Chapter 3
The Application of Transdisciplinary Theory and Practice to STEM Education

Susan Malone Back
Texas Tech University, USA

Heather Greenhalgh-Spencer
Texas Tech University, USA

Kellilynn M. Frias
Texas Tech University, USA

ABSTRACT

The authors describe the application of transdisciplinary theory and practice to Science, Technology, Engineering and Mathematics (STEM) education at the undergraduate level. The modular approach which makes use of student collaboration within and across disciplines and input from outside experts holds promise for preparing students to address society's "wicked" problems – those with interconnected causes and for which a solution often causes additional problems. Transdisciplinary theory and practice are described and their application to STEM education is proposed along with a model of measuring transdisciplinary skills. Recommendations are proposed for future research on cross-cultural/cross disciplinary models, pedagogy, measuring student collaboration, determining effective partnership models and institutional supports, and the potential role of the social sciences in contributing to research on transdisciplinary practice and education.

INTRODUCTION

It has been widely accepted that modern educational curricula in the Sciences, Technology, Engineering and Mathematics (STEM) must help students develop critical thinking and problem-solving skills. One-way transfer of information served the needs of 19th century industry but will no longer suffice in today's high-tech, multi-faceted economy. The National Academies of Science, Engineering and the Institute of Medicine (NASEIM, 2014) call for movement beyond the current

DOI: 10.4018/978-1-4666-9441-5.ch003

patchwork of educational approaches to one that is integrated and multi-sectorial. Value-added skills such as creativity, analysis and synthesis, problem definition, and innovation will be required to sustain students as they enter a continually changing work environment.

In response to this need, an approach to problem solving has emerged in the scientific and education literature variously known as Interdisciplinarity, Convergence, or Transdisciplinarity (NASEIM, 2004; 2014). The American Academy of Arts and Sciences (AAAS, 2013) defines transdisciplinary as "an approach that represents a functional synthesis of methodologies and a broad point of view that combines different fields. This is a step beyond interdisciplinary which borrows techniques from different fields without integrating them to yield new concepts and approaches" (p.2). AAAS cites the example of the need to develop economically and ecologically sound replacements for fossil fuels as requiring input from chemical, systems and environmental engineering, microbiology, plant science, ecology, computational science, and economics, as well as an understanding of social change.

The transdisciplinary approach supersedes multi- and interdisciplinary practices and is better suited to addressing complex, open-ended problems because this approach transcends singular or interdisciplinary knowledge and applies domain-specific knowledge within an integrated framework. While multidisciplinarity approaches do include multiple disciplines; the differing perspectives are considered as side-by-side views on an issue. Interdisciplinarity extends beyond multidisciplinarity by integrating the theories, methods and concepts of several disciplines for the purpose of arriving at common solutions to multi-faceted projects or issues. (Cronin, 2008).

For example, math, physics, and engineering might be brought to bear in the design of a light-rail transportation system for a city in an interdisciplinary effort. A transdisciplinary approach would also incorporate knowledge from other disciplines such as marketing, finance, social science, humanities, and non-academic fields. In the light-rail example, transdisciplinarity might include input from neighborhood residents, government agencies, and civil society.

On a larger scale, researchers, practitioners, policy makers, and civil organizations have called upon the scientific community and society at large to address issues requiring sophisticated research and intervention involving a high degree of collaboration among disciplines. An example is the United Nations articulation of Millennium Development Goals which address several interrelated humanitarian crises including: eradicating extreme poverty and hunger; reducing child mortality; improving maternal health; combatting HIV/AIDS, malaria and other diseases; and ensuring environmental sustainability (United Nations, 2014).

AAAS (2013) asserts that *Transdisciplinary* better captures the extent of integration required than do terms such as collaboration, multidisciplinarity or interdisciplinarity. Transdisciplinarity is "the dismantling of disciplinary boundaries, rather than ad hoc collaborations, that could transform the scientific enterprise and deliver the potential to address previously intractable problems" (p. xii.) In a study of housing and health, Lawrence (2004) describes interdisciplinary research as a *mixing* of disciplines, while transdisciplinary research is characterized as a *fusing* of disciplines. In a similar vein, the National Academies of Science, Engineering, and the Institute of Medicine (NASEIM, 2014) have focused on the term "convergence" to describe the process of thinking beyond usual paradigms and approaching issues informed by many, integrated perspectives. Furthermore, the process of convergence takes place within a network of partners forming an ecosystem that facilitates basic research as well as translational applications and the potential to benefit society.

Expansion of research and teaching beyond traditional disciplines has been promoted in both scientific and business literature (Cronin,