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Convergence: a transformative approach to advanced research at the intersection of life, physical sciences and engineering and enhanced university-industry partnerships

Amanda Arnold*[1] and Melvin Greer[2]

[1]Federal Relations, Texas A&M University, USA

[2]Senior Fellow, Chief Strategist, Lockheed Martin, USA

Abstract

Convergence — an integration of the knowledge, tools, and ways of thinking from the life and health sciences; physical, mathematical, and computational sciences; the engineering disciplines; the social and behavioral sciences; and the humanities to form a comprehensive framework for tackling scientific and societal challenges that exist at the interfaces of multiple fields – is a movement gaining traction in universities across the country. Industry sees the approach as critical to educating the 2020 workforce it needs to deliver the advanced technological products and services that will otherwise go uncommercialized without the enhanced workforce capabilities for which Convergence offers the blueprint.

Introduction

A new transformative research approach is gaining momentum in Washington. *Convergence — an integration of the knowledge, tools, and ways of thinking from the life and health sciences; physical, mathematical, and computational sciences; the engineering disciplines…to form a comprehensive framework for tackling scientific and societal challenges that exist at the interfaces of multiple fields* [1] – is a movement that has thrived for some time in academia, giving way to disciplines like synthetic biology, biological engineering, and is touted by some as the next generation concept to propel the field of nanotechnology [2]. As established scientific leaders Phillip Sharp and Robert Langer wrote for *Science*, "rather than bringing together practitioners from separate silos to provide skills, there is an increasing need to merge expertise that goes beyond the interdisciplinary inter section of fields to the emergence of new disciplines [3]."

This approach is creating a new generation of scientists and researchers capable of speaking across disciplinary platforms in a way not possible in previous generations but still with deep expertise in one or, in some cases more than one discipline, in addition to working at the intersection of disciplines.

While the federal funding agencies that support research and discovery are slowly catching on to this trend [4], academia continues to wrestle with embedding Convergence institutionally while maintaining the capability to train for deep disciplinary expertise. However, the industry members who will increasingly depend on these graduates to transform product lines for health, defense, environment, and security have not been fully engaged in the discussion. This is changing as Convergence reaches beyond the frontiers of academia and government and into the boardrooms of America's largest firms. Calibrating this triad of engagement between government, industry and academia to the Convergence approach will allow enhanced system organization to enable novel solutions to grand societal challenges currently gathering dust at the intersections of disciplines and sectors.

Motivation for ongoing scholarship on the convergence trend

Over the past year, leadership at the National Academy of Sciences responded to the interest of their membership and the larger Science & Technology community in Convergence in several ways. To date, the National Research Council—the operating arm of the NAS—completed two exercises in this emerging approach; the first a study chaired by Joseph DeSimone of University of North Carolina that examined approaches for fostering Convergence in research institutions [7], and the second, a Summary Report from a meeting of the Government-University-Industry-Research-Roundtable [8], which the authors of this document co-chaired.

The National Research Council is continuing to engage in the discussions surrounding Convergence. Critical topics include a partnership with the Kavli Foundation to expand the dialogue on institutional policies that enable convergent research, a forthcoming study on social and behavioral science research on working in teams,

Correspondence to: Amanda Arnold, Principal Associate Director; **E-mail:** amanda.arnold@tamu.edu

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and an emerging interest in industry and workforce needs. The NAS has also announced a new Raymond and Beverly Sackler Prize in Convergence Research [9].

Established success and notional applications for convergence

We are only now beginning to see the potential for Convergence style research, if supported, to enable this third revolution [10] in biomedical research, the first two related revolutions being the discovery of DNA and the unraveling of the genome [11]. The applications of Convergence allow researchers an alternative view of the future.

For example, Lockheed Martin is currently investigating the ability of synthetic biology to accelerate innovation in the development and deployment of Green IT and Energy Complex Adaptive Systems. The primary focus of this work is development of a synthetically generated DNA BioFab that enhances the photosynthetic properties of algae. This research will report on the process of synthetic engineering of natural occurring DNA for a specific purpose, in this case sustainable energy.

The market potential for products resulting from, in this example, synthetic biology technology is considerable and the impact on society at large may include:

-New vaccines and drugs

-Alternative and renewable energy sources such as through

-Artificial Photosynthesis

-Sustainable economical production of chemicals and biofuels

-Repair of diseased tissues

-Novel drug delivery systems

-Countermeasures for polluting environmental toxins [12].

Another area to watch for effective applications of Convergence is advanced technologies (*i.e.* big data, cloud, and high performance computing). There is no doubt that computing will have a multitudinal impact as part of the Convergence approach to the integration of life science, engineering, the physical sciences and computing. An approach to understanding complex adaptive systems that is emerging at universities, including MIT, Stanford, University of Michigan, Arizona State University, and many others, includes harnessing the power of advanced technologies to accelerate big data and high performance computing research applied to difficult health challenges. Some in collaboration with Lockheed Martin are seeing payoffs in medical areas of opportunity like cancer and diabetes research [13].

Workforce and talent

Even before considering this new paradigm, the world's S&T industry leaders face significant workforce challenges for coming years. By 2015, approximately 50 percent of the world's working population will have been born after 1980 (known as gen Y or millennials). As many industry talent recruiters already know, this "2020" generation takes an approach to their career that is unfamiliar to older generations.

According to a Greer Institute Workforce and Talent study [14], the majority workforce in the year 2020 is projected to be both "the most educated and culturally diverse of any generation" and "notorious job-hoppers who dislike bureaucracy and distrust traditional hierarchies" [15]. Each generation is different and the health of the innovation ecosystem depends on building through workforce strengths. Given the recognition and acceptance of these changing generational approaches, it is crucial for leaders to understand how best to motivate and engage this 2020 workforce and win the war for top talent, as there are significant advantages to doing so. For instance, while many of us had to transfer to the full-time use of computers, so-called "digital natives" are entering the workforce en masse, and by 2020 many of the old school, pen-and-paper types will be looking to retire. Pair this nature to a relentless consumer-grade expectation for mobile, social, and globally-accessible tools with ubiquitous access to work product and you can see the necessity for Human Resources and IT leaders to evolve in order to deploy technology solutions to attract, retain, and manage the 2020 workforce.

Taking into accoun this changing nature of the 2020 workforce with future workforce needs for leaders with cross-disciplinary expertise and the time is right to engage industry in the Convergence discussion; they simply will not flourish without co-fostering the Convergence approach to advanced Science and Technology (S&T) with academia as the 2020 generation matures.

Industry is now more open than has historically been necessary to partnerships with organizations that train and shape the 2020

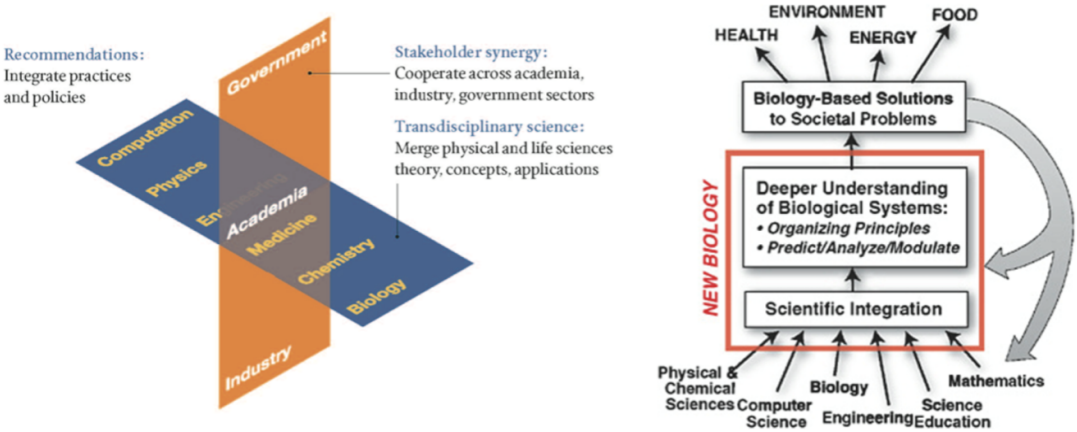

Figure 1. Two representations of the process of integration represented by Convergence. Left, in order to take advantage of new opportunities, a merger of expertise from life and physical sciences and synergy across academic, industry, and government sectors is needed. Right, the New Biology, which focuses on the life sciences, draws on integration of multiple scientific fields in the creation of biology-based solutions to societal challenges. Source: Left, [5], Right, [6].

workforce. Industry members are projecting the kind of professions that may need to be filled in the future and wondering where that trained professional will emerge given the still standard and, sometimes siloed approach, to S&T training among traditional disciplines.

In each of the emerging professions of the future, students will need to not only receive academic support to understand an expertise area in depth, but will also need to be "pi" or "comb-shaped" across multiple disciplines so that they naturally function in a cross-disciplinary manner at the intersections of established knowledge tranches [16].

Just as the Convergence approach offers an organizing framework for academia and government institutions to better understand how to enable solutions to our greatest challenges, Convergence offers industry a view inside the university machine and enables a better understanding of the feedback loops necessary to ensure complete training for the 2020 workforce.

Countering potential criticism of a new approach

While this systems approach to challenges is becoming standard for researchers, this approach is not yet embedded in the university-partner-investment approach of most major industry partners. This is a challenge to adoption as is the current challenge of university leadership struggling towards modernizing long-lived systems for rewards for faculty and students that actually inhibit this Convergence-style work.

In addition, during any discussion of Convergence, (including those the authors of this work have directed at the National Academies, the American Association for the Advancement of Science, and Lockheed Martin's annual Senior Fellows Conference), one inevitable question emerges: "How is Convergence different from cross--disciplinary science?"

The Convergence approach certainly includes attributes of team-based science and transdisplinarity, but we argue that this approach is perfectly framed to finally address the long-held challenges associated with barriers to Convergence efforts. As a un-published summary document that Amanda Arnold co-authored following a 2013 AAAS Annual Meeting states, Convergence is "an organizing framework (much like the National Nanotechnology Initiative did in practice) that can be used to overcome traditional obstacles to funding, promotion, and appointment that have slowed trans-disciplinary approaches and stymied access to knowledge potential [17]."

While dynamic conversations about Convergence are common on university campuses, and as federal agencies are running to catch up to funding the frontier of this new reality, it is not clear that industry has established its strong voice in this discussion. Industry has critical intelligence to contribute through its many researchers and technologists working on complex science and engineering challenges and its roles as an end-user and commercializer of advanced research developed by university faculty, students, and others. There is no doubt that industry's voice is going to be critical to taking advantage of the Convergence opportunities moving forward (Figure 1).

Recommendations

When developing a Convergence engagement strategy, all stakeholders should consider several of these recommended practices:

1. All sectors should acknowledge the great potential of biology in seemingly unrelated fields but allow non-biologists to direct inquiry;

2. Industry should invest in advanced co-shared facilities at major research universities to engage in the basic research undertaken in emerging fields of interest;

3. Federal Centers of Excellence associated with major national labs should coordinate closely with academic and industry stakeholders and include funding for next generation training module development;

4. A cross-section of federal agencies, together with academic and industry leaders should undertake a report to outline and detail a list of the critical workforce needs of the 2020s that currently do not exist complete with examples of positions in industry that do not exist today.

Summary and conclusions

Bringing together the insights enabled by rapid progress across multiple disciplines has the potential to transform science for the benefit of society. Its critical we bring awareness of the Convergence approach to a wider range of audiences and stakeholders and catalyze the systematic efforts necessary to harness its power most effectively.

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