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An Alternative Perspective in Engineering Education: A Parallel to Disruptive Technology*

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This paper presents a parallel between the ever-present transformation in engineering education and the disruptive technology. The shared characteristics of these two—among which, on how they affect changes in its own area—provide an opportunity to draw lessons from the manner disruptive technology transforms businesses and to use them to shape a perspective in designing an engineering education that is relevant to the current era and adaptable to fulfil the current societal and human needs. Furthermore, an analysis into how the current trend of design-based education system has acted like a disruptive technology in engineering education is also presented.

Keywords: transformation; engineering education; disruptive technology; design-based education

1. From disruptive technology to disruptive engineering education

Disruptive technology is a termed coined to describe a phenomenon in the market and business world, where technological innovations, products, services, processes, or concepts disrupt the status quo [1]. Examples such as radio transistor and digital photography that have revolutionized each field of business have been frequently used to demonstrate how disruptive technology/innovation is able to obliterate the market of existing products.

The term disruptive technology is placed in contrast to sustaining technology/innovation, which, instead of creating new markets, evolves incrementally, improving on existing parameters such as better speed, larger space, cheaper price, etc. One can cite automobile innovation as an example of sustaining innovation, since it did not create a new market out of the horse-drawn carts market, but simply changing the horse-drawn carts with cars in an existing market.

Many studies have been conducted to identify how disruptive technology, such as the Internet, has not only transformed markets and businesses, but also education [2]. The rise in online learning, the increasing enrolment to online universities, the dissemination of online materials even by established universities, and so on, are viewed as powerful examples of the effect of the Internet in particular—and disruptive technology in general—on education. They have allowed—in some cases, led—changes in tertiary education institutions in such a manner that we today witness the use of wikis, blogs, and apps as tools of education; in spite of some questioning whether this is indeed necessary [3].

This paper, however, looks at the phenomenon of disruptive technology rather differently. Instead of focusing on disruptive technology and how it has influenced the education system, we look at how design-based education system—especially prevalent in engineering—has acted like a disruptive technology and transformed engineering education system nowadays. The various transformations of engineering education into a design-based or problem-based engineering education, as presented later in Section 3, vindicate that the view of education revolution is shared by various educational institutions.

To draw this parallel, let us introduce a parallel term to disruptive and sustaining technology, i.e. disruptive education system and sustaining education system. In this line of thought, we can think of the traditional education system as a sustaining system and the design-based education system as a disruptive one.

The transformation in the mindset of a sustaining engineering education system is occupied with issues such as improving teaching materials, improving infrastructure and laboratory equipment, or providing acceleration classes/paths to excellent students. The mindset of a disruptive engineering education, however, goes beyond such mere improvement; although such improvement is by no means easy and trivial. Disruptive engineering education is concerned with issues such as bringing industrial projects into the curriculum, which potentially revamps the entire structure of university's curriculum. Nevertheless, the development in

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the industry and in the society that indicates the needs of such transformation outweighs the seemingly costly effort of revamping the curriculum.

These developments propel a shift in the engineering education ever since. The engineering curricula have traditionally been based on an engineering science model, where a solid foundation of mathematics and science are taught first for about half of the curriculum, and then only followed by engineering in the remaining half of the curriculum. Many studies have pointed out that the resulting engineering graduates are perceived to be unable to practice in the industry due to the abrupt change of theoretical-to-practice in the curriculum [4]. The alternative education perspective is viewed as a way out to solve this issue.

In this regard, design-based education system occurs as a disruptive education in the midst of well-established educational institutions. It offers an alternative to the existing learning methodology that directly addresses the problem of the lack of engineering exposure to the students by directly exposing the students to the engineering aspects since their early years.

Design-based education system, however, may evolve to be a sustaining system when it is aimed and developed at becoming the engineering education system of the future, and then permanently staying at the forefront of engineering education. It may take a role of either a complementary or substituting system of engineering education. This may well be the drawback of relying on the design-based education system without adopting the perspective of change over time that design itself has always championed. It is another interesting angle of discussion with regard to the engineering education transformation.

In the sections to follow, we will look at the necessity to change in engineering education, with respect to design, and the various examples of education transformation that has occurred in various universities.

2. The necessity to change in education

The transformation of engineering education is aimed at students and is engineered to transform students—so much more than the faculty, the industry, or the society. Stressing this underlying motivation is important in the midst of irony that it is the faculty—to a great extent—rather than the students, who determine the curriculum and even the need to transform or change the curriculum.

The motivation and the characteristics of change of the students with respect to engineering education may be better understood through *perspective transformation* [5], which is developed mainly from the theory of psychoanalytic, emphasizing on affective learning.

In *perspective transformation*, patterns of experience, be they active or passive, in childhood or adulthood, form the *schemes of meaning* [6], within a three dimensions as follows: psychological (changes in understanding of the self), convictional (revision of belief systems), and behavioral (changes in lifestyle). They form the perspective of learners about the world around them. A transformation takes place when learners are confronted with a disruption in their patterns of experience—when they find that certain patterns that they have established as 'truth' change, and then engage themselves in a critical reflection and rational discourse to form a revised perspective about the world. The former process of experiencing disruption is the catalytic stage that compels learners to reassess the foundation of their knowledge. The latter process of engagement is the stage where true learning and transformation take place, and is therefore, arguably, take more time and contribute to lasting impact.

The former process of experiencing disruption, however, is not as simple as witnessing a change. So much more than experiencing a change, there has to be a process of recognizing the transformation, followed by gaining understanding and knowledge of the transformation that has happened.

The necessity to change is further propelled by the increasingly-integrating design skills and business skills [7]; merging engineering knowledge with business/social knowledge—when viewed from engineering perspective. Businesses have moved from creating dominance in scale-intensive industries to producing elegant and refined solutions. As businesses are seeking these qualities, educational institutions are under pressure to provide graduates with such qualities or risk being wiped by other institutions which are able to do so.

In this respect, there are two differing views. On the one hand, there is a view that business people need to be designers [7], while on the other hand, there is another view that engineers need to be designers [8]. Each view departs from different—perhaps opposing—launching points; the former view from the delivery end where business people consider creating a market for business endeavour, while the latter view from the supply end where engineers consider creating solutions from their engineering capability.

The notion of design thinking—a methodology that imbues the full spectrum of innovation activities with a human-centred design ethos [9]—has provided an avenue to integrate design into engineering; and, therefore, into engineering education as well. Design thinking champions innovation powered by a thorough understanding of what people want and need in their lives and what people like or dislike about the way particular products are made, packaged, and marketed; all these through direct observation. It demystifies innovation as a systematic process with a discipline that uses the designers' sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity [9]; and can therefore be taught as a subject. The integration of technology—and engineering, in general—into design appeals to the engineering faculty for its inclusion into the engineering curriculum.

In its own right, design thinking can be viewed as a disruptive way of thinking. It views design as about the process of making or doing something new, rather than an ability to create something new; an *action*, rather than an *attribute* [10]. Design thinking is certainly applicable not only to engineering, but also to graphics and architecture as well, for example. But in engineering, where subjects are taught 'more as science than as arts' compared to others, the notion that design involves standard *actionable* stages hits more chords. It still, however, requires the right attitude, which generally falls into three general traits of open-minded collaboration, courage, and conviction; on which arguments whether these are actionable and can be taught as a subject are debatable.

3. Disruptive engineering education around the world

Transformation of education is in many cases an initiative along the direction of national development. This can be seen in Singapore, for example, one among a few countries that have developed national design policies.

In line with the directive of Singapore's government that places design in an important position in its next phase of economic growth, the Faculty of Engineering of the National University of Singapore (NUS) has introduced its design-centric curriculum from 2009 [8] [11]. Its curriculum exposes the students to design from the first year of the four years of students' time in the university, allowing a comprehensive combination of engineering, lifestyle, and cultural values in students' design projects. This has been in line with a view of 'designing' engineers who have the ability to produce all-encompassing systems and solutions that work, as well as right—in look and feel—and sustainable—in terms of environment and business.

The extensive duration of the projects done by the students allows the students to not only develop a deeper appreciation of their engineering education, but also to be drawn by the challenge of formulating innovative designs. The duration of the projects is in contrast with the usually one-semester-to-one-year duration of students' project, highlighting the education transformation introduced by this program.

On the other side of the world, the University of British Columbia (UBC) has offered a new course, namely Technology and Development, from January 2009. This course enables students to identify a knowledge gap in the curriculum, develop the course to bridge the gap, and run a related student-directed-seminar with the supervision of a faculty member [12]. One may argue that this is a student-centric curriculum. The objective is to graduate engineers with broad perspective; termed global engineers by the Engineers without Borders (EWB).

Indeed, the theoretical framework of the course has been considered as 'disruptive ideas', as well as 'anti-foundational pedagogies', in relation to well-established curricula in many universities—including in UBC itself. The learning outcomes and experience of the students are examined in comparison to the accepted standards of engineering education, such as the Accreditation Board of Engineering and Technology (ABET) and Canadian Engineering Accreditation Board (CEAB), allowing it to be compared to 'sustaining ideas' of engineering courses.

In 2001, the Massachusetts Institute of Technology released a white paper outlining a philosophy that has now spread throughout the world: Conceive-Design-Implement-Operate (CDIO) [13]. The CDIO was motivated by two paradoxical needs of developing an increasing body of knowledge and building skills to enable students to produce real products and systems. The resulting CDIO curriculum is based on a paradigm of engineering problem solving, i.e. a curriculum centred on a problem.

Started from an institution, this endeavour has become an international effort to reform engineering education [14]. It is also interesting to note that the global initiative stemming from this effort is meant as an *open architecture* which would be freely available to any and all schools that offer undergraduate engineering education. This concept of *open architecture* resembles one in today's concept of business of technology; another parallel between education and disruptive technology. There are features of sustaining and incremental improvements—without belittling its effort—such as improving level of teaching and effective assessment methods. There are also, however, features of disruptive education system such as experiential learning that moves teaching from classrooms to laboratories and workshops.

The rapid change in the engineering education that has happened within the span of the last 10 years gets the momentum of education transformation rolling, and has been pursued and urged by many other institutions [15]. Among the several assumptions suggested about the existence of these continuing changes (and call for changes) [16], the 'common vision for needs to change what to be changed' suggest that the alternative perspective of transformation in engineering education has somewhat been comparable to the effect of disruptive technology in business; among which it triggers an on-going effect of change in the field of education, as well as creating a new field of design-engineering absorbed into the engineering education.

4. Conclusions

The engineering education has been transforming rapidly and has created new fields where engineering and design integrate into a synergistic field. In this regard, it transforms in the similar manner as disruptive technology/innovation revolutionizes a market by creating a new set of market and working field.

Whether this design-based engineering education will remain a disruptive system or eventually turns into another sustaining system is yet to be seen, as evolution of education system closely links to the evolution of technology and society in general.

Still, we can learn from the phenomenon of disruptive technology that has existed up to now and apply it to the engineering education.

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