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ICTs FOR NEW ENGINEERING EDUCATION

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WHY IMPROVE ENGINEERING EDUCATION?

In October 2010, UNESCO published a comprehensive report on engineering and development, which is the first of its kind by UNESCO. This report spells out the great importance of engineering for human society in addressing and solving global issues, such as poverty, safe and clean energy, climate change, clean drinking water, among many others. It is estimated in the report that some 2.5 million new engineers and technicians will be needed in sub-Saharan Africa alone if that region is to achieve the Millennium Development Goal of improved access to clean water and sanitation by 2015. In North America, and the European Union, there is also a great shortage of engineers for the next 5 years in the order of millions.

These labour shortage problems could be traced to the shortage of graduating engineering students and the quality gap between engineering education and the skill requirements of labour markets. The challenges to engineering education have two folds. First, engineering programmes must become more attractive to draw a sufficient number of students into completing the programmes. Second, engineering programmes must nurture practical skills that answer the timely needs in relevant labour markets.

ICTs FOR NEW ENGINEERING EDUCATION

ICTs has the potential to fundamentally revamp engineering education. ICTs are a series of instruments that transform the way human collectively produce and consume information on a global scale. While many teachers and students are already utilizing some of its capabilities, school and government agencies must design appropriate resource allocation policies to better capture these revolutionary opportunities. On the macro level, policy makers need to use ICTs to collect intelligence on the global scale for the strategic allocation of educational resources. On the micro level, students around the world can have egalitarian access to abundant, high quality educational content, thanks to the ubiquitous nature of Internet. The potential of ICTs in education is further elaborated as follows:

Data collection and analysis by means of using ICTs

On the policy-making level, decision-makers of educational resources must have a scientific method to study the dynamics of labour supply. The statistics on the amount of labour demand and the qualification level of engineering skills are needed to determine the timely expansion and re-direction of educational resources. Therefore, a rigorous data collection work targeted at the skill levels of engineering school graduates and the needs of employers must be conducted regionally or even globally. This work involves huge amounts of information survey and collection, so it can only be done by the support of modern ICT infrastructures. In the process of allocating educational resources, policy makers should be working with "up-to-date" data. Without these data points as references, education policy makers wouldn't know whether the educational programmes have attained their goals on a societal level. The data collection and analysis tasks must be conducted by agencies that have the technical sophistication to gather a large amount of labour market statistics. This means that policy makers of educational programmes must be find their own ICT-enabled data/ intelligence provider, or they should invest in a reliable agency to provide this service.

ICT-enabled Pedagogical Approaches

ICTs have already significantly altered the way content knowledge is disseminated. Beside popular video-lecture websites such as MIT Open Courseware and iTunes University, individuals have also become a major contributing source of lecture content. One of most used educational video repository is recorded by one person, Salman Khan, who single handedly created more than 2,000 video tutorials, covering from basic math, chemistry, physics, to financial engineering content. With a major grant from the Gates Foundation, Khan's website started to provide interactive exercises. It can track students' individual learning progression and provide statistical feedback to their instructors. It has attracted more than 1 million unique students per month, actively using the website to conduct self-paced learning. This globalized content pool could offer students many formats and styles of explanation that cannot be covered by traditional lecture-hall based teaching methods. Online, interactive content enables students to learn and to review content on their own pace. Students can repeat any portion of the lectures and exercises when needed. According to Dr. Sugata Mitra's experiments in rural India, ICTs could deliver content knowledge to locations that do not have enough qualified instructors. Pedagogically speaking, ICTs help to multiply the influence of high quality educational content on a global scale.

Learning Process Management

ICTs also enable a new way to manage student-driven learning processes. A concrete example of ICT-enabled process control is the use of web-based learning tools, such as web-logs, also known as blogs. Blogs enables students to record their learning activities in personalized online journals. Since these journals can be centrally stored on a web server, students can exchange their learning results via this web-based medium, eliminating the constraints of spatial distances and time delays. Students scattered around the world can easily share their learning results using subject-specific blogs. Blog entries also provide a series of precise temporal records that allow teachers to assess individual student's incremental progress. Blogs can serve as a content exchange platform to inform students and instructors of the latest development in certain subjects. Some micro-blogs, such as Twitter, have already become a research tool for scholars to keep each other informed. Most importantly, these tools provide a mechanism to elevate learning activities as sociable events on the Internet. Under the guidance of instructors who manages these blogs, students can develop collaborative spirits over these digital social networks to motivate collective learning.

Workspace Design and Technology Fusion

ICT-enabled workspaces could help reduce overall costs, because it may enable traditional workspaces to serve multiple functions, therefore, reduce the costs associated with operating, maintaining, renting or purchasing redundant real estate properties. Today, laptop computers are already capable of media playback, editing, and even high performance computing. When many traditional learning functions can be conducted on students' laptop computers, schools can then invest in infrastructures that complements students' personalized computing resources. The combination of open sourced engineering software packages, and cloud computing services, is enabling educators to create unprecedented educational opportunities. For instance, expensive engineering simulation packages, such as finite element simulation environments could be cost prohibitive for resource-constrained schools. Cloud computing and open sourced engineering software packages could offer massive computer simulation resources to any authorized users on the Internet, therefore offer learning and research opportunities to more people without any geographical constraints. The latest innovations in sensor/actuator technologies, coupled with the ubiquitous ICT infrastructures have already changed the way people talk and play with each others globally. To best harvest the these reality enhancement magics offered by ICT-related technologies, educational policy makers and designers of schools' workspace must be thinking about new formats of learning activities that can leverage these ICT-enabled opportunities.

Open Source and the freedom to learn

For educational institutions that are not financially abundant, the costs to adopt ICT-enabled educational tools might be cost prohibitive. To alleviate this digital divide, the founder of Free Software Foundation, Richard Stallman, created many ICT-enabling software products and distributed their source code on a free-of-charge basis to the entire world. Today, his spirit of freedom had extended to many hardware designs as well. Students and instructors can download these "free" software and hardware designs over the Internet, and then extend upon these engineering projects without incurring any financial burden. The creative freedom enabled by these sharable intellectual properties has become a major source of engineering educational content. Learning engineering skills in this ICT-based fashion, students not only would acquire up-to-date engineering knowledge, they will also learn to cooperate with each other and build new infrastructures with many people on the Internet. Once they master a part of the engineering design, they may become contributors to this shared intellectual property. ICT-enabled engineering culture may engage students in the engineering process of industrial strength products or services. Existing education programmes have already inevitably incorporated these open sourced tools. The future of engineering education should further embrace these ICT-enabled learning opportunities, and conduct engineering courses based on these open-sourced engineering building blocks.

POLICY STRATEGY[1]

To fully realize the potential of ICT-enabled engineering education, stakeholders of these educational policies need a coherent conceptual roadmap. The roadmap is composed of five layers, as illustrated in Figure 1:

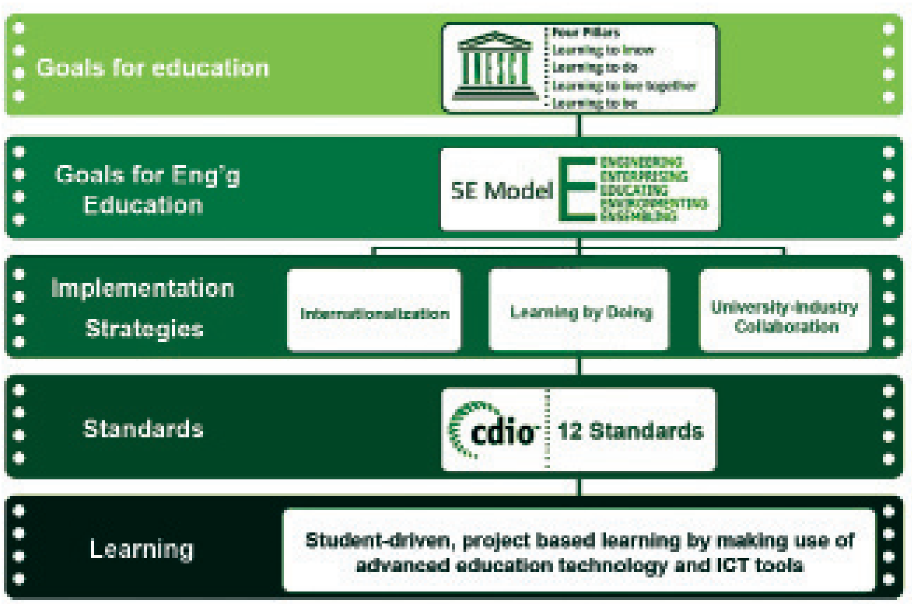

Figure 1. A five-layer paradigm of engineering education

The first layer: The Four Pillars of Education

The UNESCO's Four Pillars are addressed on the highest level, policy-making level, where ICTs should be used as a strategic instrument to enable transformations in negotiation, planning, resource allocation, and deployment of educational programmes. ICT-enabled solutions could collect hard evidence on talent supply issues, revealing to the designers of educational programmes about what and how to prepare students for "Learning to Know". For students, ICTs would enable them to learn more about the social and job-market statistics on a regular basis, therefore inform them about who are they "Learning to Be". Policy makers should also leverage ICT capabilities to provide frequent interactions with the general public, therefore approaching the ICT-enabled mode of "Learning to Live Together". When policy-makers and students started using ICTs to change their environments and professional outlooks, they are exemplifying the act of "Learning to Do".

[1] This policy strategy was suggested and tested by the UNESCO Chair at Beijing Jiaotong University.

The second layer: The 5-E Model for Engineering Education

To better integrate technologies with today's higher educational system, the Group T University College Leuven invented the 5-E Model. The five E's are: Engineering, Enterprising, Educating, Environmenting, and Ensembling. The "Engineering" in the 5E's, complements UNESCO Four Pillars, by directly including engineering education as a competency requirement for educated citizens. While most other "engineering education" approaches, primarily focus on how to disseminate specific engineering skills, the 5-E model identifies engineering education as an inalienable part of personal development. It states that modern education should equip students with an engineering mindset to survive in this technology infested world. In other words, engineering skills is an inseparable part of modern humanity studies. Without an adequate level of technology literacy, individuals' career growth is limited.

Based on the arguments above, modern, ICT-enabled engineering education programmes should invite experts in areas such as literature, history, law, business, arts, and other humanity studies, to participate in the formulation of engineering courses. People who are not entrenched in technical details are usually more likely to recognize and appreciate the magical powers of technologies. By involving non-technical collaborators as co-designers, ICT-enabled engineering education could become more attractive to its audiences. When non-engineering majors become more interested in the technology, they may also acquire a new level of technology literacy, therefore, further expand the pool of engineering minded people.

The third layer: The three strategies to reform engineering education

On the implementation level, three strategies are suggested to reform the engineering education, which are: University-industry Cooperation, Learning by Doing and Internationalization. The first strategy "University-Industry Cooperation" is to set up the necessary mechanisms to run engineering education with an industrial context. A broad platform to incorporate universities and enterprises for cultivating engineering talents and innovation should be established. For instance, schools adopted ICT-enabled tools, such as cloud-computing, up-to-date online course materials, and other modern technologies, at a clock-speed compatible with schools' surrounding industries. The second strategy "Learning by Doing", is an experiential pedagogical methodology, which requires tight integration of ICT-enabled learning activities to help students to master knowledge and skills in the process of "doing" engineering projects. The third strategy "internationalization" is to create a programme that shares global student resource and engineering education capability, through conference, exchange programmes, and ICT-enabled learning programmes. Especially with the help of ICT-enabled learning infrastructures, these programmes will be able to better foster engineering talents for worldwide human resource market, therefore, better address the talent shortage problems.

The fourth layer: A comprehensive set of quality assurance standards

To ensure the quality of educational services, quality assurance mechanisms must be made explicit. CDIO is the acronym of Conceive, Design, Implement and Operate, which represents the four developmental stages of engineering projects. CDIO model consists of 12 standards, which include: integrated curriculum design, qualifications of instructors, students' engineering competency, and a balanced syllabus that covers both theoretical content as well as practical engineering skills, adequate workspaces for team-based learning activities, among others. As of April 2011, more than 100 universities and colleges worldwide have joined the CDIO initiative. These standards provide a comprehensive set of "rubrics" to guide schools assess their own maturity levels. CDIO is useful and applicable to a wide range of engineering educational programmes, because it illustrates the functional and resource requirements of modern engineering education, without being dependent on any specific technology.

The fifth layer: Integrated Learning Activities and Resource Allocation

The fifth layer is the operational layer, which aims to move schools from conducting today's lecturer-centred instructions to operating student-centred learning activities. This transformation requires not only a significant shift in administrative approaches, but also requires many changes in school infrastructures. This model considers the entire society as an ICT-connected engineering system. Participants of different age groups and professional interests are invited to "play" functional roles in the design of ICT-enabled student-centred learning activities. They are also required to design "playful learning activities" and their supporting learning spaces. Initially, the majority of participants are engineering students. They are required to use a set of ICT-enabled collaboration tools to synchronize their evolving documents. They are required to publish their daily or weekly progress reports on public blogs with multimedia content to demonstrate their ICT literacy. Usually within weeks, participating engineering students would recognize the needs of collaborating with non-engineering students, such as artists and financial planners to participate in their learning activities, and together convinced their respective school administrations to remodel or redesign classrooms and study lounges. While the "Learning by Playing" experiment is an ongoing activity, one may already conclude that education programme designers must consider students as both the consumer and producer of ICT-enabled education technologies. There is no need to create rigid disciplinary boundaries between students. When participants learned to articulate the value and vision of their own projects, they will learn to use ICT-enabled infrastructures to organize people and attract talents to perform complex engineering tasks. As technical challenges arise, the project teams would use ICT-enabled tools to find skilful volunteers or guide the responsible participants to acquire applicable engineering skills.

CONCLUSION

Today's "digital native" students are the most effective source of innovation in the formats and content of ICT-enabled educational services and products. Therefore, engineering schools should be the operating base for the learning activities that systematically involve engineering students and other appropriate participants in the creation and refinement of ICT-enabled educational programmes and infrastructures. The design and implementation process of these "learning activities" should be guided by appropriate technology-independent quality standards. The implementation strategies should be supported by an international pool of talents, cognizant of local industry needs, and attain a balance between practical and theoretical exercises. On higher levels, the goals of general education as specified by UNESCO's four pillars must be held steady. At the same time, the goals of engineering education should not only be focused on training engineering specialists. Engineering educational programmes should be a source that supplies modern citizens' survival competency. This layered approach could drive a paradigm shift in engineering education. With the ubiquitous help of ICT-enabled infrastructures, a new engineering education paradigm should help cultivate talents around the world, so that we may collectively develop a comprehensive and sustainable solution to address the global engineering talent shortage problems.

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The severe shortage of qualified engineering work force is creating social and economical crisis on a global scale. Two of the observable factors are the shortage of engineering school enrolment and the quality gap between engineering education and society's needs on engineering talents. To address these issues, it is necessary to reform existing engineering and technology education. This document presents a five-layered model to set up a new, ICT-enabled vision for engineering education.

ICTs can play an important catalytic role in the improvement of engineering education on a global scale. When educators and policy makers employ ICTs as a strategic instrument to enable student-centred learning activities on an Internet-wide scale, it would be possible to implement an improved engineering education paradigm that addresses the global engineering talent shortage problem.

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