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EMERGING TRENDS IN TECHNOLOGY AND ENGINEERING EDUCATION

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Abstract- As new trends emerge in robotics, autonomous systems, quantum computing and other technological areas transforming our essential habits and the ways in which we learn, think and work, we need to consider changing our educational systems. As the competition among the global powers and the military industrial complexes of regional powers increases, new trends in engineering and technological education must be considered for effectively supporting national goals. Industry is ever more demanding of graduates' innovative problem solving skills, applied math skills, communication skills, employability and value. Innovations are not easy to achieve in engineering and technological projects. This study critically examines alternative trends in higher education and presents new proposals, practices and tools in order to meet industry demand in socio-economic and environmental contexts, ethical standards and stewardship of the future.

Keywords- Creative Achievement, Innovative Environment, Learning, Teaching.

I. INTRODUCTION

Through the power of new technology, age-old obstacles to human interaction and globalization, like geography, language and limited information, are falling and a new wave of connectivity, communication, creativity and potential is rising [1]. The new wave of technological innovations is having an impact on how we live and learn. "Arguably, everyone stands to gain from global innovation. More resources are now spent on innovation and related factors globally than at any other given point in human history" [2]. New technology based economies with technological and engineering tasks need a diversified work force with innovative problem solving skills. The old educational systems will not be able to deliver a diversified work force with innovative problem solving skills. In the old educational systems, millions of similar graduates were produced by standardized methods with major assessments performed using variants of standardized tests in order to serve the manufacturing industry with repetitive tasks. We live in a rapidly changing world, with a global job market, global educational competition, a globally integrated economy, conflicting educational values, increasing multicultural trends, burdening educational cost, rising security crisis, growing ethical and moral conflicts, widening income gaps and a macroeconomic volatility [3-5]. Some strategic actions are needed for development of innovative science and engineering education. Those who succeed in educational competition are likely to succeed in economic competition. Those who cannot compete with obsolete skills in the global job market due to poor education may not be able to contribute to their society even with good intention. Great nations are built by great problem solvers, and education is the most important system for developing and enhancing problem solving skills. As the nature of the problems changes, new approaches are needed for solving them and these new approaches should be perfected in educational institutions. Regrettably, many colleges and universities are not able to produce modern inventive problem solvers [3]. Some recent piecemeal changes show some minor progress. However, substantial improvements in critical thinking and innovative problem solving cannot be achieved without systematic planned changes. This is why wide ranging foundational augmentations have not been accomplished despite these isolated successful adjustments. In order to perform foundational changes, a new creative approach is needed which combines the development of talent diversity, agile teaching, appropriate technologies, and innovative problem solving in a new theoretical framework.

II. REVIEW OF TRADITIONAL APPROACHES

Several traditional educational theories and paradigms have helped us meet the job market requirements in the past. The workforce in the past two centuries was generally geared towards industry needs based on conformity rather than creativity and old paradigms were adequate to supply the industry with the needed workforce. Among the well-known educational paradigms were behaviorism, constructivism and cognitivist theory [3]. Theories from the available literature [6], on how learners learn, fall into one of several groups. Behaviorism of the 20th century by John B. Watson and B.F. Skinner is based on stimulus response [7], and suggests that behavior is caused by external stimuli, and not by the internal mental states or consciousness [7-9]. Learning was believed to be reinforced by praises or punishments as demonstrated by experiments. Skinner's experiments and explanations focused on

the idea of stimulus response and the role of reinforcement [8, 9] in the learning theory. He suggested that a human action is the result of the consequences of the same action in the past. If the consequences were positive the action that led to it is likely repeated; if the consequences are negative, the action is not likely repeated. Behaviorism submits that a learner learns by responding to environmental stimuli [10].

The behaviorism concept was meritoriously replaced by the cognitivist paradigm that Noam Chomsky founded in 1960s [11]. In cognitivist paradigm, the learners are viewed as information processors who are rational beings whose actions are a result of thinking. They are not programmed to merely respond to external stimuli. Noam Chomsky and his followers critically examined behaviorism and a cognitivist theory of learning as a viable alternative to behaviorism was developed [12]. According to this paradigm, learning is a complex cognitive process where the learner, as an information processor, can learn without external stimuli. One may become interested in learning something new based on questions generated by the learner from his reasoning with existing knowledge.

Another paradigm, the constructivism paradigm, proposed by John Dewey, Jean Piaget, Jerome Bruner, Lev Vygotsky and others [13], is where learners are viewed as information constructors who continuously form their own representations of reality. Here the new information is connected to and understood based on prior knowledge. According to constructivism, every learner constructs one's own specific ideas and views based on one's own past experiences, interactions and other learning activities. This generates one's personalized knowledge and meaning. Constructivist theories have been very influential throughout much of the non-formal learning sector [14].

Attention is also often given to the humanism paradigm founded by Abraham Maslow, Carl Rogers and others. This is based on the idea that learning is a personal act to fulfill one's potential. It is student centered and personal, facilitated by teachers, with the goal of developing self-actualized people in a cooperative and supportive environment [10, 14,15].

Barrows (1985) is credited for suggesting the classic model of Problem Based Learning (PBL). This has two key features: "a rich problem is used that affords free inquiry by students, and learning is student-centered" [17]. PBL is the educational process by which problem solving activities and the guidance from an instructor facilitate learning. PBL teaches students "to learn how to learn". It challenges students to think critically, analyze problems, be pro-active, and discover and use pertinent learning resources [18-20].

Readers who review the above theories often come to the conclusion that a new paradigm is needed that focusses on critical thinking and problem solving. New improving technologies are able to provide new flexible learning environments. It is generally realized that further progress cannot be made without emphasizing the power of learner's reflection and critical thinking enabled in a flexible collaborative way using technologies rather than just by face-to-face classroom learning environment. The classroom-based education restricted by time, space, and cost has made it difficult, if not impossible, for over a billion people worldwide from having access to quality education [21-22]. The internet and other technologies are helping us deliver materials and information by alternative methods for online education, and this is changing the concepts of time-space-cost oriented education. These benefits hold great potential and new opportunities for online education that can create a more universal approach to teaching and learning. The one-size-fits-all teaching model, where all students are expected to learn the same way, is no longer necessary. Sir Ken Robinson, in his TED talk "Bring on the Learning Revolution", suggested that a major transformation is required in the way we teach [23]. We have the opportunity and the technology, and now the challenge is to implement this transformation [10].

Our research in this paper focusses on specific aspects of new trends, namely, developing innovative thinking skills and problem solving in new environments. With new technological resources, education has no time constraint and the learner has the opportunity to reflect and think critically to understand the concepts at his/her own pace. Furthermore, group discussions promote reflective and critical thinking and the available online technology gives us the elements that enable creating geographically dispersed groups. This learner reflection and the skill necessary to think critically need to be encouraged and promoted by educators, content providers and facilitators, thus enabling and encouraging learners to take responsibility of their own learning.

III. EMERGING TRENDS

Chris Dede, a renowned educationist, suggests that "The 21st century is quite different from the 20th in regard to the skills people now need for work, citizenship, and self-actualization. Proficiency in the 21st century differs primarily due to the emergence of very sophisticated information and communication technologies (ICTs)." [24]. Similar suggestions about new skills are also found in writings of other experts [25-26]. Are new technologies transforming our basic habits, and the ways in which we think, learn, teach, experience, and remember? These emerging new technologies may lead us to a new approach to education that allows us to develop diversified, creative, innovative problem solving workers.

"Innovative thinking is considered a critical element in today's economy." [27]. Minor educational

reforms may not deliver innovative thinking skills. "Critical problems of inequity and polarization have now far outpaced the efforts of education systems to reform themselves. These realities call for systemic changes in the approaches to education and a readiness to accept new paradigms to guide educational policies and practice." [28]. Through the power of innovative emerging technologies a new wave of connectivity, communication, creativity and potential is rising [1]. These have opened up opportunities to develop the potential of the individual learners, so that they can concentrate on their interest and develop it to the fullest extent. The use of computers in engineering education has introduced a highly self-directed form of learning in engineering, thus creating self-learners. Today computers are extensively used for simulation of highly complex concepts and systems in engineering and they are becoming a vital component of tools used in this new paradigms in engineering education.

The flipped-classroom approach of the Khan Academy delivery method, developed by Salman Khan, shows enormous potential for an effective alternative to old education paradigms. It has drawn considerable attention among learners, teachers, investors, and philosophers [29]. This new approach in teaching is a pedagogical model in which a standard class lecture, consisting of a "talk" to the student body by the instructor, is replaced by short video lectures, available in online libraries, viewed by students remotely outside the class session. This focuses in-class time to group problem solving, presentation of projects and interactive discussions of topics among students. The video lectures are the key ingredient in the new flipped approach and, with emerging computer technologies, such lectures can be created, and the most complex concepts in engineering can be clearly explained by animation, emulation, and simulation, and viewed repeatedly as needed by students both before and after the lecture. Or, in an online modality, they replace the lecture. With emerging and powerful mobile technologies, the class educational resources and videos can be easily accessed by students at times and places that were not possible in the past. According to Inside Higher Ed, a recent study by the Campus Computing Project showed that "more than two-thirds of U.S. colleges and universities are already, or willing to start, using lecture-capturing software to make lectures available to students at home - the gateway to a large-scale flipocracy. Proponents argue that flipping courses inspires students, gives them more control over their own learning, and frees more class time for meaningful interaction . . ." [30].

The flipped classroom shifts the role of an instructor from delivering lectures to engaging students in problem solving and experiential, hands-on exercises during the class-time. The emerging new paradigm of flipped classroom moves the responsibility for learning to the students, thus creating self-learners, and gives them encouragement, time to absorb the content, and opportunity while building self-confidence, for experiments and problem solving. However, the flipped classroom model introduces students to an environment of reduced face-to-face lectures. This will have particular impact upon students who learn best from personal lectures presented in person by instructors [3]. The flipped approach can be delivered in an accelerated format with fully flipped or partially flipped classes [31].

Another pedagogic method, in which the name is similar to the medical term 'Minimally Invasive Surgery', Mitra introduced the pedagogic method Minimally Invasive Education (MIE) [32-34]. This was based on observations and educational research carried on at NIIT, India. It was concluded that a groups of children, left on their own, were capable of learning the use of well-designed computers with minimal instructions [35-36].

Sir Ken Robinson's philosophy of development of diversity of talents for creative problem solving in new learning environments introduces a paradigm shift in education [23,37]. He suggests that one needs to find his/her element, and nurture and develop it through education [37]. Sometimes very creative people, such as Steve Jobs, drop out of traditional colleges because they find it difficult to nurture their primary interest in an innovative way. Those who stay in college under these circumstances endure it and do their best to survive. In Steve Job's words ". . . it was one of the best decisions I ever made. The minute I dropped out I could stop taking the required classes that didn't interest me, and begin dropping in on the ones that looked interesting." [39]. A major part of Robinson's philosophy explains how the traditional educational system is structured in an outdated learning environment of "one size fits all", without paying needed attention to interests of the learners. The system enforces strict rules on learners based on obsolete pedagogical traditions of conformity. Although this issue has been raised in the past by researchers and theorists, Robinson clarifies it more forcefully.

According to Robinson, the primary motivation behind the traditional practice is to supply the industry with mass production of workers in some arbitrary categories, packing them up like bars of soap, without recognizing their individual talents [39]. Robinson, in his writings and videos, explains different and individual ways people learn. The central problem being that the "traditional teaching methods largely ignore the multidimensionality of experience, of the subject, of phenomena and of knowledge itself. As Robinson concludes, the result is often how only a small portion of students find themselves in a position where the information that is rigidly handed down to them can be grasped, and in a way where they manage to work through the restrictive and highly ideological confines of that information" [39]. Robinson and his followers

suggest that rather than sponsoring and encouraging the exploration of phenomena in open and divergent ways, the current methods subject students to rigid and 'one size fits all" forms of education. Many of the old paradigms promote an authoritarian and controlling theory of education over an organic theory of divergent and free-flourishing education [39]. Therefore while the traditional paradigms are driven toward conformity and standardization, Robinson suggests that we need to go the other way. Robinson is working out the details of identifying one's element or talent and then organically developing it. He states that "Finding your element is a personal quest" [39]. The main advice from Steve Jobs to students reaffirms the same theme. Steve Jobs would also agree with Robinson's (2013) principle #2: "You create your own life" [38]. In addition to the major trends mentioned above, there are several other minor trends that can be found in the literature [40-48].

IV. EDUCATIONAL RESOURCES

With the advancement of high speed internet and other related technologies, now more online educational resources are available than ever. Currently, many reputed universities worldwide are focusing on ways to increase access to quality education for anyone, anytime from anywhere. In this way, teaching and learning are being enhanced. These open educational resources help to prepare better citizens to create a peaceful and enjoyable environment to enjoy quality life. However, a given course content may or may not be appropriate for an educational program you are considering. Before making a firm decision, one needs to carefully review the course materials in order to ensure that the program learning outcomes properly serve the courseware. Most graduate computer science programs need to deal with computer security issues. A graduate course on "Computer System Security" available from the MIT Open Courseware is an exemplary course with a structured reading-list, syllabus and other course components that will serve most computer science programs [49-50]. There are a number of other sources for free online courses provided by universities and/or organizations:

Harvard: Open Learning at Harvard: https://www.extension.harvard.edu/open-learning-initiative
MOOCs: List of MOOCs offered by the Best Universities and Entities: https://www.mooc-list.com/
MIT: MITOpenCourseWare: https://ocw.mit.edu/index.htm
Open Culture: 1200 Free Online Courses from Top Universities
http://www.openculture.com/freeonlinecourses
Coursera: Courses online for anyone to take, for free: https://www.class-central.com/provider/coursera
edX: Best Courses. Top Institutions. Learn anytime, anywhere: https://www.edx.org/
FutureLearn: FutureLearn is a private company wholly owned by The Open University: https://www.class-central.com/provider/futurelearn
Canvas Network: Canvas Network Canvas Network offers open, online courses
: https://www.class-central.com/provider/canvas
Class Central: List of 39 Providers offering free online courses: https://www.class-central.com/providers
CSU: California State University Free Online Courses:
http://als.csuprojects.org/free_online_courses

At National University, many professors selectively use these free open resources as references for their online and onsite classes when there is a good match between the Course Learning Outcomes and the course materials.

An important emerging need is a course on Quantum Computing which may introduce the subject in various ways to our students. This field cannot be ignored anymore. Quantum Computing (qcomputing) uses quantum particles which are very tiny (size in nano meter or smaller scale) and they behave quantumly. Some of these particles include electrons, protons, neutrons, ions, photons, positrons, etc. Current computer architecture uses eight bits (either 0 or 1) to create a byte and several bytes to create a long string (4, 8, 16, 32, etc.) processor. In contrast, a quantum computer uses quantum bits (qubits) encode zero and one distinct quantum states and superposition and entanglement. Quantum Superposition provides multiple states at the same time like 0 and 1 (+1/2 and -1/2 or up and down) at the same time [51].

Quantum particles behave the entanglement which is a strong correlation that exists between two quantum particles (strongly linked together even if they are separated by a large distance). The entangled quantum particles intrinsically connect so that they can communicate with each other instantaneously. Einstein described entanglement as "spooky action at a distance." These superposition and entanglement provide extra computing ability to process vast number of calculations simultaneously. It is expected that quantum computer (qcomputer) would be used for superfast and secured computing and communication purposes. In the recent Prism Magazine [51] published by American Society for Engineering Education reported some success stories of qucomputing methods: tapped ions in vacuumed magnetic field (spin-off ionQ) by University of Maryland, silicon chip based photonic quantum computer by University of Bristol and superconducting cross-shaped circuit qubit made of aluminum film deposited on sapphire [51]. Recently, Microsoft Corp Research facility at the Delft University of Technology in Dutch found an

innovative way to build commercial qcomputer with qubit using the fundamental particle known as Majorana fermions, which is an elusive subatomic particle associated with its own antiparticle [52]. Scientists at Microsoft claimed that they have clear evidence how to create of this Majorana fermion and its antiparticle in a tiny wire composed of both semiconducting and superconducting materials. In another report, a research team at Oak Ridge National Laboratory claimed that they were able to split light beams into their frequency modes and encoded photons with quantum information [53]. This research team is currently engaged in examining the compatibility of these encoded photons with the existing telecommunications infrastructure and other off-the-shelf components. If encoding phenomena of photons are compatible to function with the existing telecommunications infrastructure then scientists believe which could spur the advancements in quantum computing technology. Currently, there are many other major industries: Google, IBM, Intel, etc. are conducting aggressive research to utilize the qcomputing concepts to build commercial qcomputers for future use [54, 55].

These three technologies have their own merits and demerits. Scientist and engineers are debating and conducting more research and developing prototypes for validations. The researchers are now focusing on investing different methods to develop quantum technologies. Now universities need to provide new curriculum to produce not only quantum physicists, but quantum engineers, quantum programmers, quantum technologists, etc. It is expected that in the future quantum network, quantum internet, quantum hardware and software would be developed and applied in almost all areas including, manufacturing, communications, medicine, cybersecurity, etc.

CONCLUSIONS

Very promising educational trends are emerging, no doubt. Debates and discussions about teaching-learning of innovative thinking skills should continue in order to examine the best emerging methods and practices with their social ramifications. Social and technological changes provide challenges and opportunities which need to be reviewed without bias or prejudices. In order to take advantage of collective learning in rapidly changing technologies, discussions may be encouraged in the context of current and future opportunities and challenges in engineering and science education including the global competition for new technologies, rising cost of higher education, limited access to higher education, the increasingly interdisciplinary nature of the profession, the continued underrepresentation of women and minorities, and a steady decline of ethical and moral values. In the meantime, the authors continue to monitor and continue to explore the developments of new emerging trends and participate in the educational activities in their respective educational institutions. Hopefully discussions, debates, and exchanging ideas will eventually clarify issues through dialogs and serious monologs and promote global citizenship. Humans are generally hungry for knowledge, peace and prosperity. As we try to understand the nature of changes that are taking place now we adjust our teaching-learning strategies for the benefit of global society and development of stewardship of the future.

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