AC 2010-949: DEVELOPMENT OF PERSPECTIVE IN A GENERAL ENGINEERING DEGREE

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Development of Perspective in a General Engineering Degree

Introduction

In fall of 2004, a team of faculty at Arizona State University (ASU) was tasked with the creation of a new undergraduate engineering program for ASU's Polytechnic Campus in Mesa, Arizona. ASU already had a full suite of traditional engineering programs taught in the Ira A Fulton Schools of Engineering on its Tempe campus. These programs all offered a disciplinary specific degree and generally emphasized a rigorously analytical approach to learning. In most cases, nearly all credits not used to satisfy university general studies requirements were allocated to math, science and engineering. These programs in fact closely approximated the description that one finds in chapter 2 of Sheppard et al.[1]. This team was asked to avoid duplicating any of these degrees. Otherwise, the slate was clean. After extensive discussions, it was decided to build a general engineering program that emphasized three values: engaged learning, agility and a focus on the individual.

As our goal was ABET accreditation, we developed a set of program outcomes, one of which we called perspective. The perspective outcome is:

> An understanding of the role and impact of engineering in contemporary business, global, economic, environmental and societal contexts.

In this paper we will discuss the structure of our program, our hopes for student demographics, how it relates to our student's life goals, the logic behind the development of the perspective outcome, the methods by which we pursue its development in the student and an assessment of our relative success in our first generation of graduates.

Differentiating Values

As mentioned above, the main constraint that we faced in our program design was how to differentiate our new engineering program from those already in existence at ASU. While accreditation would supply an official distinction, we felt that this would probably not be of great concern to many entering freshmen. We looked for other ways of differentiating our program from others. We settled on three differentiating values. None of these is unique to us but we believed that we had an opportunity to build a program that emphasized these values. We selected engaged learning, agility and a focus on the individual.

Engaged learning means utilization of pedagogical approaches other than lecture. In our case, we decided to build a program in which a distinguishing feature was a project course every semester. This provides us with an excellent example of what Sheppard et al.[1] call a professional spine. Agility has two aspects. First, it is in part an aspirational goal for our graduates. We wish for them to be agile. This in fact is very similar to one of the attributes of the Engineer 2020[2]. The NAE Engineer 2020 report describes it this way:

> "Given the uncertain and changing character of the world in which 2020 engineers will work, engineers will need something that cannot be described in a single word. It involves **dynamism, agility, resilience,** and **flexibility**."

The second aspect of agility has to do with the program. We wanted a program that provided students with an ability to tailor their education to fit their own needs and interests. Obviously, this second aspect overlaps with the third differentiating value, a focus on the individual. This third value was motivated in part by a comparison of our campus, which is a smaller campus, with the Tempe campus which is where ASU's other engineering programs are offered. Well over 50,000 students attend the Tempe campus and as is often the case at a large campus, some students feel that they are lost in the crowd. So far, we have been successful in avoiding large classes (our record is 48 students and we have exceeded 40 on only several occasions) and also have been successful in using some very personal style assessments, most notably an interview in which two faculty interview one student for 20 to 30 minutes at the end of a project.

Structure of the Program

The only real restriction we faced was that the program could not duplicate the engineering programs found on ASU's Tempe campus. That, when combined with the reality of starting new, caused us to choose to accredit this program under the general category of ABET. In this accreditation model the program satisfies just the general criteria of the Engineering Accreditation Commission but does not concern itself with any of the program specific criteria. This type of accreditation had been recently reviewed by Newberry and Farison [3]. Newberry and Farison noted that one of the more common purposes of this approach is associated with the launch of a new engineering program and that as the program matures the "general" program is abandoned and replaced with discipline specific degrees. Our intent however is to permanently remain. Newberry and Farison then identified three main "uses" for general engineering programs: philosophical, instrumental and flexible. A philosophical program operates under the assumption that a broader engineering BS degree is a good thing. In an instrumental program, the student generally selects from a menu of discipline specific options inside of the general degree's umbrella. In a flexible program, this degree would be used to offer students an ability to construct a non-discipline specific degree by selecting from the offerings of an associated set of discipline specific degrees.

Our program design blends features of all three approaches. Newberry and Farison describe a philosophical program as generally requiring the ABET minimal engineering content that perhaps includes a "short stem" of disciplinary specialization. We require just above the minimum content but view the last two years of the engineering program as being centered in a primary focus area which the student selects from a menu that currently consists of three choices: sustainable land development; electrical integration of engineering systems; and mechanical systems. Prior to the junior year the student does

not need to select any particular focus inside of engineering. These foci are probably larger than Newberry and Farison's "short stem" but are definitely smaller than that the disciplinary options of an instrumental program, which Newberry and Farison describe as typically closely resembling a program that actually has a disciplinary specific accreditation. (Design of our focus areas has been described elsewhere[4, 5]). Our students also have a "secondary focus" which can be literally anything they want. A majority of the students currently select a secondary focus that clearly builds on their primary focus but some pursue an interdisciplinary route. One common example is students who view themselves as roboticists and select mechanical and electrical systems as their focus areas.

The general structure of the curricula is driven by ABET and university mandates. ABET requires that students take one year of math and science, one and a half years of engineering and satisfy the university general studies requirements as well. The general studies requirements of ASU mandate about one-third of a year of freshmen composition, humanities, fine arts and social and behavioral science. A little more than a semester is left inside the 4-year degree program after all of this. Our program differs from many engineering programs in how we address this remaining semester. In our case, the student is given these credits as electives. While many students do elect to spend most of this elective content on more engineering, they are free to take any courses of their choosing. In contrast, many engineering programs (including the ones already extant at ASU in 2004) require that this semester of credits be used to take additional engineering, usually lying inside the specific discipline of interest. In fact, the student often has absolutely no credits in which they are free to take any course of their choosing. This is illustrated in figures 1a and 1b. In these pie charts the mandated engineering content is divided into two portions: a multidisciplinary portion and a concentration.

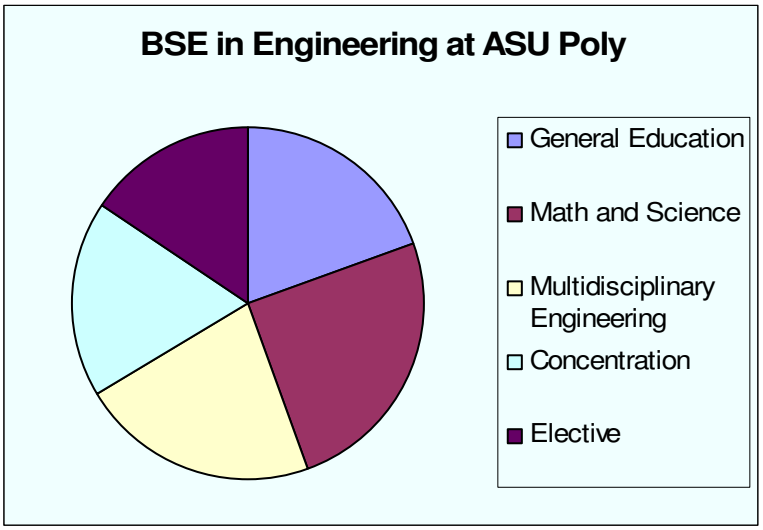

Figure 1a. A pie chart showing the credit allocations inside the BSE degree in Engineering at the Polytechnic campus of Arizona State University

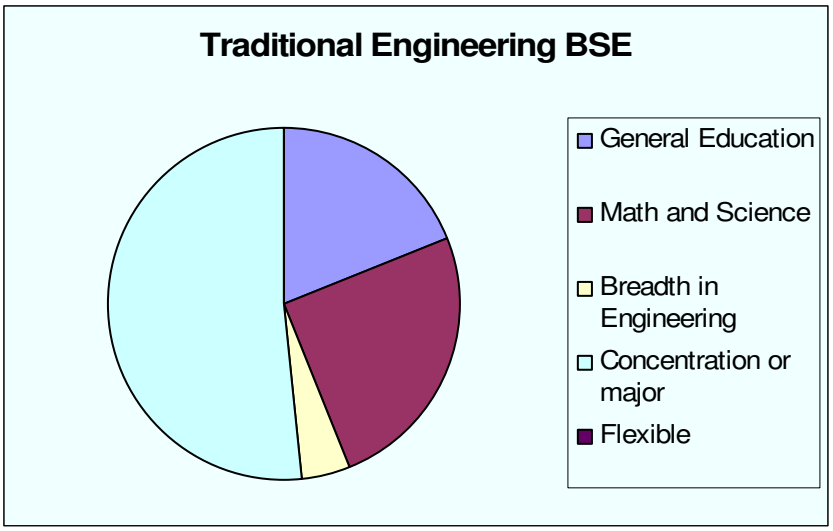

Figure 1b. A pie chart showing the credit allocations inside a more traditional BSE degree in Engineering at the Polytechnic campus of Arizona State University

This flexibility lets many of our students to function in a fashion much more similar to a liberal arts student that is normally the case for engineering major. Being new to a program with such flexibility, the faculty are still learning how it can be used to benefit us. One hope is that we can learn how to make such a flexible engineering program be more attractive to the large subset of students who choose their major after they start attending college.

In our experience, discussions of student recruitment, and in particular of the recruitment of women as engineering students, very often fall into a narrative that we call the pipeline narrative. In this narrative, one must go down to middle school and convince 12-year olds that they wish to be engineers. Then, one tries to work with high schools to maintain the student's interest through high school. Success means that they arrive at the university and major in engineering. There, we need to retain them inside the engineering program. We need to put them into the pipeline in middle school and then retain them until they graduate. The possibility that a student might arrive at the university unsure of their path in life, spend a semester or two exploring their options and then pick engineering perhaps a year into their stay in college essentially never appears in the conversation.

The problem with the pipeline narrative is that it focuses on producing students who are well suited for the traditional, heavily specialized and somewhat rigid engineering program. If one does not get started in that program early on in college, one rapidly finds that switching into the program will add one or more semesters to one's college experience. This can be a significant barrier to what Ohlund et al.[6] call in-migration. In effect, we are looking for students who make the curricular design easy.

This makes the data summarized by Ohlund et al. crucial. They present data on students majoring in business, engineering, computer science and the liberal arts. The data for 8th

semester students shows that while only 10% of the 8th semester engineering students had started in a different field and transferred in, 40% of the 8th semester students majoring in science and mathematics had "in-migrated" to that field from a different area. One cannot attribute this to any difference in the desired high school preparation for engineering as compared to science and math. A second point of particular interest is that engineering is the only field in which one finds no seniors who originally were "undeclared". For almost every other field, "undeclared" was the second largest source of 8th semester majors. The data for math and science is important in that it shows that some of these "major switchers" and "initially undeclared" students are not avoiding math and science. We hope that our flexible program can provide a vehicle by which a larger level of in-migration occurs. One way of visualizing this is to picture a program as having a process window. The pipeline strategy is to focus more students into a narrow window whereas our goal is to seek ways to appropriately broaden the window.

While our initial student body was too small to allow us to develop statistics, our first 15 graduates included individual students described below:

- One student started in college as a communications major and dropped out. They then supported themselves by playing in a heavy metal band. This student joined our program after the band broke-up;
- About 5 students over the age of 30;
- Another student who plans on going to law school (political science was this student's secondary focus);
- A student who used their experience as a student in our program as part of the data for their Ph. D. dissertation in Education;
- A student who seriously explored a dual major in engineering and history. They decided not to pursue it but found that only 8 to 10 additional credits would have been required;
- Several students who switched in from other engineering programs;
- A student whose secondary focus area was Swedish;
- A student who spent their first semester at ASU as an "exploratory" student and joined our program in their second semester.

So, while we lack statistics, we have a reasonable number of interesting anecdotal data points.

When we ask our students why they selected our program, the most common answer is the projects. They wanted a "hands-on" aspect to their education. The next most common answer has to do with the focus on the individual and the comparative size of the campus. Some students also like the ability to delay any choice of specialization until they are juniors. While we do find some students who are attracted by the flexibility of the program, this factor is not mentioned by most students.

Development of the Perspective Outcome

The general process by which we developed the program has been described earlier[7]. We started with the 11 ABET outcomes, the set a through k. Then we added in two additional outcomes: l and m. A team then visited Alverno College in Milwaukee, where

they have been doing outcomes driven education for several decades. (A comprehensive review of the approach is found in Mentowski & Associates[8].) At Alverno we learned that they sensibly gave their outcomes names. So, instead of discussing "ABET outcome g", and having most be forced to look at reference materials to realize that one is discussing the ability to communicate effectively, at Alverno one would have been discussing "the communication outcome" in the first place. This is particularly important when one tries to make the student an active participant in the outcomes development and assessment. We then followed the Alverno model and re-arranged our outcomes into a set of 8 outcomes, one of which we labeled perspective. This is illustrated in figure 2. As can be seen, the Perspective outcome is the combination of two of the ABET outcomes: (h) the broad education needed to understand . . . global, economic, environmental and societal context; and (j) a knowledge of contemporary issues.

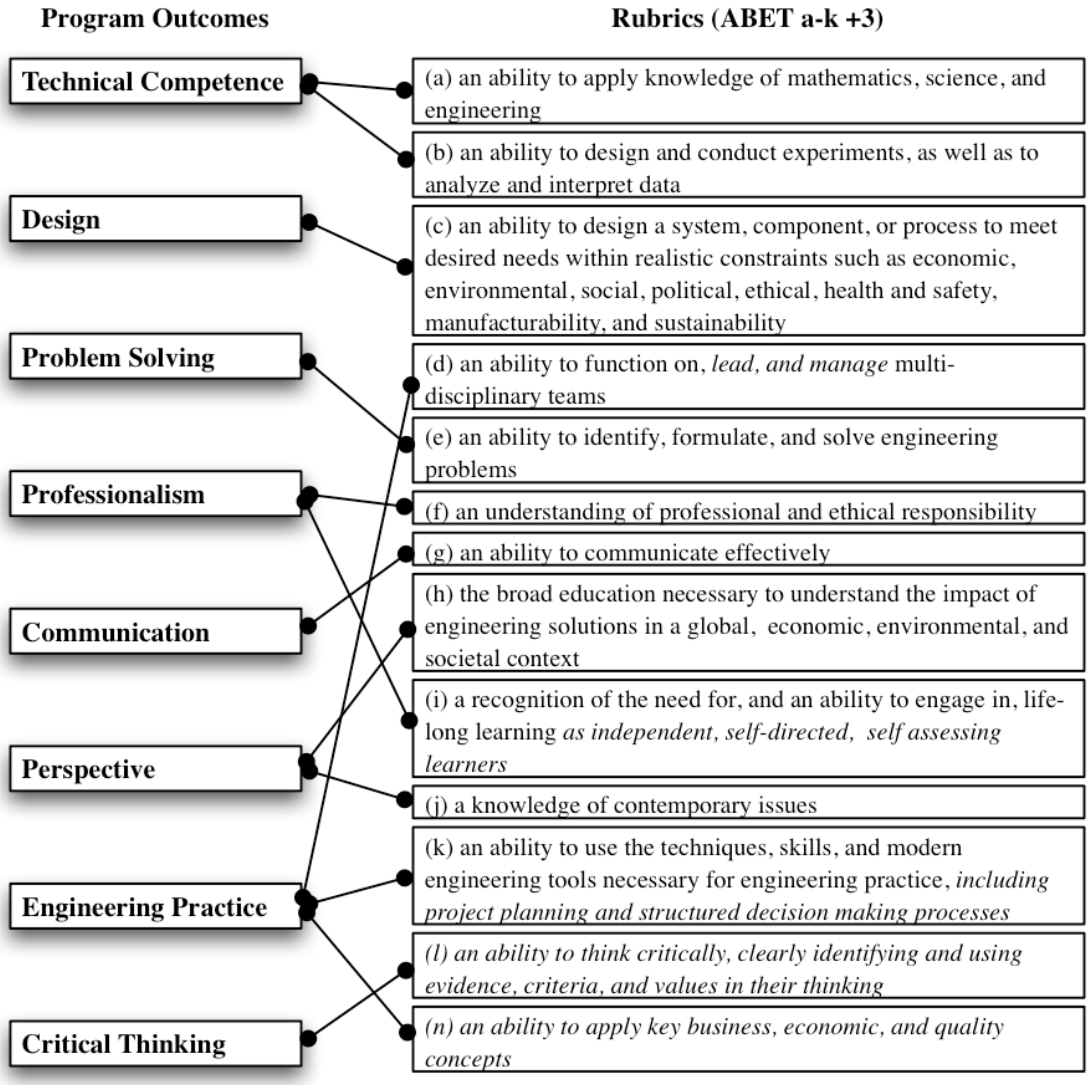

Figure 2. The connection between the 13 outcomes, 1-m, and the 8 named program outcomes.

We Discover the Liberal Arts

ABET additionally requires program objectives which should describe the graduates 3 to 5 years after commencement. A change in our objectives occurred during our first year of operation. This change is particularly relevant to the issue of liberal arts. We originally had three program objectives, all related to professional success as an engineer. On the first day of class, we asked the students to write a brief, informal essay in which they described where they hoped to be and what they hoped to be doing in 10 years. As they were freshmen, this involved their describing their lives about 5 years after graduation, in effect their personal version of a set of program objectives. We discovered that our students' hopes and plans were not narrowly focused on professional success as an engineer. In fact, a majority of them didn't mention engineering at all. Instead, they provided an embarrassingly richer description of their lives than we envisioned in our original three objectives. We have repeated this exercise several times since and obtained the same result every time. So, we added a fourth objective to our list of program objectives. The fourth objective is:

> Graduates will have the skills and knowledge necessary to attain their desired levels of financial security, entrepreneurial success, and post-baccalaureate education while being well rounded human beings who participate in a rich spectrum of human activities.

It is extremely interesting to compare this fourth objective with common descriptions of the liberal arts. For example, Wikipedia states that the original sense of the phrase has to do with the difference between educating free people (hence the "liber") as opposed to slaves[9]. The usual implication is that a liberal arts education is not centered on professional or vocational skills. Our student body includes students who want some professional skill development but do not want that to totally dominate their education at the expense of all else.

This fourth objective also fits a set of students who make up 10% or more of the national engineering bachelor's degree holders [10, 11]. These are students who receive an engineering degree but do not seem to pursue either employment or graduate education in engineering after graduation.

We just finished our first ABET evaluation this fall, as we had our first graduating class in May 2009. Assessment of these objectives lies in our future.

Development of Perspective in the Student

The key word here is "development". What ABET desires is an outcome that describes the graduate. One would hope that graduates though are further along the path than entering freshmen. So, a developmental model of an outcome is useful. For example, Alverno uses such an approach and we decided to describe our outcomes in terms of developmental stages as well. There are a wide variety of theoretical models for student

development available.[8, 12, 13] While we cannot assert that any particular theory has been rigorously applied by us, we generally find that the lowest level ends up being associated with factual knowledge and then one or both of two somewhat parallel paths of development are explored by us. Along one path the student demonstrates an increasingly sophisticated ability to apply and use what they know. Along the parallel path the student demonstrates an increasing sophistication in their evaluation of their own ability and knowledge. In the case of the perspective outcome, the level description was heavily influenced by Nelson's presentation[14] of Perry's model[13]. In Nelson's presentation, at the lowest level the student is like Sgt. Friday of the old Dragnet TV show. They just want the facts. All questions should have just one right answer. They then proceed to a level in which they become aware of the possibility of questions having many answers but view the selection of one's preferred answer as being a matter of taste, much like one's choice of a preferred flavor of ice cream. Beyond that, the student begins to select and justify answers using values consistent with their professional community.

In the context of our Persistence outcome, the student would start at level one and progress toward level 4. A student who lays in-between level 2 and level 3 would be our goal for the typical graduate. Level 2 is a minimal goal for a graduate. Level 4 is aspirational. These levels are:

Level 1: Understands that technological change and development have both positive and negative impacts

Level 2: Identifies and evaluates the assumptions made by others in their description of the role and impact of engineering on the world.

Level 3: Selects from different scenarios for the future and appropriately adapts them to match current technical, social, economic and political concerns

Level 4: Has formed their own model for the probable future of our society and makes life and career decisions informed by this model.

In our initial assessment, students were asked to submit a portfolio of evidence that demonstrated that they had achieved an appropriate level of development in the perspective outcome. Most were judged by the faculty to be demonstrating either level 2 or level 3. Of immediate interest here is a comparison of where the student went to find evidence with our hypothesis about where and how they would develop perspective in the course of our program. 10 students submitted portfolios.

We hypothesized that the student would develop a broad perspective in our program through the following paths.

- We have helped develop a course inside the humanities/ social science program that helps the students develop an improved awareness of the social, economic and political impact of technological change by supplying them with a set of historical examples of such changes. The course is entitled "History of Engineering".
- The engineering portion of the program is project based. This places technology in perspective. Should we use a wind turbine on a Native American reservation? How should we propel boats used in national parks? How can one introduce technology to rural African villages?

- We require a course in critical inquiry for second semester students. The goal there is to have them develop a broad perspective on engineering and to begin the process of becoming a rational thinker instead of a rationalizer.
- In the ethics area, we have a small module at the sophomore level that we are developing it in the context of a campus wide effort at having ethics education permeate the curriculum. Most of these students did not have an opportunity to take this module and it is not a formal degree requirement.
- All of these would supplement the Humanities and Social Science part of the general studies program.

We now show the fraction of students who drew evidence from each of the above developmental experiences, along with several other developmental experiences mentioned by the students that are not the consequences of our program structure or activities. It is arranged in rank order.

Projects were mentioned by 70%
Course work in humanities and social science was mentioned by 50%
A diverse population on campus was mentioned by 40%
The History of Engineering course was mentioned by 30%
The Critical Inquiry course was mentioned by 30%
Projects or papers in math and science courses were mentioned by 20%
Work experiences were mentioned by 20%

Obviously, one cannot push this data too far. However, all of the experiences that we felt would help the student develop perspective were mentioned by multiple students, with the exception of the sophomore ethics module which was first taught during these students' senior year. In addition, the diversity of the student body and work experiences were mentioned by several students.

If we had to extract one main thread it would be this. Engineering students seem to notice it when they either do projects which will impact some society (provide wind power on an American Indian reservation, provide water to an African village, a quiet clean motor for boats in the grand canyon) and they also notice when a mathematics or science instructor asks them to use math and science to evaluate some real ethical or economic problem.

Generally, our hypothesis about where they would develop perspective seems to be valid. What is impossible to ascertain at this point is the relative efficacy of these various experiences. That will be the basis for future work.

On a closing note, it has been our pleasure to go through an experience that 99% of the readers will never have, that of starting an engineering program from a clean slate. As we noted, the only constraint imposed on us was that we could not generate a degree that duplicated the discipline specific degrees that ASU already had in place. We were forced into multi-disciplinarity. At first, we resisted. Now, many of our faculty find it to be liberating. From our new vantage point, we can see some things more clearly than

before. What clearly happens to "liberal arts" education in a traditional engineering program is that it gets squeezed out because faculty view the degree as a specialty degree. As an example, the electrical engineering faculty of ASU do not really worry about whether or not their students know more electrical engineering than a chemical engineering major at ASU does. On the other hand they do worry about whether or not their graduates know as much or more electrical engineering than the electrical engineering graduates of the University of Arizona. The embedding of engineering education into a discipline specific model at the undergraduate level generates a significant competitive pressure to have our specialists be as specialized as possible. As we illustrated earlier, this results in the production of degrees that are much more specialized than is actually required by ABET. Overcoming this pressure is a major challenge in the generation of liberally-educated engineers.

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