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Editorial

Keeping Science and Technology Education *In-STEP* with the Realities of the World Stage: Inculcating Responsibility for the Power of STEM

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Science and technology as Zeitgeist

The world is becoming evermore involved with, shaped by, and reliant upon science and technology (S/T). In light of this, and the rise of S/T capabilities in both western nations and those countries that previously did not exert leverage in global S/T economics, there is an increasing call for fortified science, technology, engineering and mathematics (STEM) education in the United States. This is important for a number of reasons, not least of which is the need to re-constitute a culture of curiosity, exploration, invention and innovation that characterized much of the twentieth century, and that was instrumental to what has become known as "Big Science" mindsets and agenda. Such a reconstitution of scientific and technologic capability will be necessary in order to keep pace with, if not strive to lead — international efforts and achievements, and maintain a position of technical, economic and social parity on the rapidly shifting and highly competitive stage of global affairs.

Toward these ends I believe that it is important to re-assess extant educational systems to evaluate if and how core competencies are being met both *in* science and technology, and through the prudent use *of* science and technology. Indeed, there is much discussion about STEM education and training in the "K through 20" years of kindergarten up to and including graduate education (1, 2). This speaks to a defined need for early inculcation and ongoing reinforcement of ideas, methods of inquiry, scholarship and skills, and the establishment of a functional nexus between the early school years, and those increasingly specialized academics of high school, college and university. Such educational reform should be positioned to address questions of 1) how to teach students to assess the benefits, burdens, risks and value(s) of S/T in society, 2) how S/T can and should be employed in education, and 3) whether such use constitutes enablement, treatment or enhancement. Detailed examination of these latter ethico-legal and social issues is beyond the scope of this essay (for further discussion, see (3, 4)). However, when taken together, the aforementioned questions can be seen to reflect a crisis in education — literally, a time of change — that is predicated upon the need for academic systems that will truly educate (by definition, "to bring up to the fore") citizens who will be well-prepared to face the realities of a scientifically and technologically enabled, pluralistic global community and world market. But let us not forget that science, technology, engineering and mathematics are human pursuits that are enacted in the socio-cultural sphere, and thus it is vital to ground such STEM competencies to an appreciation, sensitivity and obligation for humanitarian regard.

STEM education and inter-disciplinarity.

Guided by historically perdurable philosophical questions, society of the 21st century will employ science and technology to both address the nature of life and the world, and to exert changes that affect the human condition and predicament (5). To be sure, the 21st century will witness the merging of science, medicine and the arts in ways that are inventive and industrious, harnessing the tools of technology as resources, goods, and services within the milieu of human ecology and economics. Therefore, any practical approach to human inventiveness, interactions

with our own and other species, the environment and the natural world, and human ability to control each and all of these dimensions of living reality, must constitute the fabric and focus of education if we are to foster both innovativeness, and responsibility for potential benefits, burdens and harms (6). Education and research can no longer be bounded in silos of academic solipsism. Authentic representation and apprehension of the dynamic interplay between the physical, natural and social sciences, medicine, engineering and technology, humanities, and education must embrace the de-siloed model of disciplinary convergence, as both a task and a tool, to foster new opportunities for collaboration, invention and innovation that more accurately reflect the shifting epistemic, anthropologic, technical and social architectonics of the new millennium (7, 8).

Such efforts toward intellectual and academic disciplinary convergence are not a wholly novel concept. This call for a pluralogue of disciplinary voices and skills was the essence of the educational model posed by Alexander von Humboldt during the early to mid-19th century (9), and there is explicit interest in renewing and expanding the Humboldtian concept — both in the US and Europe — so as to enable such inter- and trans-disciplinarity. This was also the vision of education and the university expressed by philosopher Karl Jaspers, who, asserted that "…science is essentially a whole. The structure of the university must be such that all the different sciences are represented" (10). Jaspers argued that the goals of education in a world progressively involved in, and defined by S/T was to "…seek truth through science", but in order to avoid creating generations of mere technocrats, must be a "…method of imparting knowledge and skills…to the intellectual training of the whole being" (10).

The concept of education as contributing to the whole being speaks both to the individual, and to what being "whole" entails. According to Jaspers, "…our all-embracing nature is no mere juxtaposition. We are existence and reason, and these…are related like opposite poles. We are existence and being at one and the same time…in such a way that existence…is manifested in being" (11). Appreciating the human as "being" necessitates that education be focused upon concerns and protection for life, not in an esoteric way, but in acknowledgement of the competitions, strivings to flourish, and asymmetries of relationship and power that typify existence. Recognizing the human as rational imparts a sense of understanding, temperance, and prudence necessary to sustain existence in a community of individuals, groups and institutions (11, 12). Hermann Horn has noted that this Jaspersian vision "…seeks to safeguard the individual citizen in profession and politics, but is not confined to …familiarity with forms of public behavior, [or] acquisition of professional expertise", but rather "…extends beyond [as an] integration into society" (12).

In-STEPS: Integrative science, technology, ethics, and policy studies.

Indeed, science is crucial, yet as Jaspers recognized: "scientific knowledge cannot set goals for life"; nor is it able to "…answer the question as to its own meaning" (10). These are the tasks of the social sciences and humanities, which enable more thorough insight to what science and technology have achieved, frame these accomplishments in social contexts of human endeavor, and seek to develop "…reasoned balance, investigation of contrasting possibilities, self-criticism", and in so doing provide "education in reason" that is both scientific and able to look upon and guide the current and future conduct of science as human enterprise affecting the natural world (10).

Educational curricula devoted to this approach would integrate science, technology, ethics and policy studies (what I refer to as In-STEPS) at the high school, undergraduate and graduate/professional levels. Such a project would create a practical nexus between 1) a generalized early exposure to these issues as important to the social implications of any/all research and applications of science and technology,[i] and 2) a subsequent, graduate and professional venue that provides a more deeply articulated understanding of specific ethical, legal and policy issues that are relevant to the ways that frontier science and technology alter the human condition, human predicament, and aspects of social regard and action.[ii]

Specifically, I believe that such programs should:

- Address the frontier areas of S/T and explore (a) how these developments affect and are utilized within healthcare, public life, and national defense, and therefore impact the social condition; and (b) the particular ethical, legal and social issues (ELSI) that arise in and from these endeavors.
- Identify whether current courses and curricula effectively address core competencies and attitudes that are pertinent to an understanding of ethics and policy in frontier areas of science and technology.

- Modify existing curricula and/or develop new programs to integrate studies and didactics in ELSI that will (a) effectively inform high school, undergraduate, graduate and professional students about the social profundity of scientific and technologic progress; (b) foster deeper and broader competencies in both S/T ethics *and* policy, in order to (c) confer a level of knowledge that enables competent leadership in S/T policy formulation within the healthcare, industrial, governmental and public sectors, so as to (d) instantiate preparedness for, and prudence in ELSI generated by the rapidly advancing scientific and technological developments.
- Employ novel combinations of educational modalities (e.g., traditional lectures with small group participation, distance learning, intensive seminars and practica, and supplemental engagement in national/international symposia via teleconferencing methods).
- Maintain authenticity, realism, flexibility and currency through the use of extant and newly developed evaluation tools that provide valid and meaningful data to enable curricular revision, improvement, and ongoing attraction of extramural support.

Toward articulation and sustainability

This raises questions about the viable articulation and sustainability of In-STEPS' programs. In 2007, Congress passed the America COMPETES Act (H.R. 2272); Section 7009 required institutions that apply for National Science Foundation (NSF) funding to "…provide appropriate training oversight in the responsible and ethical conduct of research to undergraduate students, graduate students, and postdoctoral researchers" (13). With this legislation, NSF joined the National Institutes of Health (NIH) in mandating that all funded institutions develop and implement defined educational programs in the responsible conduct of research (RCR) as required coursework for federally-subsidized programs in S/T. These requirements reflected increasing consternation expressed by both the research community and the public sector about integrity and honesty within science, technology and research, and therefore can be seen as a call to strengthen social confidence and trust in the constructs, contexts and activities of the S/T enterprise as a public trust (14).

While, most colleges and universities provided basic undergraduate, graduate and professional coursework in ethics, many of these offerings only nominally met the requirements as set forth by the NSF and NIH (and subsequently the Department of Defense (15)). In the main, their somewhat limited scope 1) did not provide a comprehensive treatment of ethics and socio-legal issues in frontier areas of science and technology that the forthcoming generation of students and scholars will require; 2) did not meet the expressed need for more cohesive coursework in these areas; and thus 3) fell short of the intent and educational goals articulated by the aforementioned federal agencies, and in this way 4) failed to support and serve students and faculty, and may therefore be viewed as inadequate to prepare future leaders in the field who are cognizant, receptive, and ready to respond to ethical, legal and social issues incurred by and in S/T.

Due in part to these federal mandates, and consistent (if not amplified) professional and public concerns about potential threats posed by research and use(s) of frontier disciplines, such as nano-, geno-, neuro- and cybersciences, this situation is changing. Several undergraduate, graduate, professional, and even high school programs are addressing ethical issues that are relevant to the past and future conduct of science as a public good. Still, in order to provide the depth and scope required to better uphold current educational mandates, significant improvement and enlargement of existing curricula, if not altogether new curricula will be required if such programs are to remain current and applicable. The goal is not to diffuse STEM education, but rather to fortify it in ways that enable more effective pacing with the social effects fostered by the iterative developments and uses of S/T. Such programs could provide a cadre of professionals who are well-trained in both S/T (and thereby intimately aware of the methods, demands and rigors of scientific work), *and* the humanities and social sciences, who could then operate to inform, advise, advocate and participate in the formulation of guidelines, policies, and laws. The idea is to create a STEP workforce capable of fluently bridging "books, bench, business, and the boardroom" to enable the technically right and ethico-legally sound translation of S/T research in healthcare, public life, and national security and defense.

To exert any meaningful effect, such programs must be sustainable, and this requires financial support. Recent draw-downs in federal S/T funding do not bode well for any such efforts (16) Moreover, the relative allocation of federal monies to support ELSI and/or policy aspects of S/T research is arguably insufficient (6, 17). Of course, it takes significantly more money to establish and run a

scientific research laboratory or technological production site than to fund an ELSI working group. Yet, I argue that it is not a question of total monies allocated, but rather the percentage of grants and contracts devoted to ELS and policy issues that is telling. In this light, I posit that a defined funding allotment of 15-20% of all S/T research grants should be devoted to supporting ELSI projects that are directly related to trends and trajectories in current and planned (S/T) research and development. This percentage need not (and some might contend should not) be wholly borne by federal agencies, and could be accommodated by specific philanthropic organizations with expressed interest in the scope, conduct and guidance of S/T. However, such efforts should represent a reciprocal interaction between federally established programs of S/T R/D, and the coordinated support of studies that are explicitly dedicated, if not detailed to examining ELSI and questions, describing the social, economic, and political terrain created by current and future S/T developments, and posing possible solutions to the problems generated by S/T research and applications. Simply put, the far-reaching effects and implications of S/T research, development and use demands equal footing of projects and programs — if not a broadly construed paradigm — for addressing, evaluating, and guiding ELSI.

History has shown the power, and potential of S/T to evoke goods and harm, and these are valuable lessons. As Karl Jaspers noted over half a century ago, education is the bridge between past, present and future, and that only through a spirit of responsibility can the past and future be reconciled (11, 12). Science, technology and education are human endeavors, and as such any such future lies in our own hands. Thus, we bear responsibility for educating and training those citizens who will be dealt our successes, liabilities and failures, and who — through their innovations, inventions and interventions — will shape the world and its societies of the future.

Notes

i. As a contemporized version of the *Gymnasium* or *lyceum/liceo* systems of broad-based liberal arts in the general educational years, that would then serve as a foundation upon which to build increasing knowledge and capabilities in STEM as human endeavors for human endeavor.

ii. The concept of homogeneity in upper-level education is argued to be (one of) the core issue(s) addressed through the Bologna Process, and this has stimulated considerable discourse, debate, and tension. An in-depth address of the Bologna Process, and its effects upon contemporary and future higher education is provided by the Thematic Issue of this volume, edited by Prof. Scott Karakas.

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Disclaimer

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Competing interests

The author declares that he has no competing interests.

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