Redefining Engineering Education as Skill Training

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ABSTRACT

The year 2020 has forced many institutions to suddenly convert wholly to online education as necessitated by a global pandemic. Online education introduces a physical distance between the instructor and the students that creates many barriers to learning in traditional lecture-style teaching. However, the rapid shift to online learning has opened many minds to the value of online educational tools from both the instructor's and student's points of view. For engineering education, the value of online learning can be increased through the adoption of a new perspective that engineering is a skill.

Students who graduate from engineering programs are valued for 12 key skills: (1) problem-solving, (2) computer science, (3) industry skills, (4) pressure management, (5) teamwork, (6) creativity, (7) structural analysis, (8) communication, (9) attention to detail, (10) educational commitment, (11) data modeling, and (12) leadership. Possession of these skills has even led to many engineering graduates being recruited outside of the field of engineering due to the value they offer. With the true value of graduates being the skills they possess, it stands to reason that the curriculum of engineering programs should be designed for the development of these skills.

By adjusting the curriculum through the use of repeated attempts on assignments and quizzes, students can be prompted to increase their investment in courses and thus improve the skills they develop. Offering immediate feedback through the use of online tools can further improve skill development by highlighting shortfalls to students so they can adjust accordingly before engaging in their next attempt. Redefining engineering education as a skill development offers the opportunity to take advantage of the current online learning situation to create new learning environments that are more optimized for the production and development of skillful engineers that are highly valued in the workforce.

Keywords: online education, engineering curriculum, pandemic.

1   Introduction

The year 2020 has forced many institutions to suddenly convert wholly to online education as necessitated by a global pandemic. Online education introduces a physical distance between the instructor and the students that creates many barriers to learning in traditional lecture-style teaching. However, the rapid shift to online learning has opened many minds to the value of online educational tools from both the instructor's and student's points of view. For engineering education, the value of online learning can be increased through the adoption of a new perspective that engineering is a skill.

1.1   Principles of Skill Development

The literature on skill development can be divided into two main categories: (I) development of specific skills, and (II) methods of skill development. The first category mostly consists of books and workbooks that are devoted to the development of a particular skill using the methods of skill development from the second category. From the plentiful amount of literature devoted to the methods of skill development, there exist five common themes:

- (I)   Personal Investment
    - a. (Hollins, 2019a; Kaufman, 2013)
- (II)   Practice
    - a. (Ali, 2016; Coyle, 2009, 2012; Hollins, 2019a, 2019b; Kaufman, 2013; Marelisa, 2015; Wentz, 2012)
- (III)   Feedback
    - a. (Ali, 2016; Coyle, 2009; Hollins, 2019b; Kaufman, 2013; Wentz, 2012)
- (IV)   Realistic Expectations
    - a. (Coyle, 2012; Edwards, 1999; Hollins, 2018, 2019a; Kaufman, 2013; Marelisa, 2015)
- (V)   Supportive Environment
    - a. (Coyle, 2009; Hollins, 2019a).

(i)   Personal Investment

In order for new skills to develop, there must exist a base of motivation that drives individuals to overcome any barriers that may inhibit their progress. Most of the literature is devoted to finding useful skills that present career opportunities and seizing the vision of the potential of the future as the fuel that promotes personal growth. The key to "seeing it through to the end" is that the chosen skill must be personally meaningful.

(ii)   Practice

All of the literature on skill development prescribes repeated practice as the key to growing competency in new skills. One particular viewpoint from the literature (Kaufman, 2013) is that an investment of 20 hours can establish basic competency in a new skill and that the growth beyond that point takes more effort to hone the new skill. Another viewpoint (Gladwell, 2008) on the growth of skills over time suggests that it takes 10,000 hours of practice to master a skill.

(iii)   Feedback

Simply committing to practice is not enough to grow a new skill as the practice is only meaningful if it is accompanied by feedback. Feedback serves as the guide for practicing a skill where feedback can identify specific weaknesses that are targeted in the next practice session. One caveat to feedback is that negative results can demotivate individuals and thus result in the abandonment of the attempt to develop a new skill. To avoid this issue, feedback must be constructive, and personal investment must create a strong motivation to overcome any deficiencies.

(iv) **Realistic Expectations**

One main reason why individuals abandon their attempts to develop new skills is that their initial expectations are set too high. First of all, the literature (Kaufman, 2013) points toward a required investment of 20 hours, and thus individuals should not expect to be competent in a new skill before that time commitment is met. Secondly, mastering a skill is estimated to require 10,000 hours (Gladwell, 2008) or 20 hours a week for 10 years, thus expecting to master a skill quickly is entirely unreasonable. Setting unrealistic expectations will quickly demotivate individuals when those expectations are not met. Also, setting expectations based on the performance of others can create similar issues with demotivation. Individuals should base their goals on their personal performance history and periodically reevaluate those goals as they progress in the development of a new skill.

(v) **Supportive Environment**

In addition to personal investment, a supportive environment can motivate students to overcome obstacles. The main contribution of a supportive environment is to provide reassurance when doubt inevitably arises. That reassurance can simply be a reminder of the importance of the chosen skill and the reasons why the individual began their journey of skill development.

2   Methodology

Traditionally, engineering courses are designed as lecture-assignment-quiz-exam dissemination of knowledge. In this design, new knowledge is given through lecture instruction and assignments serve as the application of new knowledge. Quizzes and exams serve as the assessments of how well that knowledge is absorbed in a timed format that tests how individuals perform under pressure. There are three main issues with this approach: (I) time delay of feedback, (II) limited practice opportunities, and (III) assessment of compound skills.

The first issue is that when students complete an assignment, it must then be graded and returned to them which creates a multi-day feedback loop. If the feedback is received after the course has progressed to new material, then the students do not have time to review their work, and thus the impact of feedback is lost. One major idea from the literature is that practice is not meaningful without feedback, thus, even if students complete multiple similar questions, their practice will have a limited impact on the development of new skills.

The second issue focuses on the key idea that only one practice session occurs between feedback. Thus, each assignment counts as only one practice session because feedback is missing. Following a 15-week semester, if an assignment is given each week, then a traditionally taught course would only have 15 practice sessions. Such limited practice opportunities are not conducive to the development of new skills.

The third issue focuses on the fact that engineering is a conglomeration of skills, with quick and efficient problem-solving being the chief industry-valued skill. Quizzes and exams in engineering are designed to test an individual's ability to perform under pressure, which is a separate skill from the skills associated with the application of new knowledge. Thus, each quiz and exam serves as one practice session of a different skill, and the assessment is in

effect evaluating the synergy of multiple skills where individuals have inadequate amounts of practice.

3   Results

Countering the three major implementation issues through the inclusion of skill development principles from the literature takes careful thought and planning that begins with identifying the core skills that a course is supposed to develop in the students. Then, multiple practice opportunities must be built into the curriculum such that assessments identify competency in well-practiced skills.

The first principle of skill development, personal investment, is built into courses through students' investment in their grade point average. The second principle of skill development, practice, can be implemented by allowing multiple attempts on assignments where feedback is provided after each attempt. In addition, each attempt will need to be on a different set of questions to limit cheating and promote more growth in students. The issue with the implementation of this strategy is that the feasibility of prompt feedback and grading of multiple attempts would place a significantly larger burden on the professor. Online tools can be leveraged in this regard to not only reduce the instructional burden but also enhance the impact of feedback.

Blackboard is a learning management system that provides an online environment to facilitate course delivery. Blackboard offers the ability to "program" questions where the instructor can define variables within the questions and set ranges of values that are randomly generated. Thus, each attempt on an assignment will be the same questions with different sets of variables and thus different answers. The implications for the students are that they will be forced to develop their skills rather than simply search for the correct answer. Additionally, the use of the tools in Blackboard will enable instant feedback where students can immediately review their work after it is submitted. To prompt students to review their work, the personal investment of the students must be leveraged such that students can improve their grades with subsequent attempts. Also, students need a supportive environment, thus, they need to know that they can reach out to their instructor if they are not improving with more practice, which is indicative of confusion on course concepts that will need instructor intervention to overcome. The implementation of multiple attempts on quizzes is also necessary because quizzes assess a different set of skills that need to be practiced, namely pressure management and quick problem-solving.

4   Conclusion

Engineering graduates are valued for the skills that they possess; therefore, the engineering curriculum should be designed on the principles of skill development to maximize the value of the students. The major takeaway from skill development is that multiple opportunities for the practice of skills are required for growth. The review of the literature on skill development has generated the following set of recommendations for implementation in the engineering curriculum:

- Multiple attempts on assignments and quizzes allowed students to practice

- The use of online tools can enable instant feedback that improves the impact of each practice session
- If practice does not improve results, then instructors can engage students and offer support
- The establishment of realistic expectations of the skill development process can prevent students from disengaging

Implementation of the principles of skill development in the engineering curriculum has the potential to change the approach to engineering education in ways that establish better student growth. It also involves a shift in the mindset of instructors from focusing on the delivery of knowledge to the promotion of the development of skills in students. Concentrating on skills also creates the possibility to track student progression on common skills from course to course, thus enabling easier identification of when to engage students that are not keeping up with their peers. The benefits of skill development in the engineering curriculum are plentiful and thus heavily warrant the need for further study.

5   Declarations

5.1   Competing Interests

The author certifies that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

5.2   Publisher's Note

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