-and-switch is highlighted by considering the policy context that motivates contemporary engineering education recruitment initiatives in the first place, particularly at the K-12 level. In education policy-making, the decreasing number of US students who choose to pursue engineering in higher education creates anxiety for many observers, particularly around US national and economic security. Even though US students' performance in math and science has remained consistent (if only average) in international rankings over the last few decades, changes in the global economy have buoyed the now-pervasive idea that STEM education and jobs are requisite to US competitiveness in the international marketplace.[6] Certainly, some sociologists of education argue that using educational change to achieve economic reform puts the cart before the horse—that is, it misses the fact that a precondition of successful education is economic opportunity within the communities being educated.[7] Nevertheless, education and economic policy makers continue to frame the need to recruit more US students into STEM education as a national economic concern.

The relatively small number of US students pursuing higher STEM education concerns many observers in both private and public sectors. Since the Reagan Administration issued the policy document, *A Nation at Risk: The Imperative for Education Reform* in the early 1980s, the US school system has been constructed, both nationally and internationally, as underachieving if not failing.[8] *A Nation at Risk* stresses that, while the US was once "unchallenged" in the areas of science, technology, and industry, the country is now (i.e. as of the early 1980s) falling behind globally. Since the 1980s, substantial education reforms were instituted to ease national anxieties under No Child Left Behind and Race to the Top, both of which aim to inject more students into the STEM pipeline. Still, anxieties about the position of the US in science, technology, and industry continue unabated.

In 2008, the US Congress House of Representatives Committee on Science and Technology observed that US students begin to fall behind students of other nations as early as fourth grade, a trend that continues through high school. Concerns around national competitiveness are heightened even more as the number of international students finding positions in US STEM higher education and employment increases.[(ii),9,10] Since the problem here is understood

[(ii)] In both popular culture and education policy-making, the concept of "national competitiveness" draws on nationalist tendencies that position US students against students from other nations that the government deems to be economic threats, particularly China and India. Anxieties over the decrease in US students pursuing engineering in higher education often play out as *us-verses-them* narratives that construct these countries as infringing on the economic and intellectual security of the US. In an age of environmental crises uncontained by national boarders, it is questionable whether such narratives are productive for long-term problem-formulation and solving—efforts likely requiring cooperation and collaboration among diverse, international experts.

primarily as one of having too few US students entering STEM higher education, the solution is simply a matter of making STEM attractive enough to interest students early on and keep them sufficiently engaged to apply to and enter STEM higher education programs: The hook is thereby baited.

Interrelated with efforts intended to recruit more students (in aggregate) to STEM higher education are concerns specifically over the lack of women and underrepresented minorities in STEM fields. In both education policy and STEM recruitment discourses, the targeting of women and underrepresented minority groups is often argued as an essential strategy for growing the overall numbers of STEM students. Often, such diversification efforts are motivated by the same logic of national economic competitiveness, as when Rensselaer Polytechnic Institute President Shirley Ann Jackson (2007) discusses the "quiet crisis" in STEM education:

> If we are going to succeed in filling the emerging gap in engineering and science talent, the United States cannot continue to ignore the 30 percent of the population represented by ethnic minorities in this country, and women who, together with minorities, comprise the underrepresented majority of the STEM workforce. We must begin to engage the complete talent pool.[11]

However, a distinct motivation is also often at play in diversity initiatives, one involving questions of fair access, social equity, and diversification itself—all important educational reform goals in themselves. Many engineering recruitment initiatives (at both K-12 and university levels) emphasize engagement and design activities both in pursuit of educational pluralism and in recognition of the multiple potential solutions to any given (engineering) problem. In this way, "diversification" has both social and intellectual dimensions, which taken together entail an impulse for inclusion different from economic competitiveness.

The underlying goal of inclusion is distinct in each justification for diversifying engineering, complicating any analysis of diversification efforts. In the case of economic competitiveness, the goal is simply production of the maximum number of STEM graduates. The strategy is putting more bodies into the beginning of the STEM education pipeline so more come out the other end. In the case of educational pluralism, the goal is more about economic (and career) opportunity "for all," and inclusiveness and diversity as desirable social and educational foundations in their own right. These two diversification logics often fold together in practice—and are often conflated by STEM education reform advocates—confusing the conceptual foundations for many STEM inclusiveness initiatives. Therefore, while policy support for broad-based STEM recruitment generally relies on an economic framing, this is constantly being negotiated within STEM classrooms and programs at various levels and for diverse reasons. Even the usefulness of the "pipeline" as a guiding metaphor is brought into these negotiations.[12] Together, such negotiations potentially confound our analysis by producing diverse, sometimes conflicting narratives of what engineering is, who is—or ought to be—an engineer, and how best to achieve desired outcomes via educational reform or transformation.

Another potentially confounding variable in our analysis is the lack of state standards for K-12 engineering content and the absence of associated testing regimes. This gives K-12 engineering educators tremendous flexibility in determining what to include in their programs—flexibility that is not available in implementing, say, mathematics or biology programs. This flexibility allows educators and education policy makers to design engineering curricula almost exclusively around the goal of recruitment: by baiting the curriculum with creative, hands-on, student-led design-and-build activities. In contrast to this flexibility at the K-12 level, university engineering education is considered by many observers to be highly inflexible, even rigid, and has remained largely unchanged for decades[13]—particularly within its technical core. Engineering bait-and-switch, as we seek to understand it, is facilitated by these flexibilities (allowing K-12 educators to go where students will follow) and rigidities (constraining university educators to a model of engineering education unchanged for over 50 years).

Characterizing K-12 Logics of Engagement

Engagement is a key logic undergirding K-12 engineering education initiatives, particularly as they "bait" students with creative, hands-on design problems. This *logic of engagement* differentiates K-12 engineering education from the dominant logics of university engineering education based upon fundamentals-first pedagogies. K-12 engineering initiatives attract students by systematically, often explicitly, portraying engineering as creative, hands-on design, often with activities that invite students to bridge popular youth culture and real-world problem solving. As research from the National Academies indicates, K-12 engineering education curricula make design a centerpiece.[14] For participating K-12 students, engineering becomes associated with hands-on group work and trial-and-error discovery learning, both of which leverage and develop individual student agency. By connecting with students "where they already are" in terms of their interests and abilities, and by providing wide latitude in where they may take their design solutions, K-12 programming casts a large net by attracting diverse students with wide-ranging interests and intelligences.

While K-12 logics of engagement rely on a form of educational pluralism, they typically also build explicitly upon economic frameworks that steer educational programming towards workforce preparation intended to bolster national competitiveness. For example, in a promotional video for the high-school engineering program, Project Lead the Way,[15] students are positioned as burgeoning engineers, ready to enter the STEM higher education pipeline. In the video, high-school students enthusiastically describe their experiences with the program, with their head-shot interviews intercut with hands-on design activities (see Figure 1, left). The students also narrate how Project Lead the Way has prepared them for being an engineer and how it helps them more generally to understand how the world works.

Throughout the video, students are interspersed in a way that promotes a vision of engineering education that is highly pluralist—one that works for students from different racial backgrounds and across genders, with broad interests and divergent goals around engineering design itself. Yet, when the first adult appears (see Figure 1, right), he passionately declares, "Our country needs more engineers, we need more technical people," shifting the focus from educational pluralism to workforce preparation and, ultimately, national economic competitiveness. The shift exemplifies how logics of engagement often conflate distinct motivations underlying recruitment initiatives.

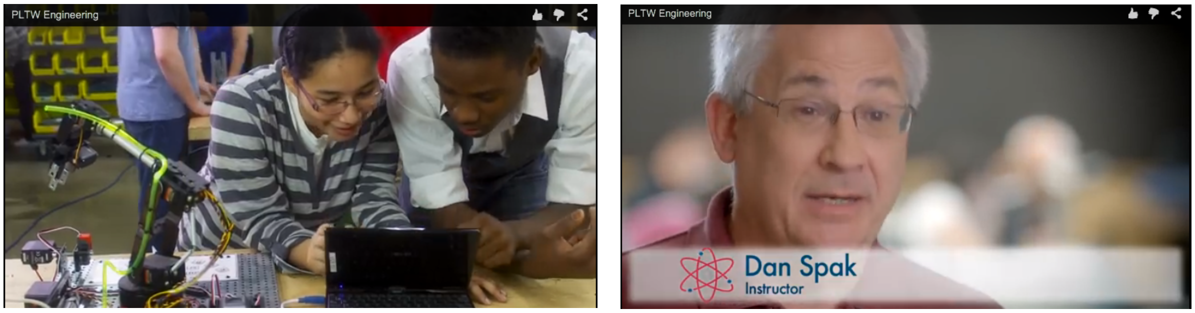

Figure 1. Project Lead the Way Promotional Video: Student Diversity (left) and Economic Competitiveness (right)[11]

In characterizing K-12 engineering programs as operating according to a logic of engagement, we do not mean to suggest that such initiatives are prominent within K-12 educational settings or even that a majority of university engineering students have participated in such programming. They are on the rise, certainly, but K-12 engineering initiatives still reach only a fraction of K-12 students in the US. This limited impact is due to a host of factors, including the historical exclusion of engineering content from K-12 education as well as lack of earmarked budgeting for such programs. Teachers who have the interest, opportunity, and incentive to pursue K-12 engineering initiatives rely on a mixture of foundation, philanthropic, federal, and private-funded programs and resources to introduce engineering to students in formal (schools, classrooms) or informal (after-school, museum, community center) settings. Some of the major K-12 engineering initiatives that are the outcome of such partnerships include: Engineering is Elementary (elementary school) and Engineering the Future (high school); Project Lead the Way's Engineering curriculum (high school); LEGOengineering (teacher professional development); and Georgia Tech's Learning by Design (middle school).[(iii)] We will look at a few of these programs to elaborate what we mean by logics of engagement and to identify some of the different strategies used to engage students with engineering.

One of the most pervasive engagement strategies employed in K-12 engineering education is use of real-world, context-driven engineering design. This is especially true of the Engineering is Elementary (EiE) curriculum for grades K-8. EiE's mission statement is "fostering engineering and technological literacy for ALL elementary school-aged children."[16] The EiE curriculum is sponsored by the National Center for Technological Literacy and is hosted by the Museum of Science, Boston. Through curriculum development, research, and teacher professional development, EiE disseminates engineering design-based curriculum for life science, earth and space science, and physical science. The science focus in EiE is consistent with engineering science requirements in higher education, but unlike the fundamentals-first approach, EiE students engage science content through a simple engineering design process. In this process, students are taught to iteratively "ask, imagine, plan, create, and improve" to meet the goal of a range of engineering design challenges.[17] The design challenges in EiE work to engage students through real-world application of engineering design, often in cross-cultural contexts.

Unit-by-unit, EiE students explore different science topics by applying engineering design to problems that are contextualized in countries from Ghana to Denmark.[18] In the physical science

[(iii)] These are just a few of the engineering design-based K-12 programs. For a more extensive list, see 1.

unit, "Sounds Like Fun: Seeing Animal Sounds,"[19] students explore acoustical engineering basics like volume and pitch by learning about Kwame, a young, blind drummer from Ghana who discovers his music is made up of vibrations that can be represented visually by different scientific instruments. This narrative is content-specific, and the cross-cultural strategy for teaching engineering design can be understood as part of larger reform effort around multi-cultural education aimed at diversifying the student body of engineering programs. Furthermore, students engage in a hands-on activity where they create their own music and sounds to study volume and pitch. Using music to bridge liberal arts and physical science education targets students with diverse interests and backgrounds in an effort to establish more pathways to engineering.

Some of the strategies used to engage students in K-12 engineering initiatives could be fairly understood as "edutainment." Edutainment is the blending of education with entertainment for purposes of heightening youth engagement with academic subjects, often through connections with popular youth culture.[20] For example, LEGOengineering at Tufts University's Center for Engineering Outreach engages students in engineering design by drawing extensively on the wide appeal of LEGO products within youth culture. This project is supported by LEGO Education (the for-profit education arm of the LEGO Group) and the LEGO Engineering Design Group Educators (a by-invitation group sponsored by Tufts' LEGOengineering). The LEGO Engineering Design Group Educators (LEGO EDGE),

> …consists of about 20 innovative educators [from 16 different countries] with a passion for LEGO robotics that have been selected to provide advice about the content and structure of this site, as well as come up with new ideas to help and inspire other teachers and students.[21]

The LEGOengineering program stresses engineering design as desirable both for math and science classrooms and for the liberal arts.[22] The inclusion of the liberal arts draws together the popular tradition of the "LEGO System" of play with the LEGOengineering mission "to inspire and support teachers in bringing LEGO-based engineering to all students."[23] In the LEGO System of play, LEGO bricks are granted the "potential" to become part of any design that young people can imagine,[24] so that LEGO engineering design becomes an extension of children's unique imaginative capabilities. LEGOengineering translates the LEGO System into educational materials on mechanical and software engineering design of robotics systems using different iterations of LEGO Mindstorms and other LEGO products. For example, in the "OmniSonic Inspired Challenges,"[25] students learn about the body's circulatory system while using LEGO Mindstorms to design a simulation of the removal of a blood clot.

Like EiE, the LEGOengineering program centers on hands-on engineering design that affords multiple solutions to the problem at hand. Unlike EiE, LEGOengineering design problems are not situated in real-world, cross-cultural contexts. Its engagement strategy can be understood as edutainment because it uses LEGO play (e.g., designing a robot that simulates a biological function) as a mechanism for conveying academic content (e.g., the actual workings of the biological function). It thereby leverages students' interests and abilities (around building with LEGO bricks) to teach concepts in biology and to familiarize students with scientific concepts more generally. Critics of edutainment worry about the relative emphasis of the entertainment dimension over the educational one, not to mention to the commodification and commercialization of educational programming.[26] But those concerns notwithstanding, the effectiveness of the engagement strategy, at least for the targeted audience and intended purpose, seems immutable.

Another criticism leveled against K-12 engineering curricula responds more directly to their reliance on a logic of engagement: Due to a lack of relevant curricular standards, this criticism goes, K-12 engineering curriculum developers have the freedom to emphasize design in ways that "unevenly" prioritize engagement at the expense of key engineering concepts such as constraints, optimization, and analysis.[27] Here, we see allusions to a fundamentals-first pedagogy, yet the fundamentals identified are less the underlying scientific principles and more the concepts that make sense of and structure "the design process" as an engineering practice. This criticism—engagement-over-academic-content—raises the critical issue of "scaffolding": what to emphasize when and how to order academic content for students at various levels of educational development.

Within constructivist educational theory, *scaffolding* refers to the idea that people build new knowledge upon what is already known.[28] Like the temporary scaffolding used in building a house, students ought to be provided bits of information and the experiences necessary for learning key concepts, which can be removed later when a more foundational structure of knowledge has been built. According to the scaffolding framework, emphasizing engineering design in K-12 is based on the notion that concrete manipulation of objects will help students better understand the abstract ideas later to be found in engineering disciplines. Once students have a solid foundation of hands-on experience connected with simple abstractions about how the physical world works, the hands-on activities can be removed and students can rely exclusively on manipulation and development of increasingly sophisticated abstractions.

In this way, the experiential, hands-on activities are a type of scaffolding, temporarily erected to support student development and then appropriately removed as students enter higher levels of education. However, the abrupt removal of the design scaffolding between engineering secondary and higher education also takes away opportunities for contextual understanding of engineering problem formation and solving through design. Additionally, this approach to engineering presumes that hands-on design is a means toward the end of engineering analysis, and that design problem solving itself is not fundamental to engineering practice. Both phenomena are consistent with engineering bait-and-switch critique.

Characterizing Higher Education Logics of Exclusion

Characterizing K-12 engineering initiatives according to an underlying logic of engagement aligns well with those initiatives' explicit goals and strategies, scholarship on diversification within engineering education, and even STEM education policy discourse. The logic structuring university engineering programs is more difficult to characterize. While many engineering educators and engineering studies scholars acknowledge that a fundamentals-first educational approach is dominant within university curricula, there is not similar agreement as to the larger conceptual logic motivating the fundamentals-first approach. Short of such agreement, we have striven to identify the underlying points of contrast—from the perspective of student experience—between K-12 engagement logics and the dominant educational forces at play within typical university programs. In other words, if K-12 engineering initiatives are noteworthy because of their high degree of student engagement with context-driven, open-ended content, we seek to identify what is noteworthy about university programs in terms of their relative *lack of engagement*.

Part of the answer lies in the pedagogical theory underlying the fundamentals-first approach, what many have referred to as "the banking model of education"[29]—in its extreme, sometimes also caricatured as the "fire hose theory of education." The banking model treats students as empty vessels ready to be filled: Teachers deposit tokens of information into the student-vessel, thereby filling the student with knowledge like a savings account is progressively filled with money. In practice, this pedagogical approach has been shown to alienate students by separating their lived experiences from school, education, and learning itself.[30] Fortunately, the banking model's view of students as empty vessels when they enter the classroom is widely discredited within educational theory.[31] Constructivist learning theorists, such as Piaget, Freire, and Vygotsky, were early to point out that students do not arrive into any classroom "empty," and their learning—even when in a totally new domain—always builds upon prior knowledge and experience.[32] Constructivists reject that learning occurs primarily through the accretion of discrete, context-free "tokens of information," but rather has as much to do with how new information is organized and connected with existing information according to schemas held by students.

Yet it is precisely the idea that students' experiential understanding of the world can (and should) be erased and then re-built through instruction that aligns the banking model comfortably with the fundamentals-first approach to engineering education. In this regard, the fundamentals-first approach contrasts markedly from contemporary educational theory, relying as it does so completely on the accumulation and manipulation of decontextualized, disembodied, scientific principles.

While pedagogical models and educational approaches are a part of the answer to the question of why university programs fail to engage the desired numbers and diversity of students, we argue that a deeper logic is at play within most university engineering programs: *a logic of exclusion*. By logic of exclusion, we do not intend to suggest that engineering programs are in any way designed explicitly to turn people (generically) away. But we do argue that an important, perhaps essential, part of identity formation among university-level engineering students is proving one "has what it takes"— that is, the technical-analytic aptitude as well as the personal and intellectual discipline—to be an engineer. Gone is the big-tent inclusiveness of K-12 engineering programs designed to connect with a broad base of student interest and aptitude. Emphasis shifts, instead, to aligning students with a much narrower version of engineering as well as its preferred styles of teaching and assessment—creative, synthetic design problem solving is out, differential equations, free-body diagraming, and equation balancing are in.

The logic of exclusion operating within higher engineering education has two major manifestations. The first is most obvious: the exclusion of those students who, over time, are deemed not to have what it takes to be an engineer. These students either prove themselves without the necessary aptitude or discipline (e.g., poor performance in calculus, physics, chemistry, etc.) or they opt out of engineering willfully when it turns out not to be what they expected. The second manifestation of the logic of exclusion is less obvious, involving the ways in which various facets of a student's identity are excluded (i.e., kept apart) from that student's identity *as an engineer*. Here, students' personalities, values, commitments, and even worldviews are all deemed to be irrelevant, in some cases antagonistic, to their standing as an engineering student. According to the logic of exclusion, not only is the prototypical engineering problem decontextualized in this way, but so too should be the ideal engineering student: a technically rigorous number cruncher and problem-set completer, one who solves problems efficiently as given and does not fret over problem framing or implications of solutions extending beyond the problem as given.

Hence, higher education engineering tends toward being both bodily and epistemologically homogenous. Admissions criteria and curricular structures have been shown to discourage minorities from entering engineering fields.[33] Furthermore, while women have struggled since the 1800s to enter into engineering education and workforce, engineering continues to be decisively male dominated and strongly masculine in orientation.[34] Initiatives to increase diversity in the field are complicated by multi-layered educational conventions of "weeding-out." While many are familiar with the concept of weed-out classes—classes designed to displace those without adequate aptitude—Downey and Lucena show a different type of weeding-out, a weeding-out of mentalities.[35] For students to be successful in an engineering course they must not only keep up with work, but must also exclude certain ways of thinking about what engineering is and how it is carried out. This weeding-out of mentalities emerges alongside cultures of "disengagement," which push apart matters of public and community welfare from engineering education.[36] Furthermore, critical and feminist STEM education scholars who challenge the banking model[37,38] have shown that when knowledge is decontextualized from the teachers' and students' lived experiences, both groups are more likely to feel alienated from the subject matter at hand.

Across all of these modalities of exclusion, the offering (i.e., engineering education curriculum and culture) is taken as being fixed, so all necessary malleability is left to the student: The student "cuts it" or does not. Not surprisingly, students who leave engineering point to both individual and institutional inadequacies underlying their decision,[39] raising the obvious question of what educational programs might do to better align their offerings with a more diverse audience. Of course, every academic program faces the question of "fit" between the dominant approaches within the field and the interest and aptitudes of any given student, but that is not exactly what is at issue with the systematic exclusions surrounding engineering higher education. At issue is the degree to which such educational programs are *defined by* such exclusions—the degree to which such exclusionary mechanisms constitute the positive identity of the students. Too many engineering students, particularly in middle years of university education, identify as engineers not because they have a clear sense of the range of activities engineers do after graduation and their aptitude for those activities, but simply because they "made the cut."

The narrowness and surprising uniformity of university engineering programs with regard to portraying what it takes to be an engineer and in determining how one ought to get there contradicts the diverse, messy, deeply contextualized professional practice of engineering. In the field, engineering problem formation and solving requires responsiveness to many of the social and cultural conditions that provide context for the problem, otherwise important variables may go ignored and anticipatable negative outcomes unnoticed. This is especially true of "engineering for development" scenarios, where engineers from the global north work on projects in the global south.[40] If the engineering design is not socially and culturally responsive it can reproduce social inequalities as opposed to alleviating them. Attending better to the social aspects of design in engineering curricula may also help, in part, to overcome retention problems that engineering programs face with women and "Non-Traditional Engineering Organized" students.[41] The narrowness of fundamentals-first curricula not only weeds-out and alienates students from their past and present lived experiences, but also excludes imaginative thinking surrounding what real-world engineering experiences are possible in the workforce and beyond.

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As an organizing theme of our analysis, bait-and-switch is not intended to suggest K-12 engineering initiatives have magnified enduring problems of retention among engineering students in higher education, particularly among women and members of underrepresented minority groups. We may speculate that the clearer K-12 students are about associating engineering with creative design, the clearer they may become about their dissatisfaction with the disembodied, decontextualized thrust of fundamentals-first education. However, our ultimate goal is not about addressing retention challenges in any direct or immediate way. Rather, bait-and-switch helps us explain the gulf in experience (and overall satisfaction) between the modal participants in K-12 engineering initiatives and students in university engineering programs.

In terms of our overarching argument, the logic of engagement that characterizes K-12 engineering initiatives throws in sharp relief the exclusionary logic dominant at the university level. The bait-and-switch metaphor helps clarify the misalignment between K-12 engineering recruitment strategies and the experiences of many university engineering students who struggle to fit comfortably within the field of study they chose for themselves, even if with imperfect information about what they were signing up for. This is not to say that all engineering programs are the same, and part of our purpose in highlighting bait-and-switch is to draw attention to university educational paradigms that explicitly grapple with the dominant logic of exclusion. These programs provide a way to rethink the transition from K-12 to university engineering education.

Experiments in Higher Education Reform: Easing the Switch

Many engineering and related higher education programs seek to supplant logics of exclusion with logics of engagement along the lines of those that have been successfully implemented within K-12 initiatives. This is not to make a causal claim, given that many university engagement initiatives predate the explosion of interest in K-12 engineering. But with the increasing prevalence of engaging K-12 programming, we expect similar new attention directed at engagement in the university setting. What is particularly relevant to the arc of our analysis is where university engagement efforts confront fundamentals-first frameworks in engineering education. Rather than attempting to review the many programs relevant to this specific comparison, we will describe the key features and strategies for confronting exclusion of one example initiative, Rensselaer's Programs in Design and Innovation (PDI). PDI employs a variety of engagement strategies alongside the fundamentals-first curriculum, with the goal of supplanting the logic of exclusion with the logic of engagement.

PDI is made up of students who are dual majors in a traditional engineering program and the humanities and social science infused Design, Innovation, and Society program. PDI students take traditional engineering (including math and science) courses organized according to the typical fundamentals-first approach, but they do so alongside a design studio sequence that emphasizes open-ended problem solving in real-world contexts.[42] PDI has a number of similarities to the "engineering for all" mentality found in many K-12 initiatives, including by employing diversity and inclusivity as foundational educational goals. Professors, teaching assistants, and students engage in curricular content that is design-centric, driven by real-world problem solving, based on interdisciplinary collaboration across domains of knowledge (engineering, social sciences, computer science, and others), and allows for individual latitude among students so they can contextualize engineering design according to their personal and community values.

An interdisciplinary co-instructor model, where courses are taught by multiple professors from departments from graphic design to nuclear engineering to social sciences, increases the likelihood that a diversity of design frameworks and processes will be represented, including but extending beyond traditional engineering design approaches. In one such configuration, PDI professors engage students in semester-long engineering design projects based on feminist and non-Western theoretical orientations.[43] In another configuration, projects respond to "Grand Challenge" water problems combining insights and methods from engineering, STS, and graphic design. Across all of these projects, instructors representing diverse disciplines help students clarify their own goals and commitments, and they help each other question the disciplinary assumptions underlying each instructor's teaching and worldview. In this way, matters of context, including values around social equity and justice, are not weeded-out but are positively reinforced as critical components of engineering work.[44]

Whereas interdisciplinary is achieved among instructors via a co-instructor model, PDI courses, projects, and even students are inherently interdisciplinary, or perhaps more precisely extra-disciplinary. Students take open-ended, real-world design projects as a normal part of their educational experience, and so the boundaries frequently established around "real engineering" are not part of PDI students' early educational indoctrination. PDI's positive simultaneous engagement with social, cultural, and technical issues offers students opportunities to do technical problem solving without necessarily identifying it as engineering, or to include non-technical dimensions without distinguishing it as non-engineering work. Non-engineering students are also part of the mix within projects, so majors in computer science, mechanical engineering, communications, and business can collaborate on the same design teams. PDI adopts the inclusive "engineering for all" mentality as with K-12 engineering initiatives, yet instead of classifying everyone as an engineer, students learn that diverse domains of expertise can contribute to engineering design problem solving.

This type of higher education engineering is a much milder contrast to what students experience in K-12 engineering initiatives. In fact, many students and families that visit PDI recruiting activities have remarked: "This is what I thought *engineering* was like." Yet, PDI courses are not meant to displace or supplant the fundamentals-first engineering curriculum: They exist side-by-side, institutionally parallel as opposed to convergent. Therefore, an element of bait-and-switch remains, but the outlet of creative, synthetic, hands-on design in an intimate, supportive learning environment is both present and institutionally legitimated as part of students' formalized educational experience. This arrangement challenges the logic of exclusion prevalent within the engineering-only programming by overlaying a logic of engagement on top of the standard fundamentals-first engineering curriculum.

Since PDI operates outside of Rensselaer's core engineering curricula, it provides only a partial corrective to engineering's logic of exclusion. It does, however, provide a completely different overall educational experience, as well as identity, for those students who participate in the program. Not only is design systematically added to the curriculum, but the program also integrates across broad student interests, aptitudes, and personal value commitments. This integration helps motivate many students to push through otherwise frustrating, often alienating fundamentals-first courses. This type of approach better aligns with the recruitment strategies of K-12 initiatives, reducing the experience of bait-and-switch, but more importantly reducing the exclusion from engineering of all but a narrow subset of our potential student body.

Conclusion

This paper uses the metaphor of bait-and-switch to characterize the misalignment between K-12 logics of engagement and higher education logics of exclusion. In response to policy and curricular support aimed at making engineering "for all," K-12 engineering education uses design-based activities to engage students in real-world, interests-driven problem solving. These logics of engagement are in harsh contrast to fundamentals-first curricula and logics of exclusion that persist in higher education engineering. While engineering for all certainly appears to be effective at attracting diverse students, without serious attention to the misalignment between the K-12 logics of engagement and higher education logics of exclusion, any engineering educational reform effort risks being undermined by the curricular and cultural practices that pervasively shape student experience and outcomes and drive away too many could-be engineers with diverse interests, aptitudes, lived experiences, and values.

PDI's response to the bait-and-switch problem employs design-oriented logics of engagement in parallel with the fundamentals-first approach, which provides a partial corrective to the logic of exclusion. This configuration offers educators new avenues for thinking about explicit and implicit connections between the design-centric emphasis in K-12 and the content-driven model of fundamentals first. Moving forward, we hope to conduct empirical research using participant observation and interviews to compare students' experiences with different sorts of engagement approaches. By furthering our understanding of how to make engineering education more inclusive, we hope to achieve the broader goals of creating a diverse, competent, engaged and committed engineering workforce and, through this, advance both national and international interests.

Acknowledgements

The authors would like to thank the three anonymous ASEE reviewers, whose insightful, remarkably detailed feedback at every stage of review process greatly improved the paper.

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