Changing Geers: an Engineering perspective on education

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Abstract

This paper looks at engineering instructor perspectives on education. It discusses how engineering education is different from traditional education, the attitudes of instructors involved, and how engineering and education can connect.

Keywords: Engineering Education, CEAB graduate attributes,

This paper is based on coursework for the Faculty of Education qualitative research course EDUA-7480. During which I did a pilot study on the motivations and attitudes of engineering instructors towards teaching. The underlying question being, what’s important to them as engineering instructors?

Right now, engineering education in Canada is in a state of transition. In 2008, the Canadian Engineering Accreditation Board (CEAB) changed the accreditation requirements of engineering schools to be more goal focused, rather than prescriptive (Table 1). And by 2014, engineering schools in Canada need to embody design, leadership, and teamwork within a program that teaches technical excellence.

Table 1
CEAB graduate attributes for 2014 (Canadian Engineering Accreditation Board, 2008)

| 1. A knowledge base for engineering | 7. Communication skills |
| 2. Problem analysis | 8. Professionalism |
| 3. Investigation | 9. Impact of engineering on society and environment |
| 4. Design | 10. Ethics and equity |
| 5. Use of engineering tools | 11. Economics and project management |
| 6. Individual and team work | 12. Life-long learning |
Qualitative research was chosen for this project, because the challenges of change, the attitudes of those affected are not accurately represented by quantitative measurement. And if the goal is to understand what’s happening in a profession, one must look at the attitudes of the people involved. If one wants to help create change, then you need to understand the reasons people have for embracing it.

So the fundamental question in this work is - what are engineering instructors trying to achieve in their classroom and how do they do it?

**Engineering Education as a discipline**

In the minds of engineers, engineering education is a unique discipline with it’s own challenges and problems. (Vest, 2008) (Sheppard, Macatangay, Colby, & Sullivan, 2009) (Haghighi, Smith, Olds, Fortenberry, & Bond, 2008)

One challenge in particular is that engineering instructors are hired for their technical expertise, their ability to bring research money to the university, not, because they are great teachers. Additionally, they don’t generally read volumes of material on educational theory and practice. Their journals are technical in nature.

“*In applied sciences so forth you are, you get hired because you know a subject matter not because you’re pedagogically gifted.... But we are not taught the art of teaching.*” (Beta)

Engineering schools in many parts of the world have found that industry is saying that their graduates are not trained properly, and that they need soft skills, business skills, and communication skills. (The Canadian Academy of Engineering, 2005), (The Royal Academy of Engineering, 2006), and (National Academy of Engineering, 2004). And in response to these pressures, organizations like CDIO (Conceive Design Implement Operate) and CEEA (Canadian Engineering Education Association) have
been formed. Engineering instructors believe in the value they are bringing to society, and see themselves as creating professionals. And there is a real move within the discipline to change how we teach.

“we cannot teach the same way we were taught... [Y]ou know, we can’t just turn our backs to the classroom and [write] on the whiteboard or chalkboard, [turn around] 45 minutes later, [ask] any questions and then leave the room. No, that’s done. That does not work any longer.... You know, there is a place to lecture. But that’s not teaching. Lecturing is I give you materials, it’s up to you to absorb. I think that is just not enough any longer.” (Beta)

**Engineering as a unique body of knowledge**

“*Engineering is problem-solving, goal-directed and needs-fulfillment activity.*” (Koen, 1985, p. 69)

Engineering is unique from other disciplines in that it has its own way of thinking. (Godfrey & Parker, 2010). And although students are taught math, physics, chemistry, and biology, their focus is different. They want to take that knowledge, and apply it to solve problems. Engineers are looking for the best answers rather than a right answer. Because many of the problems we deal with are have incomplete information, are approximated, multi-faceted, and have conflicting constraints. In math and science, getting a right answer means getting the same answer as the instructor. In engineering, you are expected to come up with a best answer given the resources at hand. Compromise and constraints are at the heart of everything we do.

“One of the most deeply ingrained assumptions associated with the Engineering Way of Thinking was that engineering dealt with a tangible, definable, measurable, quantifiable reality. Valued knowledge was seen as knowledge that is relevant to real life. ‘What would we use this for?’ was the justification for learning.” (Godfrey & Parker, 2010, p. 10)
Methodology:

This research project was done as a pilot to understand the attitudes of engineering instructors toward teaching. Participants were randomly selected based on availability and a minimum of three years of teaching experience. Of the respondents, four were chosen (Alpha, Beta, Gamma, Delta) from disciplines within engineering. Interviews were one hour long and followed a semi-structured format. Once transcription was complete, each participant was encouraged to review their transcript for accuracy. Coding of the data was done heuristically, following a grounded theory approach.

Key Findings:

Through discussions with these four participants, the common theme between them all was creating professional engineers. And the need to connect their courses back to the real world as much as possible to get students thinking like engineers.

“My duty is to produce future engineers... If I don’t teach them... how to think outside problems then, then it’s a failure to me. That’s why it’s important to me.” (Alpha)

Interestingly, although they all focused on creating professional engineers, what that meant was flavoured heavily by their area of expertise. Each participant had a very different core message (Table 2) and vision of what engineers are. Two of the four stressed developing the students as professionals,

<table>
<thead>
<tr>
<th>Participant</th>
<th>Core message</th>
<th>Engineers are</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>Connect theory and practice</td>
<td>Real world problem solvers</td>
</tr>
<tr>
<td>Beta</td>
<td>Learn for more than just a grade</td>
<td>Communicators and leaders</td>
</tr>
<tr>
<td>Gamma</td>
<td>Serve society and yourself</td>
<td>Planners and managers</td>
</tr>
<tr>
<td>Delta</td>
<td>Find what you love to do</td>
<td>Technical experts</td>
</tr>
</tbody>
</table>
while the other two focused on what the students would become after graduation. And each highlighted a different but equally valid viewpoint of what engineering practice is about.

In order to teach and convey these messages, each professor tried to connect what they were teaching back to the real world professional practice. In Alpha’s case, he used the lab to build observation skills, and the data collected used as a focal point for discussion to connect what they saw, with what happens in reality. In Beta’s and Gamma’s case, they used projects to get students perceiving themselves as junior engineers, dealing with issues like uncertainty, customers, and groupwork. And Delta’ used anecdotes to illustrate professional practice, to get students thinking about where their careers were going and what they wanted to be in the future.

“*We do that in the lab first. Then we ended up coming to the classroom with it... I normally actually use a lecture period actually, [to ask students]. What strikes you. What did you observe... can you actually describe... like the failure process”*

“If you have a design project, you have to be willing to work in groups. You have to be willing, to ah, behave like a junior engineer” (Beta)

“So I try very much too, to tell them, I mean to give them stories about good engineers, about this guy I was telling you about from CN about how good engineers are supposed to be and how it is very a good career.“ (Delta)

And as the students perceived themselves as more and more as engineers they become more interested, more engaged, and more responsible for their learning. In a word, the students take **ownership** of their work. They learn to become “self critics” and move beyond the grade. Ultimately, they have to learn to take ownership for the quality of their work.
“I say if I mark you A+, what’s an A+. And one say, 90%. I said good. Yeah, it sounds good. Now, you have to go on a holiday, or you’re flying to visit your family in Vancouver or whatever. You go to the airport, and the air Canada person tells you this plane is 90% safe... 90%. Would you go on the plane or not?”

Most don’t raise their hand, they don’t want to take that risk

“Because 90% is good for your exam, because you’re exam doesn’t impact anything yet.” (Delta)

In the context of educational theory

Considering engineering education in the context of the knowledge and cognition domains of Bloom’s Revised Taxonomy (Krathwohl, 2002) (Table 3), we see that program as a whole builds towards a metacognitive knowledge and a synthesis based cognition. Students grow from learning factual and procedural knowledge (engineering science) in years one and two, to building conceptual knowledge (engineering application) in years three and four. Finally in the capstone or thesis course, students are suppose to be grounded enough, that they can move easily transition into metacognitive knowledge – knowing how to solve their own problems and understand the limits of their knowledge. With cognition, the students are expected to remember and recall formulas in physics, calculus, chemistry... Yet in later years, these concepts are assumed to be something that would be looked up when needed. So more time is spent understanding the problems, and learning how to solve them
### Table 3

*Engineering in the context of Bloom's Revised Taxonomy*

<table>
<thead>
<tr>
<th>Year</th>
<th>Knowledge</th>
<th>Cognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Factual knowledge</td>
<td>Remembering</td>
</tr>
<tr>
<td></td>
<td>i.e. Mathematical theory</td>
<td>Recognizing terminology</td>
</tr>
<tr>
<td></td>
<td>i.e. General Science</td>
<td>Recalling formulas</td>
</tr>
<tr>
<td>2</td>
<td>Factual and procedural ( Discipline specific)</td>
<td>Remembering/Analyze ( Discipline specific)</td>
</tr>
<tr>
<td></td>
<td>i.e. Electromagnetics</td>
<td>Solving equations to idea problems</td>
</tr>
<tr>
<td></td>
<td>i.e. Programming</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Conceptual and procedural</td>
<td>Understanding and applying</td>
</tr>
<tr>
<td></td>
<td>Systems design courses ( constraints)</td>
<td>Introduction of non-ideal considerations</td>
</tr>
<tr>
<td></td>
<td>Learning about what’s design parameters</td>
<td>Interpreting real world measurements</td>
</tr>
<tr>
<td>4</td>
<td>Metacognitive</td>
<td>Evaluating and creating</td>
</tr>
<tr>
<td></td>
<td>Elective courses in specific areas</td>
<td>Integrating technical concepts into real</td>
</tr>
<tr>
<td></td>
<td>Thesis/Capstone projects</td>
<td>world problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Designing systems</td>
</tr>
</tbody>
</table>
“I’m more looking at the concept, not solving the differential equations. If they know the concept, they heard about it… Then they know how to get the solution… But now it’s even easier, with the whole computer thing, does it all for you, right. But you, you have to I think, its important thing is you have to understand… what does that differential equation mean. And you understand it’s a way of getting the solution. But… I don’t ask them to actually solve the equation because that’s not the focus of [my class].” (Alpha)

Although problem solving is the mantra of engineering. Students do not enter the program with the theoretical background required. The knowledge of math, and science take time to build. Thus, the deeper understanding of how the knowledge aggregates together is left until much later in the program. Thus students entering engineering find themselves facing a tirade or lectures and an intense calendar of the theory based courses. With those prerequisites in place, only then do students have the abilities to tackle “real world” problems.

“We tend to like be very theoretical for the students. In the physicality’s of engineering. But later we can give them [projects]. And [apply] the aggregate knowledge from different courses towards this theory. So in the first place we are doing some kind of disaggregation ok. These courses just concentrating on this area, and other courses area are concentrating on different area. But later if you have already gone through it, you can have some kind of aggregation of all this knowledge to be applied and more go to the physical.”(Gamma)

“[In] the fourth year course…they are beyond the fact that you have base knowledge, and now have, would like to have them have some applied knowledge. Some design knowledge, some…problem solving in real cases.” (Beta)
Connecting with education

When we look back and think about engineering education and traditional education, they are strikingly similar. Both faculties want to create capable students. Both faculties want to create problem solvers. Both have to deal with the issues of building a knowledge base and helping their students put it into practice. Yet in both education and engineering, the world is changing. It is exerting pressures on these faculties to change. To change what they teach and how they teach it.

Often in education, we are guilty of teaching students to look for one right answer. Being right means getting the same answer as the instructor. The challenge is, we need to teach our students to adapt and overcome in the face of things we cannot even predict. By teaching students to focus on getting the same answer as the instructor, we leave them handicapped when faced with the unknown.

Unfortunately real world problems are complex and filled with unknowns. Often data is incomplete, people’s opinions come into play, and we have to make assumptions. We have to find a way to solve problems that work in spite of factors we cannot control.

And that is where both engineering and education can learn from each other. Engineering educators can learn about creating classrooms that work for their students. That go beyond chalk and talk to being memorable and full of impact for their students. By the same token, Education educators can benefit from working with engineers to create a design based curriculum that teaches students to methodically tackle problems, make assumptions, and create solutions. By bring both camps together, we can create an education system where students learn to tackle the unknown with confidence and skill. Rather than graduating students who freeze because the problem is too big or too undefined.
Conclusion

The engineering students or “Geers” of today are facing a different world than previous generations. They have to be competitive internationally. They are expected to be both technically competent and functional in industry. The profession is changing, and CEAB requirements are just one reflection of this.

In Canada, our challenge is to incorporate leadership, teamwork, and life-long learning into our curricula. With this in mind, this paper looked at where we are right now. How is engineering education unique? But also how engineering and education can find common ground. In both professions, our teachers are deeply to the success of their students as professionals. And by bringing engineering and education together, both can be stronger. We can learn to educate engineers more effectively and we can learn to engineer a more effective education system.

References


