What is Engineering Education?

Engineering Education as a Foundation

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Engineering Education Synthesis Assignment

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I need something to stand on. PLOTTING A FOUNDATION

As a young adult investigating future career options, I was all over the map. One day I wanted to be a teacher, then next day a dentist, or another day an architect. I knew I wanted to be educated, but my interests in life are so expansive, it was super challenging to pick one educational path. Even after I was introduced to a program in engineering, I was still wavering in my decision. How was I expected to pick what I wanted to do for the rest of my life at eighteen years old? Finally, someone offered me some really excellent advice. I was told that pursuing an education in engineering would be the best option for my future because the skills and knowledge I would learn would be transferable to almost any career, not just engineering. They said that if I started with a degree in engineering, I could become all those things I'd imagined: a business leader, a master marketer, a teacher, or a US Ambassador. With additional advanced degrees, I could become a patent lawyer, biomedical doctor, or architectural engineer. The important idea I was challenged to recognize was that that degrees in these specific fields would not be equally transferrable. (Figure 1)

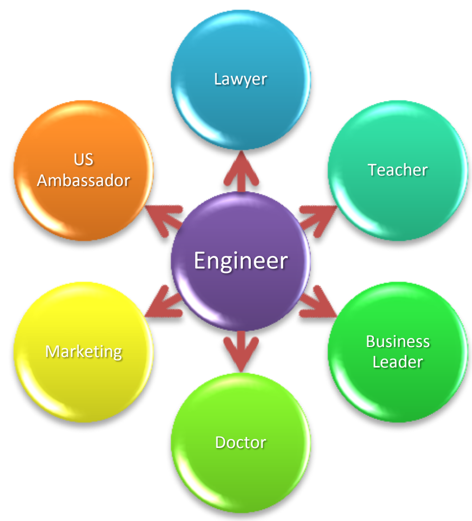
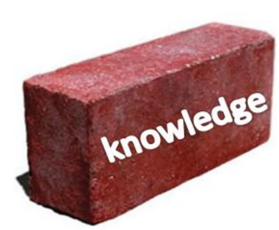


Figure 1 Career Options with an Engineering Education

American politician Christine Gregoire once said, "Education is the foundation upon which we build our future." As I pondered my future career opportunities, I came to envision an education in engineering as my platform, the foundation from which I could build many possible careers. My next inquiry and subsequent journey led to answer the following question: what were the bricks and mortar that I needed to plot this foundation?

What do I build the foundation with? FINDING THE BRICKS YOU NEED

I quickly discovered that the first thing I needed to build this foundation were the fundamental building blocks to engineering: knowledge of engineering theory, and rich problem solving skills.



Engineering education requires, like any educational program, that you learn particular information. However, knowledge is more than information. Bucciarelli writes that the "distinction of information from knowledge… makes knowledge, as knowing, an event in time requiring action on the part of those who provoke and those who would come to know (Bucciarelli, p45-47)." For example, Schön described in a discussion on institutional epistemologies that an elementary school is "organized around "school knowledge" – knowledge contained in a curriculum, held in the minds of teachers and communicated by instruction to pupils (Schön, p28).” He explained further that a subclass of school knowledge consists of “math facts.” Math facts consist of counting, addition, subtraction, multiplication, division, algebra, etc. In order to teach these math facts, they are divided into progressive modules where “the more advanced are constructed on the foundations of the more basic (Schön, p28).” These modules are integrated into lesson plans, which can be compiled to create curriculum, creating the idea of “school knowledge.” Engineering school knowledge is certainly more advanced than counting, but the idea of progressive modules in the curriculum is the same. “Engineers… make use of existing theory and methods in the explanation of how their alternative designs will behave in particular settings (Bucciarelli, p71).” Learning the engineering theory and methods and earning those bricks is imperative to having a strong foundation.

“The subject matter and the processes taught… become the tools in the problem solver’s kit bag. Students come to realize that the more *knowledge* they have, the broader and richer their solutions are (Culver, p225, emphasis added).” The second fundamental building block necessary for a foundation in engineering is problem solving, or “design, the basic engineering approach to solving problems (Engineering in K-12, p37).” The subject matter and the processes taught should provide the student with the ability to identify, formulate, and solve engineering problems, an ABET requirement for engineering programs (Jonassen, p139).

Schön describes the challenge of rigor or relevance in educating engineers in problem solving:

> “In the varied topography of professional practice, there is a high, hard ground overlooking a swamp. On the high ground, manageable problems lend themselves to solution through the use of research-based theory and technique. In the swampy lowlands, problems are messy and confusing and incapable of technical solution. The irony of this situation is that the problems of the high ground tend to be relatively unimportant to individuals or to society at large, however great their technical interest may be, while in the swamp lie the problems of greatest human concern (Schön, p28).”

Problem solving is certainly a learned skill, especially in engineering design. Problems are most often ill-structured, open-ended, and generally messy, requiring the problem solver to engage in risk-taking as there are trade-offs for any solution. The engineer must base their decisions on the theory and methods they’ve learned, and add to those bricks, the skills of problem solving. As more and more bricks are laid for the foundation, it is necessary to acquire the ingredients for the mortar that binds.

How do I securely arrange the bricks? Applying Mortar that Binds

As a student in engineering education acquires the fundamental building blocks of engineering and begins to arrange the bricks for the foundation, the next task is to mix the mortar that will bind the bricks. Mortar is comprised of three key elements: sand, aggregate (cement), and water. (Figure 2)

Figure 2 Engineering Education Mortar

Sand (Experience)

Experience is the first ingredient to the engineering education mortar. Each experience is like a grain of sand, where many experiences are needed to have the right consistency in our mortar. Schön, in describing Deweyan inquiry and action research, paints a good picture of the generation of experiences:

> "Design inquiry consists not only in creating plans but in enacting them. It is undertaken in particular *situations of practice*… In framing the problem of a problematic situation, and strategies of action appropriate to its solution, in such a way that both the problem and the action strategies can be carried over to new situations perceived as being similar to the first… The newly generated *practice knowledge* may be modified and incorporated into the practitioner's repertoire so as to be *available for projection to further situations* (Schön, p31, emphasis added)."

As a student, it is often hard to gain extensive experience without the instructors providing situations for experiential learning. Svinicki modified Kolb's Experiential Learning Model for instructional design. This process involves four processes which she states must be present for learning to occur most completely. (Figure 3)

> "The cycle begins with the learner's personal involvement in a specific experience. The learner reflects on this experience from many viewpoints, seeking to find its meaning. Out of this reflection the learner draws logical conclusions (abstract conceptualization) and may add to his or her own conclusions the theoretical constructs of others. These conclusions and constructs guide decisions and actions (active experimentation) that lead to new concrete experiences (Svinicki)."

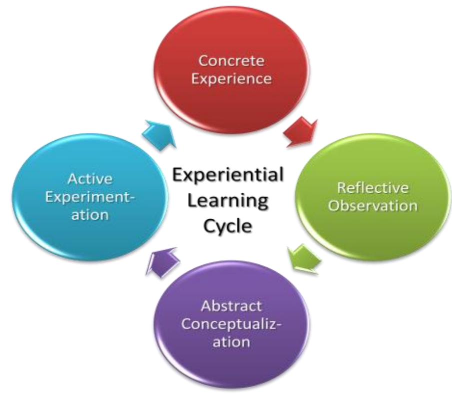


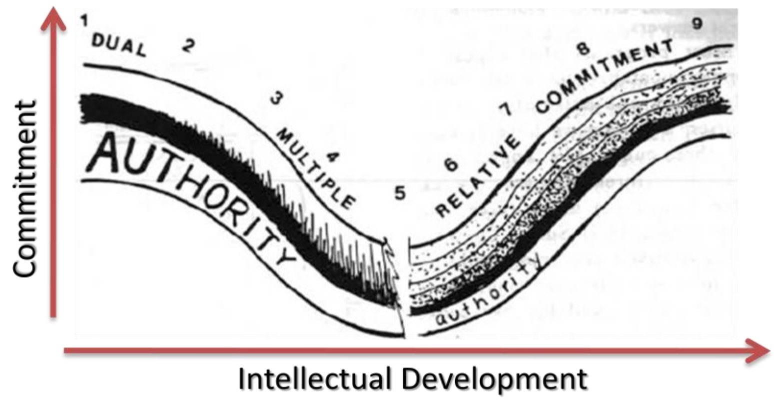
Figure 3 Svinicki's Experiential Learning Cycle

By integrating this technique into the classroom, engineering students have a greater chance of developing experiences that will add value to their knowledge and problem solving skills. Through this process, the act of abstract conceptualization will help to develop critical thinking skills, and promote cognitive growth, the second ingredient in our mortar.

Cement (Critical Thinking, Cognitive Growth)

"In order to solve workplace problems, students must develop adequate conceptual frameworks (make meaning) and apply those frameworks in solving complex ill-structured problems (Jonassen, p139)." A student is capable of developing conceptual frameworks as they mature intellectually, increasing critical thinking skills and reaching cognitive growth.

In Culver's study of using Perry's Model of Intellectual Development (Figure 4) at the Colorado School of Mined, he found that "those student's taught according to the Perry-based scheme achieved significantly more intellectual (cognitive) growth than those in the traditional classes (Culver, p226)." Engineering educators that provide students the scaffolding to develop into intellectual critical thinkers, will in turn provide for greater cognitive growth.



Stage Name	Stage Description
Dualism	Division of meaning into two realms --good versus bad, right versus wrong. We versus They. All that is not success is failure. Right Answers are to be memorized by hard work. Knowledge is quantitative. Agency is experienced as external, residing in authority, test scores, the right job.
Multiplicity	Diversity of opinion and values is recognized as legitimate in areas where right answers are not yet known. Opinions remain atomistic without pattern or system. No judgments can be made among them so "everyone has a right to his own opinion; none can be called wrong."
Relativism	Diversity of opinion, values, and judgment derived from coherent sources, evidence, logic, systems, and patterns allowing for analysis and comparison. Some opinions may be found worthless, while there will remain matters about which reasonable people will reasonably disagree. Knowledge is qualitative, dependent on context.
Commitment	An affirmation, choice, or decision (career, values, politics, personal relationships) made in the awareness of relativism (distinct from commitments never questioned). Agency is experienced as within the individual with a fully internalized and coherent value structure.

Figure 4 Perry's Model of Intellectual Development

Hogsett poses a question that challenges teachers: "How can the teacher lay the foundation of knowledge all the while preparing the way for the student to *make her own use of or indeed to question* the very knowledge she is imparting, whether at the time of the learning experience or later (Hogsett, p30, emphasis addes)?" This ability to question knowledge and use reason is a skill of critical thinking. Hogsett further challenged teachers in her analysis of Bloom's Taxonomy: "The Bloom group saw the solution to the general problem of rote-learning in the establishing of higher levels of *cognitive experiences*, in prodding the teacher to attend not only to the imparting of knowledge but to the skills and abilities involved in using that knowledge (Hogsett, p30, emphasis added)."

Therefore, an engineering education that provides more than just information, but opportunities for experiential learning and intellectual development will allow the student the necessary aggregate to seal everything together.

Water (Soft Skills)

The final ingredient that an engineering student needs before mixing and applying the mortar is water. When the student pours into the mortar mix their soft skills of communication, collaboration, leadership, flexibility, and a desire to be a lifelong learner, the mortar is ready to be stirred and applied to bind their foundation.

A study done by the National Academy of Engineering (NAE) entitled *Changing the Conversation* found that "many students believe engineering work is sedentary, performed mostly on computers, and involves little contact with other people (NAE 2008, p7)." However, in a 2004 report, *The Engineer of 2020: Visions of Engineering in the New Century*, the Academy described engineers as needing many soft skills that were previously not required. The student misconception of engineering as sedentary can be addressed by providing opportunities in engineering education for students to develop the necessary soft skills needed to succeed in their future. Good engineering will require good communication, both an ability to listen effectively as well as to communicate through oral, visual, and written mechanisms. Collaboration is imperative to engineering design, as engineers must be able to be able to work in multidisciplinary and multicultural teams. Engineers must understand the principles of leadership and be able to practice them in growing proportions as their careers advance. Flexibility is important as engineers must be able to adapt to a changing marketplace and work environment. Finally, a good engineer must be a lifelong learner, always ready and willing to add onto the foundation to which they stand. (NAE 2004, Culver)

Sand, Cement, and water when mixed and applied to brick make a strong foundation. Experience, critical thinking, and soft skills when mixed and applied to knowledge and problem solving skills make a strong engineer with limitless future opportunities.

Isn't this more than just a foundation? Transformation to a Launching Pad

One can do many things with a strong foundation[1]: convert to a parking lot, expand for a road, build a house, or erect a skyscraper. Engineering educators have a responsibility to provide their students with a strong foundation through lessons and labs that enable the student to develop the key skills. An engineering education rich in fundamental knowledge, problem solving, experiential learning, critical thinking, and development of soft skills will provide this strong foundation. The final discovery, however, is not part of the foundation. It exists on the shoulders of the student: the discovery of self. This leads to the confidence needed to transform the foundation into a launching pad, a platform ready to launch the engineering educated adventurist into a world of opportunity.

[1] It is noted that a strong foundation would be built of cement and steel reinforcements, but this didn't sound as eloquent for my analogy. ☺

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