How would philosophy of engineering help us conducting better classes in engineering disciplines?

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Abstract

Recently, there have been valuable, creative, and systematic attempts for to identify, define, and work on a philosophical basis and foundation of engineering. Researchers in the area believe that the foundational philosophy (or philosophies) of engineering should not necessarily be the same as the philosophies for sciences[1-2]. In this important endeavor to search for and identify the philosophical basis for engineering and engineering education, a fundamental premise exists. The assumption is that having a better understanding of the philosophical basis of engineering will help educators to design and deliver classes with pedagogical approaches that result in more effective engineering training. The questions regarding why and how this effort will be useful to engineers and engineering educators need to be discussed, debated, and examined. This paper is an attempt to identify and focus on some of the major issues of such discussions with emphasis on the pedagogical perspectives.

Motivation

In today's age of technological and engineering advances, engineering fields and discipline-focused approaches are merging, expanding, and growing beyond educators' imaginations. Naturally, engineering educators try to engage in challenging activities to preserve the essence of engineering[3-7]. At the same time, in order to keep up with newly developed advances, educators are offering new classes that address modern challenges and developments in engineering and technology. The intention is to help students have a more in-depth understanding of the subject, develop their skills, advance their analytical capabilities, and be able to identify major governing concepts, equations, and trends.

In addition, the traditional classes that are considered the foundations for each engineering discipline continue to change. In most cases these classes are packed with a wide range of material because of their importance in particular disciplines. For example, in the area of electrical engineering, traditional classes such as circuit analysis, electronics, signals and systems, power, electromagnetism, and communications are considered basics. Consequently, many schools try to have elements of these important areas in their curricula. As a result, most engineering disciplines have ended up with what is called "packed-curriculum conditions"[2]. This "packed-curriculum conditions" is a problem for student population. Often, what has been developed in these classes does not align well with learning approaches and interests of new student populations. Students are seeing many topics that are important but do not have any connection nor integration of the material. Some of the newly developed and modified programs are avoiding the condition of "packed-curriculum conditions" by introducing an integrated program where the important information are integrated, with repeated coverage, throughout the core classes that are in the first few years of the program. Consequently, the last years of the program can be filled with more specific classes to help students do deeper into few areas of specialization.

Most of the schools are struggling with these issues. Most of the schools and departments are struggling with similar questions and needs for further developments. At the same time, the need for mathematics, calculus, statistics, physics, and other basic sciences remains to be important. It must be mentioned that few programs have been successful in circumventing these issues. There are some great programs that do not fit in this approach and have been developing a much more connected, integrated, and cohesive engineering programs.

Naturally, one needs to think about how to achieve so much in 4 years of college education, meet all of the ABET requirements, and produce effective engineers.[1-5] This paper is mainly focused on US institutions. This trend does exist intentionally. Many international schools are also examining these issues and challenges. In addition, with the recent interests in ABET accreditations at the international level, it is clear that other institutions are also thinking about similar challenges as well [6].

What would philosophy of engineering offer?

While the importance of in-depth and critical thinking is apparent in all areas of higher education, the connection of philosophy in this process is not very well understood, nor is it believed, by most engineering educators. The typical engineering educator does not see the importance or the necessity of the connections between philosophy and a philosophical basis of engineering to their everyday engineering classes (or to everyday engineering practice.) Consequently, the most important question for engineering educators is "what would philosophy offer or contribute to engineering education?" This is an important practical question to address. In order to have a better understanding of the related issues, we tried an experiment.

During Fall 2013, with collaboration between our engineering college and a European university, a set of seminars with the title of "Critical Reflections on Engineering,

Engineering Pedagogy and Philosophy" were conducted. Engineering faculty, graduate, and undergraduate students attended the seminars. In addition, faculty from Physics, English, and Rhetoric also participated in most of the discussions. Seminar readings and the material were provided to the patrons via an Internet site. Consequently, many faculty, students, and administrators were following the seminar and would follow the discussions and the invited guest's reflections on developing a working philosophy for engineering educators. This was a successful activity for all of us and brought about many interesting questions that are of utmost importance to engineering and engineering education.

Observations

Perhaps the most important set of observations was the fact that the discussions were of interest to engineers (student and faculty). They understood the importance, but they mostly struggled with one main question: "How would all these discussions, words, and reflections help us with our engineering tasks, and engineering education?" Based on the reflections of the students and the faculty, it was obvious that the engineering groups were looking for a set of action items. They wanted to see a set of steps to take and a list of activities to practice in order to become more effective engineers and educators. Some of the main comments and questions that were generated by this group included:

1. "These are wonderful words: How do they help me be better educator? "
2. "Knowing all of this is fine: How could it help me do better as an engineer? "
3. "If engineering is taking action, doing and designing things, how does philosophy help me do it better? "
4. "This is of great value and importance. We do not have anything like that in our curriculum, and it has worked well."
5. "Do we really need to change anything in our education system? It seems to work. "
6. "The engineering curriculum is based on skills, math, physics, and all of engineering concepts and practice. If we engage in philosophical discussions, reflections, and debates, it could reduce the students' engineering knowledge base. We would then develop weak students."
7. "What would industry think? Would they still hire our graduates?

While the engineering team had many questions that would undermine the need for the discussions in the seminar, the physics, linguistics, and rhetoric professors did not have such questions. For them, such engagement was important, necessary, and fruitful. This was expected. After all, the liberal arts and sciences do have more reflective engagements and are historically closer to philosophical basis of their fields than engineering has been in recent years. Perhaps one of the most interesting observations was that the physics faculty always found the discussion of great importance.

One may think that physics and engineering faculty are very close in their perspectives. It should be noted that until late 19th century, physics was called natural philosophy in academic institutions. To-date, most physics curricula have kept their liberal nature of

Another interesting finding regarding the engineering group was that the reflective nature of philosophical discussions (while seen as interesting and important) did not seem to have any connections to their engineering practice, design, and their educational activities. For them, the practical nature of the field, and needed problem solving activities, were overwhelmingly overshadowing the need of philosophy and reflective activities. However, reflective practices are important and essential to all education activities. Consequently, the question is "how can such practices be infused into the engineering curricula?" The national activities such as active learning, flipped classes and similar approached and have been showing success during that last 20 years. Consequently, a more direct approach to infuse reflection, and reflective activities connected to philosophical basis of engineering are the tasks that technological literacy division has been leading within ASEE activities.

The new approach and keeping engineering essence

From a pragmatic perspective, engineering education needs to have the connections between sciences, math, design, and engineering practice. Studies have shown why most of the educational approaches have ended up emphasizing and celebrating more theoretical and less practical elements of engineering education[7-10]. Until recently, most engineering programs were happy to have packed and information-pleasing curricula based on physics, mathematical foundations, and problem-solving exercises based on theoretical aspects. The more such classes were added to the curricula, the less space was allowed to open design and design iteration activities. Students tended to spend more time and focus on instructional laboratories and procedures, and less on building and designing challenges.

This model worked very well for technician training. So, it seemed to be useful for engineering training. The old model was to start with the technician training and infuse more science, and mathematical version of the 50's-60's technician trainings. However, the pragmatic essence of engineering to build, design, and make things was fading and began to disappear in most curricula. Consequently, ABET tweaked its emphasis to ensure that engineers are developing the right balance of hard and soft skills.

One perspective on the ABET requirement was to liberate engineering education by bringing together the most important essences of engineering (design, building systems, and ethics.) Many programs strive to achieve all of that. It is interesting that most colleagues claim that during an ABET visit we all reflect, reshape, and reconsider our efforts, and try to understand a better overall picture. In a sense, we reflect. One argument is that the ABET criteria and suggestions are enforcing the essential engineering basics together with a liberated form of engineering studies[3,7].

What would philosophical awareness bring to engineering education?

Engineering education is producing engineering problem solvers, and philosophical reflections help us develop our critical thinking abilities. There doesn't seem to be much of a difference between the development of engineering problem solvers and critical thinkers. However, as discussed by a few authors, the case of packed curricula can impose huge barriers to the true development of the students in engineering education[12-15]. Philosophical awareness of the foundations of engineering is not the same as the philosophical foundation of science[1]. Bringing the right philosophical approach to engineering and engineering education will not only facilitate us toward a more pragmatic essence in our education, but also will bring about a needed reflective disposition[16] that is essentially missing in our education. This will be beyond what we are doing in most programs and what is needed by all. Students need to be asked to reflect on their learning, question the purpose, the ethics and the societal impacts of what they do. In addition, each student needs to create connections between what he or she learns and engages in.

Due to the heavy syllabi and abundance of material that is covered, students do not have time to reflect on their learning. They have an overwhelming practice in analysis, but the true nature of synthesis and higher meta-cognitions are missing in their development[19-20]. Consequently, due to lack of effective reflection, and getting many facts out-of-context in classes students not only do not engage in any reflective activities but also (and more importantly) do not know how to do that. In general, most engineering students seem to be incapable of such activities. Consequently, they will not appreciate such activities in their professional lives. This has been studied in the last decade and is documented by Heywood and Hannemann[19-20]. How an in-depth reflection with a philosophical basis would help engineers and engineering educators is summarized as:

1. Integrating their knowledge base

2. Becoming more creative in their work and design

3. Having a better understanding of their goals, purpose and missions

4. Having a more ethical and societal connection in their work and activities

5. Making them more effective learners and problem solvers

6. Enabling them to be life-long learners and adaptable designers

Challenges for the early adopters

An engineering education that includes liberating elements needs to have a sound philosophical foundation. In order to facilitate a liberated future for engineering education, one needs to develop an understanding and personal reflections on the philosophy of engineering (as well as their connections to engineering education.) Each of us (engineering educators) needs to seek and understand important questions and challenges with bearings on defining and shaping engineering pedagogy for the future.

1. What is our understanding and personal reflections on the philosophical basis of
   a. What is engineering?
   b. How can we train engineers for the ever-changing future developments?
   c. What are the most fundamental concepts and skills that every engineer should know?
   d. What are the discipline specific concepts and important skills that students need to acquire?
   e. Is it possible to train engineers (with all of the skills, concepts, and knowledge base) in 4 year (perhaps 5 including industrial experiences)?

2. Having a philosophical basis for our actions as engineering educators, we need to address the following issues
   a. To train the flexible future engineers, they need to have ample opportunities to reflect
   b. Reflections need to be included in curricula as constructive elements in the lectures, team work, and projects
      i. Considerable attention and monitoring by the educators is essential for enriching the reflective practices
      ii. It should be noted that, the need for various forms of reflections includes of the most important essences of cooperative learning, team based learning, and project based learning in engineering education.
   c. When including such activities, educators need to keep up with educational developments (research papers and reports from conferences, journals, and funding agencies and authorities such as NAE and NAF)
   d. When reflections are added, something needs to be taken out
      i. Currently our syllabi are filled and packed.
      ii. To add reflections, something needs to be omitted

3. It is the role of the educators to bring about an integrated approach that includes the basics, the skills, and connectivity in the class and across curriculum (it takes a team, and departmental awareness)
   a. A reflective approach with emphasis on basics, major concepts and

constructs, and skill development that is integrated throughout the curriculum is needed.

Engineering education from the pragmatic perspective can be very similar to the thought and developments of education leaders such as John Dewey and Piaget [21-24]. In addition, it should also be emphasized that in the engineering education model there is a core knowledge base that needs to be in the training. This is well established by some of the early developers of the ideas of philosophical approaches to engineering.

In order to adopt such an approach, educators should not only be aware of the developments and concepts of philosophy, education, and engineering, but they also need to be reflective themselves. In order to develop creative ideas, and to train more creative designers, we need to remember that creation comes from mental reflections and iterations. Ideas are developed from personal perspective and analysis, as well as through social interactions, discussions, debates, and critical questionings. Ideas are mostly developed by a round-and-round trip of concepts, findings, and trial-and-error activities. Given enough time, reflections, and carful examinations, a special spiral of thoughts will be generated.

Engineering educators need to rethink and hesitate from teaching too many facts and drills, and let the students reflect, discover on their own, and discuss their ideas, failures, and successes with peers, and faculty. It is not a coincidence that many of our students claim that they learned something that was covered in a class (with lots of drills and practices) later in their careers watching a video on the Internet when they needed to finish a project. When there is a need and a purpose and venues for thinking reflecting, we all learn better. Our role as educators is to make sure that students have the right basis, reflective capabilities, learning skills, and the sufficient practice to learn on their own and participate effectively in teams.

When an educators start thinking, reflecting, and working to develop their philosophical basis and beliefs, they may feel challenged by other faculty who believe in more traditional perspectives. The traditional belief in pure drilling, hard science approach, and the type of approaches that made most of the traditional faculty obviously worked (that is what they think), so why should we not follow it. From their perspective the traditional way is the way to train good engineers, however, that does not include many important elements.

1. The dynamic students: Students are changing and what worked for a generation needs to be adapted for the new ways of the new student perspectives
2. An engineering faculty does not represent the engineering students (with exceptions). Very small percentage of the current engineering students will end up in academic positions. So faculty need to be careful not to adhere the belief that because they used to be like the students they automatically understand what the students need.
3. Teaching facts out of context (and not allowing students to critically examine them and challenge themselves) only results in non-reflective as well as dogmatic belief structure[21]. Will such approaches really help future engineers who need to be flexible learners, team players, and multidisciplinary operators?

Conclusions

Establishing a philosophical basis for engineering and engineering education will help the future development of our pedagogical approaches. In an ever-changing world with unexpected and unpredicted challenges, engineering and engineering education need to change in a dynamic manner. Having the right philosophical foundation will help this transition. Engineering educators need to identify and be reflective on the elements of the engineering philosophy that they believe in. Based on their philosophical approach, they need to adopt the best strategy to train students to face and solve the colorful challenges of the future. There are many questions and many important items to think about and discuss and debate. Many details are still open for debated and experimentation. However, having a philosophical approach in engineering education will bring reflective thinking and discussions that are essential in problem solving and critical thinking. Engineering educators are encouraged to start more reflective practices in the education process, and help students focus on their engineering perspectives and relationship with their learning, the foundations of engineering, and integrate their knowledge base and skill sets. Based on that, engineering curricula need to allow space for such activities. Too much facts out of context and drill exercises can and will bring closed mindedness and will weaken reflective development. These are necessary tools for human development. The process for achieving the balance between knowledge base, skill sets, and transferable knowledge and capabilities to the new generation of students need to be constantly revisited and dynamically progressed for better. It is with the right philosophical basis, and reflective disposition that it can be effectively achieved.

There is not a single menu for educators to follow and let philosophical basis help them education better students. It can only be achieved by true reflective exercises of the faculty and engineering educators. This has to be done at each department, college, as well as national and international levels. Every educator needs to share ideas openly to discuss and frame a better future for our activities. Having the flexible and open-minded approaches and philosophical basis together with shared engineering values and concepts are essential for paving a better road to the future of engineering and engineering education.

Acknowledgement

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