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TRANSDISCIPLINARY ENGINEERING & SCIENCE

A NETWORKED APPROACH TO TRANSDISCIPLINARY RESEARCH & EDUCATION

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TRANSDISCIPLINE: Integrating science and engineering principles

"...Today, complexity is a word that is much in fashion. We have learned very well that many of the systems that we are trying to deal with in our contemporary science and engineering are very complex indeed. They are so complex that it is not obvious that the powerful tricks and procedures that served us for four centuries or more in the development of modern science and engineering will enable us to understand and deal with them. We are learning that we need a science of complex systems, and we are beginning to construct it..."

Nobel Laureate Herbert A. Simon
Keynote Speech, 2000 IDPT Conference

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Abstract

Recently, there has been increasing interest among researchers and educators for organized collaboration on the national and international levels. The evolution of large scale collaborative efforts between researchers from diverse disciplines was spawned from the necessity to increase efficiency in solving complex problems that require knowledge from multiple disciplines. Realizing the benefits from organized collaborative research, several initiatives have been launched to develop transdisciplinary research groups. The objective of this paper is to present a networked approach to transdisciplinary research and education and propose the initiation of an virtual organization called ***T****ransdisciplinary* ***Co****llaborative* ***R****esearch &* ***E****ducation or T–CORE as a new research and development infrastructure within The Academy of Transdisciplinary Learning and Advanced Studies (TheATLAS).*

Keywords

Collaborative Research and Education, Complex Problems, Virtual Organization, Networked approach to Research.

1. Introduction

In attempts to solve complex problems, one of the most constructive forms of knowledge transfer occurs, for all partners involved, during collaborative research, where companies and universities work together in pursuit of specific objectives that are of mutual benefit, and jointly managed under a collaborative agreement. In comparison with standard consultancy, contracts, or grants, collaborative research is more interactive in nature and has the potential to productively persist for longer durations. Disciplines developed over the last few centuries are convenient for organizing information and for basic educational activities; however, approaching complex problems and developing complex social and technological systems to address such problems requires a transdisciplinary approach [1, 2, 3, 4, 5, 6, 7, 8, 9, and 10]. Complex problems by definition cannot be contained in disciplinary boundaries.

The objective of this paper is to define the future establishment of a new virtual infrastructure called Institute for ***T****ransdisciplinary* ***Co****llaborative* ***R****esearch &* ***E****ducation* (T–CORE). The institute will be dedicated to the development and promotion of innovative applications of transdisciplinary research and education applied to unstructured problems (primarily in *Design, Process, and Systems)* currently faced by the state, nation, or the world. T–CORE is proposed as a new virtual research and development infrastructure housed within The Academy of Transdisciplinary Learning and Advanced Studies (TheATLAS).

2. The Impending Shift in Engineering Requirements

The engineering profession is a small but influential community whose performance affects almost every aspect of modern life. Engineers are practical people. They utilize the knowledge from the sciences, while combining it with the best practices to create innovative products and services. The ultimate creation and operation of engineering artifacts originate, in large measure, from initial requirements, which emanate from the changing needs of society.

These requirements have expanded significantly over the years. Before the industrial revolution of the eighteenth century, the primary engineering challenge was functionality. In the intervening two-hundred years, new requirements have hit the engineering profession like a series of tidal waves. A few of these include: production volume, cost reduction, production efficiency, improved looks and marketability, quality considerations, pollution controls, safety concerns, automation, computerization, miniaturization, complex systems integration, and resource constraints. Engineers have met these challenges within an evolving and expanding disciplinary structure. While multi-disciplinary and inter-disciplinary approaches have certainly produced some interesting developments, the focus has primarily been the artifact *as* a complex system not the artifact *as part of* a complex adaptive system.

The engineering profession is again being challenged with a new and potent set of requirements, which appear imminent: environmental change. For example, these include observable changes to the atmosphere, hydrosphere, and biosphere resulting in significant shifts from the environmental norms under which the artifacts of our civilization were originally designed. In the past, these aspects of the engineering design could be taken for granted, due to the apparent stability of the environment within a narrow, acceptable, and predictable range of change. However, shifting requirements from environmental changes will not be easily addressed with methods descended from our industrial age. The environment is a complex adaptive system defying prediction, especially long-term prediction. With environmental change, solutions may not be so amenable to the usual disciplinary approaches. The unexpected may soon become unavoidable, and our system must adapt with these changes.

Buried within the design details of many artifacts exist specifications of operational limits. In many cases, they tacitly assume an environmental stasis. Environmental change could not only trigger a whole host of changes to existing products and infrastructure, but suddenly force new requirements on future designs. For example, information technology companies and other computer facilities are demanding new levels of power reduction from chipmakers and system builders because of cost increases from higher electricity rates. Fluctuating gas prices and emission concerns have sent car manufacturers in search of new, zero polluting, fuel efficient engines.

In a period of environmental change, engineering must garner all its resources, across all disciplines, and face this new challenge. Not only will more engineers be required, but also they must collaborate and interact in new and more integrated ways to confront the engineering changes of the future. Engineering must now consider the whole, which includes the earth's environment, and directly address complex adaptive systems design. Engineering education must produce a new kind of engineer, one that breaks the barriers of disciplinary thinking. Transdisciplinarity must become an integral part of this venerable profession's future.

3. Transdiscipline

Within many fields, such as medicine, biosciences, and cognitive science, there is a growing awareness of the need for transdisciplinary approaches. Likewise, engineering education and research needs to be supplemented by a fundamentally new way of addressing the multidimensional, complex problems that society faces today. Because of the nature of modern engineering systems, traditional disciplinary approaches have proven insufficient; as such, researchers and educators are operating beyond traditional disciplinary boundaries to explore complementary approaches. Products have become integrated engineering systems, and design and production requirements regularly traverse disciplinary boundaries. This requires

input from multiple disciplines within engineering, as well as other disciplines outside of science and engineering, such as business, social sciences, medicine, etc. As the pace of development of new technical systems has continued to accelerate, the need has shifted from interdisciplinary or multidisciplinary design teams to trans-organizational and trans-national work.

During the last decade, the number of complex problems facing engineers has exploded, and the technical knowledge and understanding in science and engineering required to attack these problems is rapidly evolving. A few examples are the groundbreaking advancements in semiconductor and software technologies, the biosciences, and nanotechnology. The last two decades of designing large-scale engineering systems taught us that neither disciplinary, nor multidisciplinary or interdisciplinary approaches provide an environment that promotes the collaboration and synthesis necessary to extend beyond existing disciplinary boundaries.

A sound transdisciplinary science of engineering systems needs, of course, to incorporate knowledge from many different areas. The core of knowledge centered on design and process will be augmented, based on discipline-specific knowledge depending on the problem at hand. The core of design and process knowledge will also be necessarily broad, incorporating concepts and methods from separate disciplines.

Transdisciplinary education and research take collaboration across disciplinary boundaries a step further than do multidisciplinary and interdisciplinary programs. In following the transdisciplinary concept, researchers representing diverse disciplines work jointly to develop and use a shared conceptual framework that draws upon discipline specific concepts, theories, and methods, while addressing common problems through a new synthesis of a common ontology, theories, models, and methodology.

4. Is Collaboration necessary?

There are many reasons why collaboration on research and educational activities are not only useful, but also essential. Some of these are:

- Collaboration boosts scientific innovation through cross-fertilization of ideas not considered before.
- Collaboration accelerates the pace of new discoveries and the expansion of human knowledge.
- Innovation of technologies occurs through global cross communication.
- Transdisciplinary collaboration in large–scale multi–national partnerships initiates speedy exploitation of promising results, efficiently.
- Research partnerships are essential in solving complex problems and to optimize knowledge acquisition.

- Collaborative, transdisciplinary educational activities can better prepare today's students to solve the complex problems of the future.

5. VIRTUAL Institute for Transdisciplinary Collaborative Research & Education

TheATLAS, the research and publishing arm of Society for Design and Process Science, will facilitate the creation of the virtual institute T–CORE which will constitute a forum to establish new partnerships that improve the links between science, technology and the arts by fostering research collaboration across sectors — in particular, between universities and industry. Furthermore, most governments are dedicated to increase the level of international collaboration among researchers in order to realize cost savings and other benefits. By its very nature, T–CORE will be well suited for playing a significant role in international collaboration.

6. Mission and Goal

The mission of T–CORE is to provide a competitive national and international virtual research infrastructure for solving complex, unstructured problems. The solutions of such problems are to be synthesized through the transdisciplinary design, process, and systems pedagogy described previously.

Innovation often occurs at the nexus between disciplines at their frontiers and boundaries. Therefore, the goal of T–CORE is to create a leading virtual transdisciplinary institute with state–of–the–art research, advanced education, and leading edge information technology. T-CORE will foster and support transdisciplinary education and research that falls outside the realm of any traditional discipline in Science, Engineering, and Medicine. T–CORE will share resources, leverage best practices, and work on collaborative research and educational programs. T–CORE's research and educational collaborative efforts will be national and international in scope.

7. Benefits to Collaborating Partners

T-CORE will provide all the collaborating partners a viable reach into the global community of collaborative research. T-CORE will be an entity that will allow faculty, students, and practicing professionals to function beyond their normal range of activities and explore how they can help and be helped by the resources and talents of other research engineers, scientist, social scientists, physicians, and educators.

8. National Collaboration

T–CORE will be a nationally recognized virtual research institute that develops effective approaches and solutions for innovation in science, technology and the dissemination of training and research materials to meet the challenges technology–

intensive companies face. Outside of the traditional academic departments, T–CORE will acknowledge and facilitate the importance of the transdisciplinary approach to knowledge generation and will offer many opportunities for faculty and students to engage in innovative research. Some of the aims of T-CORE are:

- To foster innovation of technology through collaboration.
- To provide neutral ground for corporate and academic partnering on short and long term projects.
- To improve the speed of research by using each others resources.
- To improve the quality of research and education by collaborating with other researchers and educators.
- To improve identification, adoption, dissemination, and implementation of research results through the development and support of transdisciplinary educational activities.

9. International Collaboration

Although collaboration is not a new idea, new opportunities for collaboration exist in the 21st century's global body of knowledge and information–driven economy. Technology has reduced the limitations of time and space while enhancing communication, hence opening the possibilities of exploring new boundaries in the area of international transdisciplinary collaboration. Such international collaboration requires not only the active participation of faculty, but also participation of the top administrators of educational institutions. Faculty and administrators should find innovative ways to work together across international boundaries. Recent advances in information and communications technologies are providing new opportunities for international cooperation in education and research.

Collaboration among people from different nations in research and education can substantially benefit all parties involved. In order to meet new challenges in the 21st century, universities around the world are seeking to broaden their engineering education systems. In the near future, engineering education will be an international enterprise. Hence, institutions of different nations must work together. George Kozmetsky, in his 2000 address to the SDPS community, stated, "*Technology continues to shrink the world. There is no choice other than to participate in the global community. Science and technology is too precious a resource to be restricted from drawing the world together. That is what the 21st Century is all about."* In the current century, technical, medical, social, and cultural issues are no longer just local concerns—thus issues and problems must be increasingly considered from a global perspective.

Communication, collaboration, and education on a global scale are the keys to solving the complex problems and issues facing humankind in the twenty-first century. The successful development of a network of global collaboration centers would

provide a universal sharing of knowledge and benefit everyone by greatly enhancing the ability to solve unstructured problems the world is facing. Such problems include environmental, computational, health and medical, energy, transportation, communication, and educational issues as well as living conditions.

At its core, science is an international undertaking. The fundamental workings of nature—the function of a gene, the quantum behavior of matter and energy, the chemistry of the atmosphere—are not the sole province of any one nation. Louis Pasteur noted more than a century ago that, *Science knows no country, because knowledge belongs to humanity, and is the torch, which illuminates the world* [10].

10. Conclusions

Culture is a difficult thing to change. The culture of the disciplines grew out of the modern university system which formed at the end of the nineteenth century. Departments were created in support of these disciplines, degrees were offered, and careers were made as graduates turned into the professionals of industry and commerce. Some strides have been made in changing the disciplinary mindset but it largely remains intact. Such a change requires the formation of a new culture that transcends the present tradition of disciplines, i.e, a new discipline-of-disciplines called transdisciplinarity that is implemented through a new vehicle for research, T-CORE. T-CORE will be an integrative vehicle of discovery and innovation that links people, knowledge and resources across the boundaries that typically divide scientific and engineering progress. T-CORE will be an international, distributed organization with the flexibility to seek new solutions through new and integrative approaches.

In order to succeed, transdisciplinary approaches must be removed from the culture of discipline-centric universities. The concept of T-CORE is to invite like-minded researchers to work in separate facilities, designed specifically for transdisciplinary research. An international network of T-CORE research centers will be built to house these researchers, who will leave their disciplinary thinking behind as they enter this new environment to become transdisciplinarians. Former mechanical engineers may work on the effects of plant transpiration on forest environments or biochemistry of cell membrane transport. They can do this because no one is requiring them to work only on problems related to mechanical engineering. They are free to work with former system biologists and forest ecologists, who are also free to research topics outside their former disciplines.

In terms of computation, the T-CORE centers will be extensively networked, housing computationally intense resources for simulation, analysis, and research and collaboration. To facilitate this cross-pollination of thinking in a global environment, the centers will develop and offer large-scale, outward-facing internets which employ

semantic web applications to facilitate research partnerships and educational accessibility. The system will allow researchers to traverse large databases through schemas that will eventually understand and locate information in many languages and disciplines. Internally, a vast network of systems and supercomputers will provide the power to support the requirements of emerging transdisciplinary approaches.

Research will be in the nature of combining knowledge from the disciplines, finding solutions to problems of complex phenomena. It will be similar to 'think tanks' but more design and process oriented. The scope will encompass the sciences (physical, social, and biological), engineering, medicine and heath, philosophy, technology, mathematics and the arts. Education will be an integrated part of research. T-CORE is a place where vast networks of integrated information will collide with the motivated minds of skilled researchers to find new integrated solutions to problems never before attempted. The vision of T-CORE is transdisciplinary discovery—to go beyond the disciplines for the benefit of all humanity.

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