Integration of Skills Development Across the Engineering Curriculum

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Abstract

Engineering curricula should have the ultimate goal of producing the engineer society needs, a professional with not only a competent knowledge base, but with the skills that will enable him/her take charge in the highly competitive world of today. Therefore, engineering curricula should balance knowledge transmission with skills' development. This can be effectively achieved if engineering educators strategically plan the design of engineering programs accordingly. This paper suggests one way by which engineering educators can integrate the development of basic skills into the engineering curriculum.

Background

One can define an engineer as a professional who solves problems creatively using all his/her knowledge base, skills and abilities, information and tools, and who is capable of working alone as well as in teams while communicating ideas effectively. There seems to be a consensus about the competencies and skills an engineer must posses in order to be successful in the profession. Educators and professional societies with vested interest in the outcomes of engineering education have carefully analyzed these requirements [1,2,3,4,5,6, 7,8]. One can group them into three major categories: ***design/problem solving, communication, and awareness of self, others and the environment***. Table 1 shows these skills together with associated sub-skills.

These skills and sub-skills cannot be developed in one course or through isolated academic activities. In order for these skills to be completely mastered by the student, these must be consistently developed and practiced throughout time. And this can only be achieved if engineering educators ***systematically integrate skills development into the engineering curriculum.***

Table 1. Engineering Skills and Sub-skills

Basic Skills	Sub-skills
Design/problem-solving	define a problem look for information/data evaluate information/data synthesize information/data define goals experiential learning develop alternate solutions evaluate alternatives implement solutions manage projects be a self-learner
Communication	conceptualize organize ideas communicate orally ideas, thoughts & information listen receive/attend to interpret/respond create documents use technology for communication implement ideas
Awareness of Self, Others & the Environment	**self:** ownership/empowerment self-esteem sociable self-management define values/principles **others:** interpersonal teamwork leadership negotiation work with diversity **environment:** historical context corporate/business awareness social/ethical/political responsibility human responsibility environmental responsibility

One Way to Integrate Skills into the Engineering Curriculum

There have been various approaches by which engineering educators have attempted to develop some of the abovementioned skills in students. Industrial partnerships, freshman design courses, capstone design courses, practice-based courses, coalitions of engineering schools engaged in multiple tasks focused on developing skills, and many more. But, we have yet to see ***the systematic development of skills throughout the engineering curriculum.***

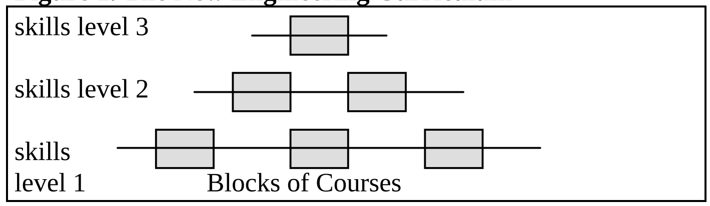
One way we, engineering educators, can approach this plight is to simply apply the engineering method of problem-solving (after all, are not we the ones that should be setting an example in its application?). That entails that we must: establish our goal (i.e., integrate skills into the curriculum), clearly define our situation (what we have), establish constraints (e.g., rules & regulations for curricular changes), design alternatives, evaluate them, and finally, choose the best alternative. Obviously, this scheme calls for the development of means of continuous process control and assessment, which will provide prompt feedback and necessary re-engineering.

There are many variables that control the educational process, namely, curricula and programs, faculty, academic processes, administrative processes, student activities, and so on. One can think of many ways in which each of these factors can be re-designed to achieve the desired outcome: the development of skills in engineering students. We will only address one: the curriculum. For the systematic development of skills into the engineering curriculum, we suggest the following steps:

1. Validate desired student outcomes (i.e., student profile). This can be performed through literature search and surveys among stockholders. Table 1 may help in this search.
2. Assess each course in the engineering program, and decide which skills and sub-skills can be developed in each. Skills can be broken into levels or phases, and one given course may develop more than one skill.
3. Identify successful and creative teaching and learning methodologies to develop identified skills, and provide faculty training.
4. Design strategies to assess student learning and development of these skills, in addition to measures of the program's success.

The new engineering program could look like a pyramid, as depicted in Figure 1:

Figure 1. The New Engineering Curriculum



This scheme calls for the re-design of the course syllabus, which should contain a list of both concepts and knowledge to be transmitted, as well as the skills and the level to be developed (introduced, mastered) in the course. Also, suggested course activities, teaching methods, appropriate assessment criteria and tools can be included.

The Manufacturing Engineering Education Partnership Experience

A recent NSF-funded partnership, the Manufacturing Engineering Education Partnership (MEEP) between Penn State University, University of Washington, University of Puerto Rico at Mayagüez and Sandia National Laboratories, used the suggested scheme for skills development for its course design. The major goal of this project is to design an undergraduate manufacturing engineering option for the three institutions, with a strong emphasis on hands-on, practice-based focus. Skills' development in these new courses is of utmost importance.

Table 2 shows the template developed and used at the three institutions. Courses are being developed as self-standing modules, containing the objectives, concepts and skills, activities and assessment modes to be utilized. In this manner, the instructor has all the necessary information to achieve the module's (and the course's) goals.

Table 2.

Module	Name	Objectives	Skills	Activities	Assesm't Modes

In course development , skills are selected from a list of competencies identified. Instructors designing the courses are developing adequate criteria and tools to assess student development and mastering of both concepts and skills, but they include multiple types, and internal as well as external elements.

Requirements

In order for systematic curricular changes of the kind we are proposing here, we must have commitments at various levels. The teaching of these hands-on, practice-based, skill-focused courses requires novel teaching methods, and non-traditional academic activities that truly and effectively develop skills in students. Thus, we need faculty training in teaching methodologies and assessment of student performance. We need to clearly define our student/engineer profile so that we target all our efforts into producing the type of individual we are seeking. And we need to be patient, for these changes entail a culture, and results from these efforts do not show in a short time.

Conclusion

We believe that if engineering curricula would balance knowledge with skills development across, provide students with novel, non-traditional learning experiences, and provide adequate criteria and assessment tools to continuously evaluate our success as educators, we would be serving society better. To be able to do so, we have to plan to systematically design engineering curricula, and be trained to understand and carry on these changes.

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