Chapter 10
New Ways of Knowing and Researching: Integrating Complexity into a Translational Health Sciences Program

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10.1 Introduction

Health science research is tasked with addressing ever more complex health issues, necessitating an interdisciplinary approach which encompasses the overlapping "biomedical, social, policy, and environmental factors" contributing to potential solutions [1, 2]. Correspondingly, the next generation of health scientists must be educated in ways that allows them to respond to "multidimensional problems" [1] with an interdisciplinary, collaborative approach required to meet this challenge. We at the George Washington University School of Medicine and Health Sciences (GW SMHS) have attempted to meet this demand by developing a PhD program in Translational Health Sciences (THS). Translational science focuses on the "process of translating basic scientific discoveries to clinical applications, and ultimately to public health improvements" [3]. Our PhD program seeks to develop the skills required for future graduates to "change health care culture through innovation, develop and apply new products and technologies, and apply discovery to practices and policies that will serve the larger health care community" [4]. Similarly, we focus on exposing future researchers, clinicians, and educators to cross-disciplinary methods for research, practice, and education grounded in a collaborative ecology and a systems approach to exploring complex problems. Ideally, this approach will promote systemic uptake of research findings for greater social impact and train the next generation of researchers, practitioners, and educators to meet the demands of our increasingly complex health systems.

Future participation in THS will require unique skills: the ability to generate new knowledge through cross-disciplinary inquiry, appraise barriers and facilitators

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J. P. Sturmberg (ed.), *Putting Systems and Complexity Sciences Into Practice*,
https://doi.org/10.1007/978-3-319-73636-5_10

to knowledge generation and translation across the translational spectrum, communicate effectively across diverse settings and stakeholder groups, facilitate the development of shared mental models when leading collaborative research projects and incorporate diverse stakeholder perspectives in research design and practice, and translate findings to maximize system uptake and social impact. Developing these skills necessitates a cross-disciplinary, collaborative, and transformational approach to education which embraces a complex systems perspective. Adoption of this approach required a paradigm shift on the part of our faculty and students. Correspondingly, we sought to achieve a shared vision of the nature of our task and how it would be accomplished. In this paper, we explore how we met these challenges, making connections among the needs of various stakeholders and creating a model for learning design and delivery which embraces inherent tensions to allow for adaptation and emergence within our system.

10.2 A Complex Task at Hand

A complex adaptive systems perspective guides our consideration of the unique characteristics of the program of study we were challenged to create. Developing a signature pedagogy [5] for Translational Health Sciences doctoral studies requires the following:

- Creating a model and conceptual framework to guide our efforts toward expanding and extending traditional research practices
- Encouraging doctoral students to cull their interests with more system-wide intentionality
- Fulfilling the promise of greater social impact from dissertation research that integrates a translational, cross-disciplinary emphasis

The matrix in Table 10.1 shows how we align the inherent complexity in program design with the desired outcomes of translational health research.

10.3 Addressing the Needs of Diverse Stakeholders

Designing a doctoral program in Translational Health Sciences grounded in a *complex adaptive systems approach* requires meeting the needs of a diverse group of stakeholders and anticipating their potential reactions to the approach to program development. Stakeholders invested in our new program of study include internal stakeholders (university leadership, faculty, student) and external stakeholders (researchers, policy-makers, federal partners, industry, patients). To develop a program that would gain support across the multiple stakeholder sectors, we had to anticipate potential reactions to our approach to design and delivery and develop appropriate responses. Table 10.2 provides an overview of various

Table 10.1 Addressing complexity in model design

Dynamics	Epistemological tensions	Impact: significant or social	Credibility and relevance	Collaborative dynamics
Tensions between different epistemologies	x			
Interdependence among teaching team members				x
Crossing boundaries: stakeholder and disciplines	x	x		
Dynamic program and curriculum development				x
Minimum specifications and structure			x	
Emergence of new research models	x	x		x

stakeholders within the system, identifying potential reaction or need on the part of each stakeholder and our program's response to the anticipated need or reaction.

As Table 10.2 highlights, recognizing and addressing the potential diversity of needs among stakeholder needs can prove challenging but is also critical to achieve the "buy-in" required at multiple levels.

At the university level, adopting a complex systems approach which integrates multiple stakeholder perspectives has the potential to attract and generate multiple impact streams to ensure sustainability.

For faculty, a shared understanding of the value of an adaptive approach serves as the pedagogical scaffolding necessary to develop and deliver an integrated, cross-disciplinary, collaborative curriculum aimed at producing agile researchers who can navigate the changing dynamics of the current healthcare system.

Students unaccustomed to systems thinking may question the value of the approach for problem exploration and research. However, developing capability in systems thinking will help to ensure the incorporation of multiple stakeholder perspectives within future research to maximize the potential contribution of research findings for social impact and change within the health system.

As future researchers, graduates may then influence the approaches of future collaborators toward the study of complex problems in health. Researchers, particularly those inexperienced with cross-disciplinary techniques, who work with our students may come to recognize that the translational research process functions "exactly" like a complex adaptive system and, thus, is continually evolving based upon changing systemic needs.

Table 10.2 Stakeholder analysis

	Stakeholder	Potential reaction/need	Program response
Internal	University leadership	How is a complex systems program an asset?	The program cultivates multiple impact streams
	Program directors	How do I show the value of complexity?	Demonstrate the application of complexity theory
	Faculty	How do I integrate complexity concepts with my teaching?	The program adopts a cross-disciplinary team approach toward design and delivery
	Students	Why a systems approach?	It is required to ensure implementation and uptake of research
External	Researchers	What does complexity have to do with translational science?	Translational science by nature is a complex adaptive system
	Policy-makers	How does the complexity of the system influence policy decisions?	The program promotes multi-stakeholder involvement in policy recommendations
	Federal partners	We need cross-disciplinary researchers!	The program prepares collaborative researchers trained in a variety of perspectives
	Industry	Who will translate science into products?	The program will develop cross-disciplinary translational scientists with an implementation orientation

For policy-makers, program adoption of a complex adaptive systems approach ensures that policy recommendations represent multi-stakeholder input and engagement.

Industries are concerned about the translation of innovations into usable products, a task that can benefit from translational professionals familiar with cross-disciplinary approaches who can upscale knowledge translation across a complex health system.

Finally, patient outcomes, a hallmark goal in all health science scholarship, will benefit from multilevel, cross-disciplinary research that considers wellness needs from initial research design to implementation and uptake of innovation at a systemic level.

10.4 The Emerging Learning Model

A conceptual framework is essential to allow the emergence of a shared mental model [6, 7] among various internal and external stakeholders regarding our approach to educating future translational health scientists able to manage complex

challenges. Three main elements form the basis of the complex adaptive learning model for this Translational Health Science program. The complex adaptive characteristics outlined in Table 10.2 challenge the traditional doctoral training; however, they provide a scaffold for learners to perceive and approach solutions to problems in a systemic environment. The model entails three unique characteristics:

- **Oscillations between subjectivism (problem-solving) and objectivism (hypothesis testing)**—These dichotomies are indicated by the brackets serving as boundaries between the problem-solving approach and hypothesis testing approaches.
- **Scaffolding of collaborative, integrative, and transformational learning**—The complex adaptive learning characteristics are represented by the transcending spring helix within the model. Ideally, the scaffolding of pedagogical approaches will combine to create a transformational learning experience.
- **From a basic science to translational learning approach**—The progression from a basic science approach to a more translational approach is indicated by the upward arrow within the helix with these labels.

Figure 10.1 depicts this learning model and its three unique characteristics. It emphasizes the progression toward a perspective of transformative learning and research aimed at achieving socially impactful solutions to complex problems. The subsequent discussion addresses the inherent tensions contributing to model development.

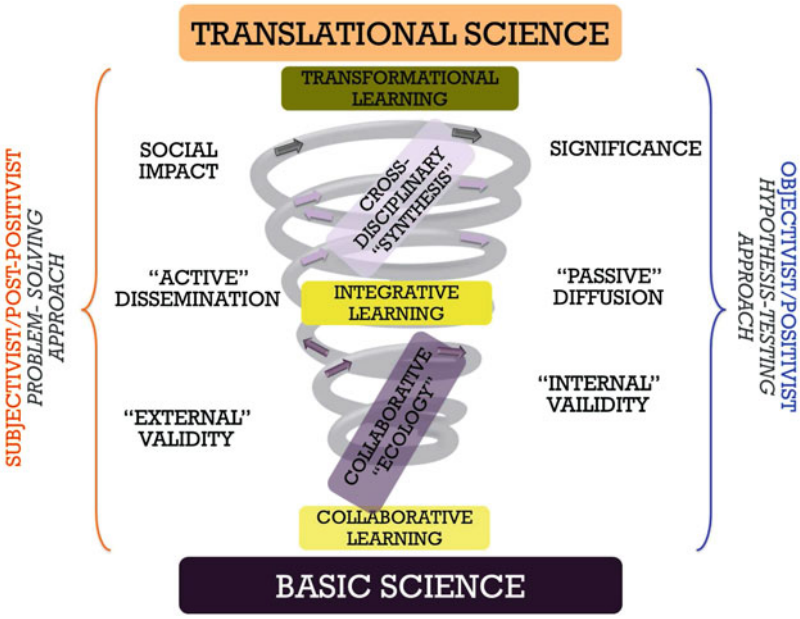

Fig. 10.1 A collaborative learning model for Translational Health Sciences [4]

10.5 The "Hidden" Creative Tensions in the Model

While this model challenges the *status quo* and may make some feel anxious to move forward, it excites by creating creative tensions to accelerate the process.

10.5.1 Epistemological Tensions

The need to consider an expanded epistemological spectrum in Translational Health Sciences stems from the indelible characteristics of paradigmatic selection that has its roots in historical models of normal sciences [8]. Several normal sciences contribute to the array of translational health inquiry including but not limited to biology, chemistry, and physics. Within health sciences, the strands of science at work in understanding the human condition often intertwine in ways; as Jürgen Habermas has described, these represent several operative conditions that make up an expanded epistemological interest typology including the natural (technical), interpretive (practical), and critical (emancipatory) sciences, all of which are key to integrated health science inquiry.

The Habermasian *knowledge interest typology* provides clearer pairings of scientific interest with dominant epistemological lenses and methods while simultaneously recognizing their individual contributions [9]. Holistic healthcare, and the research that informs it, relies on conversations among the technical, narrative, practical, social, and emancipatory interests of science; ultimately such cross-paradigmatic conversations will produce new and novel technical, theoretical, and processual outcomes. From this perspective, we can consider personalized health, environmental factors to health, and the sociology of illness through a blending of paradigmatic interests drawing from normal science but not completely bound to any one science's limited scope. Epistemological paradigms serve to encourage receptivity to the potential of chaos and complexity in research activity and knowledge generation [10].

Paradigms of knowledge not only represent different scientific lenses, but they also symbolize ideological and political viewpoints that, as in all research, contain biases requiring careful attention by the researcher.

Quasi-experimental, experimental, and naturalistic approaches all contain political biases by nature as by their rules of engagement, they all focus their aperture on only small increments of the natural world. The act of choosing a paradigmatic lens for which to conduct inquiry serves as a mechanism for framing the knowledge that one hopes to acquire through research [11]. In health science research, certain paradigms prevail as more appropriate for certain expected outcomes. For instance, positivism/objectivism is an appropriate paradigmatic lens for conducting randomized controlled trials and even for conducting social surveys because these can be quantified to achieve potential reliability and to provide deterministic results.

In contrast, health science has incorporated constructivist paradigms like subjectivism, post-positivism, and critical theory that dislodge positivism, allowing for naturalistic knowledge to emerge from human experience. Analyzed and interpreted, these experiences inform how complex adaptive systems' understandings might reveal multiple insights into a problem, which in turn reinforces the need for a cross-disciplinary approach to inquiry.

Health science research can afford to look to different approaches as research designs evolve that solve more complex problems beyond those that can be normally solved through any one epistemological paradigm or within the boundaries of any one normal science [11]. The blending of research paradigms is representative of the complex process required to reach desired goals.

For these reasons, we believe skills that encourage scholars to oscillate between the extremes of the paradigmatic spectrum are an essential aspect to recognizing the relationship between different types of research and their models and methods. Recognizing the value of a cross-paradigmatic approach will assist future researchers in informing knowledge building in a complex adaptive world.

10.5.2 Impact: Significant or Social?

In a similar strain to the tension between deterministic and more subjectivist paradigms, measures of the value of research and its ability to impact intended audiences need to be considered if research is to be truly translational in character.

Significance, as a scientific term, is used in a specific way to indicate a measure of certainty as it applies to results often based in experimental or semi-experimental inquiries. Its meaning in naturalistic approaches differs greatly, as, by definition, naturalistic inquiry does not claim determinism as a goal. In the health sciences, "clinical significance," for instance, describes the extent to which a measure quantifies the impact of services [12] and treatment and/or quality of life [13]. In training future translational health scientists to negotiate the relationship between these approaches, competence must include skills in how to manage multiple meanings of significance in research.

As an alternative to the more reductionist measures that dominate some biomedical research, Translational Health Science depends equally on scientific significance as well as social impact. Health science research which emphasizes the translation of basic, human, clinical, social, and policy sciences to products must consider the effectiveness of research to move beyond quantitative significance to a measure that includes the potential and innovative qualities that allow for research to impact human health and wellness. Here additional emphasis is on the effect of an activity on one or more populations of a community and the well-being of individuals and groups.

The need for ensuring social impact in health science is not oppositional to supplying significance in research findings. Rather, social impact is a partner element in translational research as it serves as the tangible outcome that affects

change through discoveries that are delivered to a needed public, population, or even professional community. Such products can be in the form of content analyses, software, healthcare technologies, public awareness campaigns, and teaching contributions [14] all of which depend equally on evidentiary science and the value of discovery to benefit society.

While research-intensive doctoral studies typically have not extended findings to this applied level, they have raised awareness of the need to incorporate methods and measures of the potential of discovery to impact health standards and quality. All phases of health research are required to consider what the social impact of research might be no matter what phase of the translational spectrum is in focus at a given time. The nature of multiphase translational research, in which basic human, clinical, and applied attributes of science inform one another simultaneously, illustrates the reciprocal nature of integrating various disciplinary and epistemological viewpoints.

Partnering of social impact and scientific significance will be a fundamental element to the doctoral dissertation process, so that the evidence-based biomedical sciences which often focus on deterministic factors can be paired with health sciences to accomplish pathways that impact humans and populations.

10.5.3 Credibility and Relevance

Focusing on measures of impact that research might have on the environment and the potential population health leads us to consider the validity of research for scientific inquiry and implementation.

Credibility is ultimately a combination of factors that contributes to the relationship between a source of knowledge and its trustworthiness considering its application [15]. Science relies on methods that assist in ensuring either that findings have been tested by some rigor of scientifically designed testing or that the new knowledge is relevant by nature of its ability to describe human and/or natural experiences [9].

Scientists often exploit credibility and relevance to convey the appropriate application of naturalistic or experimental findings. In other words, dependent on the epistemological stance, scientists assess the credibility of research on the reliability of the data collected either in vivo or in vitro. Ultimately, trustworthiness of this translation relies heavily upon the extent of the researcher's skills [16].

In Translational Health Science research, a combination of external and internal validity factors is more commonplace than in other more unidisciplinary sciences. No matter if they are more experimental, quasi-experimental, or naturalistic, in nature, basic discoveries depend greatly on internal validity grounded in the techniques and standards of host disciplines. These are often those sciences that dwell in the basic and exploratory regions of the translational spectrum (T0–T2). Conversely, external validity that strives to ensure that the scientific enterprise is in concert with external factors of implementation and application (T3–T4) is far

less prone to identification and controlling factors and may provide alternative explanations for results [15]. Such sources of certainty, bias, and possible error need to be triangulated on a regular basis so that measurement of validity [17] for the real world, and feasibility of delivery to the targeted populations, is a constant goal for research findings no matter where on the translational spectrum such science dwells naturally [18].

The ability to translate evidence-based science to implementable results and products requires reporting factors that might influence external validity and ultimate uptake, such as dosage, time requirements, cost, training and certification, interdependencies, etc. This task of the research process can be challenging especially when hypothesis-testing research is normative to the discipline of the post-professional doctoral trainee. Trainees from a more controlled research environment with its focus on internal validity might find the creative task of ensuring both external and internal validity in research design and application challenging [19].

This Translational Health Sciences training program will guide doctoral students to synthesize and integrate these sometimes seemingly oppositional research frameworks. Collaborative and integrative learning principles and activities will expose students to the continuum represented by these mind models and their contributions to Translational Health Sciences. Thus, students will be exposed to increasingly higher levels of scholarly consideration.

10.5.4 Collaborative Dynamics

As a core concept, collaboration serves as the vehicle by which much of the translational process might successfully occur. Collaborative teaming is much of cross-disciplinary science and the skills required to perform under these unique conditions is a key aspect of learning. Much attention has been given to the mechanisms of collaboration as it is applied to health science outcomes [20–22].

Of particular note is the emphasis on the building blocks of teaming in science that draw our attention to an ecology that highlights:

- The practical aspects of interpersonal relationships between scientific stakeholders
- The intrapersonal factors of individual readiness and disposition to collaboration
- The organizational factors necessary that foster and support collaboration
- The growing technologic factors that continually impact science and research especially in teams
- The physical environments in which people work
- The sociopolitical climate that challenges and/or supports collaboration [21]

This seemingly complex set of concerns is only a starting point for doctoral students who hope to be able to engage in higher-order systems thinking, as they consider socially relevant and impactful research topics. This is achieved by building competencies in several important areas that allows doctoral students to

gain the necessary confidence to emulate these in their scholarly work. These include growing in knowledge, skills, and abilities toward teaming, developing appropriate attitudes and growing in readiness to accept cooperative acumen, the ability to coordinate and to be part of a coordinating group, advanced skills in communication, cognitive abilities and maturity that lead to shared mental models, leadership insights, and an awareness of one's social and environmental conditions [23, 24].

Collaborative abilities are requisite skills, and their development will facilitate the performance of complex details associated with conducting cross-disciplinary research [25]. Systems thinking emphasizes the interrelationships among stakeholders within complex systems, such as healthcare systems [26, 27]. A systems approach to problem-solving and knowledge generation in healthcare is essential to anticipate how interactions among system stakeholders influence knowledge generation, implementation, and dissemination [27]. Adopting a systems approach when engaging in collaborative problem-solving and knowledge generation allows teams to recognize the value of multi-stakeholder representation in research. This in turn is a prerequisite to integrate diverse stakeholder voices into plans for future implementation and dissemination of innovations, which is ultimately required to ensure the systemic uptake of the newly generated knowledge [28].

Doctoral research that hopes to achieve high social impact and relevance must acknowledge the complexity in the healthcare system and seek to address the interrelationships among systems components by adopting collaborative, cross-disciplinary approaches that anticipate the potential impact new knowledge might have for stakeholders across the translational spectrum.

10.6 Conclusion

Going forward, our model will help to communicate the complex dynamics inherent within our program of study across various system stakeholders. It also helps support our reliance upon a team approach to course and curriculum design. Our next steps include evaluating the degree to which the model was applied in curriculum and course design and the resulting efficacy of this contribution. In our first semester, we have integrated a complex systems approach, through concepts such as stakeholder analysis, systems mapping, and influence diagrams, with critical components of collaborative dynamics, such as perspective differentiation and integration, and collaborative and team characteristics and principles. Artifacts from the semester indicate how students are operationalizing the tensions we have recognized and addressed within our model. Yet, it remains to be seen, and assessed, as to how this interdisciplinary integration will contribute to the achievement of semester competencies and overarching program goals.

This paper details our application of a complex adaptive systems lens to the task of designing a PhD program for future translational health scientists. Recognizing and addressing the needs of various system stakeholders prior to designing our

conceptual model was essential to ensuring we achieved shared understanding of the tensions inherent in working toward our goal of developing translational researchers, particularly for faculty charged with curriculum design. As we are only two semesters into our first cohort of students, we cannot yet discern progress toward our end goal of research designed for systemic uptake and greater social impact. However, our students' application of complexity concepts within the first semester of the program indicates their recognition of the value of adopting a complexity lens to fully explore tensions inherent within healthcare system that may serve as barriers or facilitators to future research and knowledge generation, which is a critical step in considering how to design future research which navigates those tensions for systematic uptake of findings. While further assessment is needed regarding the relationship between our model and achievement of program goals, this application indicates we are on the right path toward educating future researchers who can apply complexity concepts for problem exploration and future research design.

The Journey

I first encountered complexity theory in my doctoral studies. As a former naval officer with a minor in engineering, systems thinking came naturally. However, the concepts related to complex systems—self-organization, emergence, adaptation, unpredictable outcomes, minimum specifications—were initially a bit harder to grasp. But, when I started to work on my dissertation in blended learning, the increased complexity in the learning environment and the adaptation it would require on the part of the learner made the concepts of "minimum specification" and "unpredictable outcomes" more poignant when considering how to design systems that would allow for maximum adaptation but still support achievement of learning outcomes. From this point on, I could not look on a learning or leadership situation without questioning how a complexity lens might influence my approach to facilitation and problem-solving.

Later, when teaching leadership and change to healthcare professionals, I recognized the importance of teaching a complex systems perspective to problem exploration and resolution. Like me, so many of the healthcare leaders found static models of leadership and change limiting and found a complexity lens beneficial to anticipating the tensions within a system that might serve as barriers to change and innovation. For this reason, when I was designing the curriculum for our new PhD in Translational Health Sciences, I knew that a complex systems approach must be integrated at the beginning of the curriculum to encourage students to explore problems from a new lens from the very beginning of their program of study. Already, we have seen how this approach has influenced their discussions of stakeholder interdependence and barriers to change and innovation within health systems. I look forward to seeing what emerges from the minimum specifications we have provided! (Paige McDonald)

When I started my career investigating the science of team science (SciTS), I naturally gravitated toward cross-disciplinary knowledge generation and attempted to pair these fields of study. The origins of transdisciplinarity grounded in social learning and globalization fueled my interest in how we might train a new generation of translational scientists who are versed in crossing disciplinary boundaries as they attempt to solve wicked health problems while working in collaborative scientific teams. The intellectual and learning journey I am presently on has brought me to appreciate that collaboration and cross-disciplinary science exists as both complementary and conflicting constructs. Complexity science serves as a means that I might make sense of this relationship. Complexity science provides the framework by which to understand these reciprocal relationships and serves as a useful knowledge arena for new scientists to understand how they might successfully achieve these goals and generates new knowledge to inform practice in the ever-changing healthcare landscape we live in. (Gaetano Lotrecchiano)

Take-Home Message

- Adopting a complexity lens for exploring the task of developing a PHD program is essential to ensuring buy-in from many internal and external system stakeholders.
- Designing the PhD program required negotiating multiple, perhaps contradictory, stakeholder needs.
- Creating a model of the tensions negotiated within the program of study proved critical to promoting shared understanding among faculty of the task at hand.
- The learning model proposed adopts core tenets of complexity science that allow for minimal structure and emergence to serve students as they evolve in their perceptions of cross-disciplinary and collaborative science and scholarship.

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