https://doi.org/10.7165/wtr17a0515.16

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Understanding Current Issues in Research and Education in Science and Technology: A Framework of Knowledge and Action Sharing between Universities and Science and Technology Parks

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Abstract

Humanity is experiencing a very fast-paced technological evolution. As technological systems evolve exponentially, societies are becoming more global and are starting to have impacts beyond their geographic demarcations. This implies that, the actions of a person who is across the ocean from where we live could have significant impacts on our everyday lives. This article explores the complexity of globalization, identifies a number of global issues, and looks at the University and the Science and Technology Parks as potential sources of human capital to tackle current and forthcoming global challenges, ranging from new energy sources to potable water distributions. The article focuses on current efforts that are taking place across universities and science and technology parks around the world. We propose a new methodology whereby interdisciplinary work can inform the development of multidisciplinary approaches to solve some of the most complex global issues such as cyber security and educating the next generations of global leaders, providing them them with the necessary skills to be successful in a globally distributed workforce.

Keywords

Interdisciplinary, Multidisciplinary, Globalism, Cross-sectoral, Collaborations, Academia, Industry, Government, Science and technology parks, National labs, Grand challenges

INTRODUCTION

In today's world, there is considerable consensus about the importance of cross-sectoral (academia, industry, government, science and technology parks, private foundations, NGOs, etc.) collaboration to push the advancement of innovation and entrepreneurship within local, national and global contexts. This article is grounded on the university-science/technology parks component of these collaborations. Particular dimensions of this collaboration are examined within the context of critical global issues in research and education in science and technology. We highlight current knowledge about where we stand and what resources are needed to get to where we want to be globally. After exposing some of the grand challenges the world faces, we propose new directions for knowledge-action sharing for the future.

Critical and broad contemporary issues in research and education in science and technology abound. In this article, the

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World Technopolis Review
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authors identify and explore six major issues, which could be explored individually as each issue presents its very own challenges. Issue 1: Framing current research/education issues in terms of efforts to address grand challenges (e.g., in the U.S., the National Academy of Engineering proposed fourteen grand challenges and we present five of these). Issue 2: Strengthening and expanding both interdisciplinary and multidisciplinary work (among science, technology, engineering and mathematics (STEM), and across disciplines in STEM, the arts, and the humanities. Issue 3: Establishing conceptual frameworks and models for and implementing holistic approaches (e.g., holistic engineering). Issue 4: Enhancing public understanding of, and engagement with, STEM (as it relates to fundamental knowledge and controversial issues). Issue 5: Developing models to enhance innovation and entrepreneurship (especially, in the context of social good). Issue 6: Developing and implementing better approaches for science and technology management and policy.

As a context for what is to follow, the authors start by taking a brief look at how the roles of universities have evolved over their long history, as well as how science and technology parks (National Laboratories/Science Incubators, among other) have changed over their very short history. That context will help us to better understand some of the current knowledge and action sharing between universities and science and technology parks. Also, the context will help us to explore ways in which knowledge and action sharing might evolve over the next decade or so.

THE NEED FOR A UNIVERSITY EDUCATION: KNOWLEDGE BEYOND THE CLASSROOM

There is a plethora of reasons why one should attend a university. Professor of Psychology at University College London and Norwegian Business School, Adrian Furnham, states a number of reasons than range from the traditional: "To get a qualification that improves job prospects and the opportunity for a bigger salary. To build self-confidence, independence and responsibility", less visible or even cynical Reasons: "Establish a useful, network of professional friends: doctors, dentists, lawyers. Make your parents happy and proud because they never went to university", to good but hard to quantify reasons: "You find out what you are really good at. You can experiment, and find out where your talents lie. To guide and foster an interest/ passion for its own sake". (Furnham, 2014). The aforementioned reasons are by no means exhaustive and intend to provide the reader with a concise idea of why people decide to attend universities. We can agree, however, that while different, each one of the views presented by Furnham has a common threat, implicit or explicitly, change. It seems that the common thread which binds the various reasons why we might decide to attend university is that we want to become a different person. In short, people attend universities to make an investment, with the hope of having returns. It turns out that with an increasingly expanding global and digital economy, traditional models of human capital investment are facing the need to upgrade or accommodate to be able to better serve the needs to those seeking human capital. Here, we are not only limiting ourselves to students, but we think of universities, towns, cities, states, and countries. By way of illustration, the rapid dissemination and acquisition of data has had tremendous impacts on the pace at which universities can respond to science, engineering, and technological innovations. Furthermore, the incubation of businesses, as well as the rapid evolution of the high-tech sector, as evidenced by the growing number of start-ups; for instance, as of September of 2015, the United States had 27 million entrepreneurs, and 24 percent of these entrepreneurs expect to employ at least 20 people within five years (Buchanan, 2015). Back to the importance of a university education, data show that the educational backgrounds of new entrepreneurs in the United States are highly diverse. However, in a span of about 18 years, the share of entrepreneurs who were college graduates increased by 39%, increasing from 23.7 to 33 percent (Kauffman Foundation, 2015). Given this new acceleration of the creation of ideas across different sectors of society, universities are faced with the challenge of developing new methodologies that can quickly and efficiently bring ideas into the market without losing quality. Evidence thus suggest that to meet such rapid needs, it is imperative for universities to collaborate with science parks, which are the hosts of super-computers, energy accelerators, and state-of-the -art machines that are just too expensive for many universities. Universities can provide the knowhow foundation of the basic sciences, as well as physical spaces for entrepreneurs to start their projects, and for the community to become more engaged in solving the grand challenges ahead of us. The solution to these challenges could come about by the synthesis of advanced innovative technologies that are shared among universities and science parks.

https://doi.org/10.7165/wtr17a0515.16

I. RESEARCH AND EDUCATION AS GRAND CHALLENGES

The advent of the information age brought with it allowed for the creation of many global advances. Some of these advances come with both intended and unintended consequences. An important consequence has been that information can now be gathered at speeds that were unthinkable say, in the early 2000s. Consequently, we now have a plethora of information that calls for highly skilled teams to come together to understand the various aspects of such data; in other words, interdisciplinary[1] work becomes more relevant. Similarly, we now have at our disposal a breadth and depth of information and tools that naturally allow us to look at certain problems with an inspiration to find solutions to them; hence, multidisciplinary[2] work has been provided an organic niche. In current conceptualizations for research and education in science and technology, integrating aspects of both basic and applied knowledge, knowing and doing have become intertwined. Often, this purpose-driven approach is directed towards tackling some of the big problems of regions, nations, and the world. For example, gathering international input, the United States' National Academy of Engineering came up with fourteen challenges for engineering in the 21st Century. We present five of these challenges below:

a. Advance Personalized Learning:

It is now undeniable that, as individuals are able to acquire information almost continuously via mobile phones and computers, their capacity to appreciate their individual preferences, based on self-informed assessments has increased. This has led to an attitude of "personalized learning." Engineering has a big role to play in the development of these personalized learning environments which aim to suit each individual's needs. For instance, emerging research in neuroscience has shown promising results in advancing our understanding of the human brain. Nonetheless, given the complexity of the human brain, this emerging research in neuroscience poses a challenge for software engineers who are the ones in charge of developing the firmware that allows different pieces of hardware, including the human body, to communicate with their drivers—opening up new avenues for exploring the brain.

b. Make Solar Energy More Efficient and Affordable

There is consensus now that the sun is the strongest and most powerful energy source we have. Nonetheless, outside its natural state, solar energy accounts for less than one percent of the shares in the energy market. A multidisciplinary approach to this problem, however, has led to promising results. Currently, the conversion rate of solar into usable energy oscillates between ten and twenty percent, which makes it very difficult to market. But beyond that, we also face the problem of energy storage. However, engineers and scientists are making groundbreaking progress in the area of material science and engineering where nanocrystals made from lead and selenium show positive prospects of energy conversion. Fuel cells are a promising area of research for energy storage.

c. Create Global Access to Clean Water

Access to potable water and basic sanitation is indeed an acute challenge worldwide, as it is estimated that roughly 5,000 children die from diseases related to diarrhea. The water problem is one of both availability and accessibility. Most of the great sources of fresh water are located near one another and most of the places that lack water are far removed from those places with great water sources. Engineers have for many years worked on this problem. In some sea-shore and wealthy countries, desalination is a technology that has been used to provide fresh water. Recent advances in nanotechnology seems promising as they address both water treatment and usage. Until we are able to come up with feasible and accessible ways of producing and treating used water, the development of new technologies that help us maximize water uses, particularly in agriculture, can provide the path to sustainability in water usage.

d. Secure Cyberspace

As the spread and storage of information increases exponentially, and our lives depend more and more on digital systems, cyberspace has become an embedded part of humanity, and its impacts on us are as real as the impacts that any physical space may exert upon us. While there are many promising innovations such as fingerprinting and eye scanning systems, a primary challenge remains in the area of data transference.

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[1] "Relating to more than one branch of knowledge." https://en.oxforddictionaries.com/definition/interdisciplinary

[2] "Combining or involving several academic disciplines or professional specializations in an approach to a topic or problem." https://en.oxforddictionaries.com/definition/multidisciplinary

Holistic engineering could play an important role in this area, as there is consensus that safeguarding cyberspace depends on understand the system holistically and not by its parts. While this is subtle, a driving force within the whole of the system is the individual and collective psychologies of end-users.

e. Re-Engineer the Tools of Scientific Discovery

As has been the case throughout history, engineers have played, and keep playing a pivotal role in bringing ideas into the market. For instance, large as well as small scale microscopes have played pivotal role in the areas of astrophysics and biology, respectively. The design and creation of energy efficient or alternative energy vehicles in an area in which engineering expertise is at the forefront. Since the primary job of engineers is to design, create, and build the knowledge acquired via fundamental research, it becomes apparent that the challenges identified by the United States' Academy of Engineers will rely heavily on engineering expertise (National Academy of Engineering, 2016).

These challenges are all multidimensional and largely global. Then, we propose that, to solve these challenges, we ought to start looking at interdisciplinary methodologies that can inform multidisciplinary approached centered on engineering sciences and informed by the intricacy of the arts, the humanities, and the social sciences. Once we create methodologies that feed from all pertinent areas of knowledge, we may start to develop efficient and sustainable solutions to these challenges. For instance, the development of more efficient solar energy storage devices could be the key to making solar power the leading force in the energy market, reassuring its sustainability and affordability. Nevertheless, the engineering alone while could be efficient, or sustainable, may not be both. Often times, when we look at a multidimensional problem, a unidimensional approach is not sufficient to ensuring efficiency, sustainability, or both. Similarly, the issue of clean water has deep social impacts as history shows that a primary water problem is equitable distribution of water resources within many countries, where the wealthier may have an abundance of access, but the poorer do not. Engineering that ensure equitable water transportation, distribution, and utilization could leverage the issue of social power within countries where access to clean water comes with a high price. Equitable transportation depends on many factors such as accessible roads and proper transportation. Proper transportation depends on the terrain where the vehicles will be deployed as well as on well-trained drivers and access to energy. Highly important, road construction has deep impacts on peoples' social and cultural lives. Land ownership becomes family, neighborhood and often city tradition; hence, land often plays an important role on people's way of live.

Unlike most other centuries in the history of humanity, where each new century builds heavily on the scientific, technological and engineering innovations of the prior one, the privacy, personal and global security of the 21st century rely heavily on systems that had not been thought of until the turn of the 20th century, and were even unthinkable ten years ago. If we could use a holistic engineering approach, and look at cybersecurity globally, engineers would be better informed in regards to how and why they will develop and deploy certain cybersecurity protocols. It becomes apparent, nonetheless, that while engineering maybe the primary discipline behind this development, disciplines such as social and behavioral psychology, sociology, history, cultural studies, to name but dome, will be required to tackle and solve these grand challenges. Clearly, universities, science and technology parks, industries, and governments will play major roles in addressing these grand challenges. Universities, because of their relative stability, will help to support knowledge development and documentation across broad fields of science, technology, the human and social sciences. Science and Technology Parks, with their cutting-edge technologies, will be the test-beds for emerging technologies. Universities, together with science and technology parks, will design the purpose-driven strategies necessary to advance the development and deployment of new technologies.

II. STRENGTHENING OF INTERDISCIPLINARITY AND MULTIDISCIPLINARITY

Universities and science and technology parks must produce people who are experts in leaning on, and working in, highly interdisciplinary environments to do fundamental research that can lead to the solutions of grand challenges. We can learn a lot on how to develop, sustain and expand such interdisciplinary frameworks of thought from the humanities and social sciences, where such efforts have been in place for a number of decades now. Various areas of STEM, where multidisciplinary work is common place, could enhanced such approaches by leaning on interdisciplinary expertise to better understand the philosophical and tacit aspects of these grand

https://doi.org/10.7165/wtr17a0515.16

challenges. We are then talking about new ventures, where the highly philosophical aspect of the humanities and social sciences can help various areas of STEM to better understand the values and ways in which a multidisciplinary framework can guide the multidisciplinary approaches that aim to create sustainable solutions to these grand challenges. From an education point of view, case-studies on engineering-enhanced liberal arts, presented by the American Society for Engineering Education (ASEE), exemplify the kinds of STEM-Arts-Humanities mix that may be necessary to achieve stronger and more organic interdisciplinary and multidisciplinary environments. The philosophy is that engineering students should become better acquainted with general knowledge that was not traditionally part of the engineering curricula. Similarly, students who are not in engineering, or closely related disciplines, should develop a sound understanding of engineering design (American Society for Engineering Education , 2016)[3].

In addition to viewing engineering as a part of liberal arts education, it is important to acquire the deep philosophical and qualitative approaches of the liberal arts as a part of engineering education. It is our position that liberal arts-enhanced engineering curricula should be focused on providing engineering students a "deep-learning" of the liberal arts and its methodologies. Similarly, this rule should apply to an engineering-enhanced liberal arts curricula. Princeton University's CEE 102- Engineering in the Modern World course provides a well thought framework for the latter approach: "Three perspectives are used to view engineering: scientific (natural sciences), social (social sciences), and symbolic (humanities). At the same time, engineering is defined through its own categories: structures (civil engineering), machines (mechanical engineering), networks (electrical engineering) and processes (chemical engineering) (Princeton University, 2016)." The former approach is better exemplified by Ronald L. Sandler's (2001) article "Value-sensitive design and nanotechnology" illustrates how values that are more traditionally associated with the humanities and cultural studies are organically embedded into so many dimensions of an engineer's work. Sandler advances the thesis that technology is a social phenomenon and that technology, and by extension engineering, has many social implications. Such implications can be readily seen in the well document fact that technology molds the environments where we live; in modern societies, technological and engineering innovations have transformed entire geographical landscapes. Sandler relates our human capacity to innovate, use and disseminate technologies, to our capacity to socialize; in order words, Sadler ascribes our capacity to innovate to our capacity of building culture, which is a trait unique to homo sapiens. Engineering comes into play when engineers must design, build, and disseminate structures. Hence, naturally, engineers are confronted with mostly social decisions before they can even being to think about what they will design and ultimately build. These is the core of an engineer's end goals and means of design and construction. One of Sandler's strongest concussions is that, "given that engineering involves design, which involves choices, which involves value, and that the product of engineering is technology, (which we have seen is highly socially significant), good engineering practice requires technical and scientific expertise, as well as social and ethical awareness and responsiveness" (Sandler, 2001).

III. HOLISTIC APPROACHES

A systems approach, with a clear recognition of the importance of an integrated approach to STEM, the arts, and the humanities, is needed to meet the challenges of a socio-technological world. Hence, holistic approaches are emerging. An example is the area of "holistic engineering". Holistic engineering is a global approach that resonates the thesis of Ronald L. Sandler. As exemplified by the fourteen grand challenges mentioned in section 1, engineers can no longer afford to think engineering first, the end user, or end-goal, later. A holistic engineer is one who understand that the power of engineering has as bedrock issues related to culture, policy, sustainability, the humanities and the arts, government and industry. Hence, a holistic engineer is able to understand, lead, manage, and sustain complex systems that often rely on multidisciplinary approaches to reproduce, sustain and evolve. In layman's term, a holistic approach to engineering, "is a more cross-disciplinary, whole-system approach to engineering that emphasizes contextualized problem formulation, the

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[3] The following website contains specific courses designed and implemented at a number of American universities, as well as information on case studies: https://www.asee.org/engineering-enhanced-liberal-education-project/case-studies

ability to lead team-centered projects, the skill to communicate across disciplines, and the desire for lie-long learning of the engineering craft in a rapidly changing world" (Grasso and Burkins, 2010).

A number of universities and colleges across the United States have recognize that engineering is no longer a topic to be reserved for engineers. University of Delaware offers a wide range of technical and engineering courses designed to attract non-STEM students. For example, the course Sustainable Energy Technology includes themes such as how engineers develop sustainable energy solutions to develop the energy sources that fuel society ranging from the engineering principles to the economic impacts of developing such energy sources (University of Delaware, 2017). Smith College offers the course EGR 100 Engineering for Everyone, which is accessible to all students. The course provides an overview of engineering for students who want to learn more about engineering but are not necessarily interested in being engineers. Some of the goals of the course are:

- Develop your views on the importance and impacts of engineering in society;
- Use quantitative analyses and modern tools in the engineering design process;
- Develop as a community of learners;
- Gain an understanding of how engineering can contribute to your personal goals (Smith College, 2017).

Stony Brook University now has a college-wide tech requirement, which is to be satisfied by all students' regardless of their majors. The philosophy of this new requirement is that, "all students should have an understanding of technology and most particularly 'the role of engineering in the broader context of global problem solving.'" (Stony Brook University, 2017).

IV. PUBLIC UNDERSTANDING OF, AND ENGAGEMENT WITH, STEM

A number of initiatives have been launched to allow the public to better understand the roles that STEM disciplines play in their daily lives. Generally, there has been a call for raising individuals' awareness about, and understanding of, quantitative literacy. In the book Achieving quantitative literacy: an urgent challenge for higher education, the authors make the case that, "quantitative literacy is an essential element in many duties of citizens: evaluating allocation of public resources, understanding media information, serving on juries, participating in community organizations, and electing public leaders" (Steen, 2004). The book takes a socio-political approach to understanding and becoming more familiar with quantitative and scientific reasoning. Their approach emanates from the fact that, nowadays, public policy is strongly driven by factual arguments that come mostly in the form of quantitative data like natality and mortality rates. This has led to the creation of "Think tanks"[4]. The authors argue that Think tanks, have as primary purpose "to employ quantitative data to influence public policy across a wider spectrum of domains (e.g. politics, health care, and economic policy)" (Steen, 2004). The good news is that in the United States, citizens are growing more interested in scientific literacy. According the report Science and Engineering Indicators, four in 10, and six in 10 Americans, respectively, expressed to be very interested in new scientific discoveries, and medical discoveries. These is a new and positive trend in the United States. The same report also documents that roughly six out of 10 Americans could correctly answer multiple-choice questions related to probability within the context of medical treatment and about half were well acquainted with the best ways of conducting medical trials. On average, the report states, most Americans believe that the benefits of science are greater than its harms and an overwhelming majority, 9 in 10, believe that Science and Technology will create more opportunity for future generations (National Science Board, 2016). It is possible that new initiatives such as Stony Brook University's Alan Alda Center for Communication Sciences (School of Journalism, 2016), which offers a broad range of communication courses for STEM professionals, is helping STEM professionals to better communicate their work in laypersons words. We posit that as STEM professionals are better able to better express what are perceived to be controversial or out of the norm scientific concepts to the general public, the general public will provide less resistance to such concepts and the values that scientist have

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[4] "A body of experts providing advice and ideas on specific political or economic problems: 'a think tank devoted to the study of political and economic integration'" https://en.oxforddictionaries.com/definition/think_tank.

establish around them. As stated by Kahan, Braman, and Jenkin-Smith's (2010) article, "Cultural cognition of scientific consensus", when scientific concepts are presented to the public within the context of their cultural cognition, a pluralistic view, and a narrative framed around the consumers'' narrative framework, they are more likely to be welcome positively than when they are present as mere scientific or factual concepts that can be replicated under the right conditions in a laboratory. We can then see how all of the scientific and engineering knowledge we have mentioned so far always goes back to the topic of culture and society.

V. INNOVATION, ENTREPRENEURSHIP, AND SOCIAL GOOD

Another means creating and developing sustainable solutions to common world problems comes about by the role of innovation, entrepreneurship, and social good. Innovation is in a way a system and social driver in that, it has the capacity to radically change, usually for the better, the lives of many people very rapidly. For instance, there are clear positive correlations between a regions' development and its percentage of individuals with a tertiary education. Also, developing economies are more dependent on technology transfer that emanates from innovation than they depend on fundamental research (Ferguson and Fernández, 2015). These last two correlations are highly dependent on entrepreneurs, individuals willing to start a project or enterprise with just enough funding but that usually have the necessary skills to make their projects or ideas succeed and then be bought by larger investors. In a similar fashion, while contributing to it, entrepreneurs depend largely on social good. Often an entrepreneur has to rely on individuals who have at their disposal the necessary capital, or the means through they can acquire capital to be invested on an entrepreneur's project. When philanthropy and an entrepreneurial spirt meet, they harvest the best environments for innovations to raise. Within this context, the University, Science Cities and Science Parks, play an important role. Universities that establish bilateral collaborations with Science Parks have at their disposal high-end tools that can be readily utilized to bring fundamental ideas into the market. By means of its third mission, universities can provide entrepreneurs with creative spaces in which they can bring their ideas to fruition (Fernández et al., 2016).

VI. SCIENCE AND TECHNOLOGY MANAGEMENT AND POLICY

Science and Technology Management Policy is a relatively new, but much needed area of expertise. It has become clear that policy makers in our digital world need to understand a range of technical aspects that permeate our everyday lives. A number of universities, primarily in the United States and Western Europe, have taken the task to create new masters and Ph.D. programs in these multidisciplinary areas. Programs to be highlighted are Carnegie Mellon University's Ph.D. in Engineering and Public Policy. The program's aim is to produce technically skilled leaders who can take on complex policy-focused research and engineering. Carnegie Mellon states that, "Policy-focused research differs from policy analysis in three important ways: it takes a longer term perspective; it takes a more fundamental perspective; and it may focus on the development of theory and of analytical tools and techniques as well as on solving specific problems" (Carnegie Mellon University, 2016). Cambridge University's MPhil in Technology Policy. Offered through the Judge Business School, Cambridge' Mphil program seeks to provide the context and skills that professionals will need to cope with exponential growth of many technology-driven sectors. They understand that government policy can affect business and markets' behaviors. For this reason, among other, they emphasize the complex interplay between the public and private sectors and its rationale dynamics, and outcomes (Cambridge University, 2016). Stony Brook University's College of Engineering and Applied Sciences has a Ph.D. in Technology, Policy, and Innovation. Housed in the Department of Technology and Society, this program offers students the possibility to work within two specific areas that draw on multidisciplinary work: 1) Energy and Environmental systems; and 2) Engineering Education, Management, and Policy. Students in this program are expected to complete courses within appropriate social sciences and other disciplines--such as sociology, psychology, and business, to name a few. This program was designed with an understanding that "technology shapes every facet of modern life" (Stony Brook University, 2016).

VII. CONDLUDING REMARKS

It is clear that to make our world a better place, and to ensure sustainability we must understand, face, and solve a number of grand challenges and that this effort will take a lot of work, global resources and collaborations. In light of that, we hope that the reader has gained a better understanding about a number of tools that we currently have at our disposal so that we may collectively bring about enough human capital to begin such work. A number of institutions ranging from philanthropic foundations, government agencies, science parks and universities are already taking many strong steps in the right direction. At the fundamental level, we have the human capital needed to develop and execute plans of action that can solidify and bring into practice many of the ideas emanating from fundamental research. We propose that willingness to commit to a common goal is the spark that will let us build a sustainable future for all.

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Received February 20, 2017
Revised April 21, 2017
Accepted May 15, 2017