# The Epistemology of Complexity and 'Doing' Interdisciplinarity

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# The Epistemology of Complexity and 'Doing' Interdisciplinarity

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Abstract: Complexity is now well established as the driver of interdisciplinarity, but what this means for how knowledge is 'done' within Interdisciplinary Studies has not been well developed. This paper examines the theory of complexity and unpacks its epistemological implications for doing interdisciplinary work. The epistemology of complexity demands a cognitive toolkit that includes such things as open-mindedness, tolerance of uncertainty and ambiguity, and intellectual courage. This paper draws out these connections and suggests implications for curriculum development in Interdisciplinary Studies.

## Complexity, Newell, and the IDS Literature

Two ideas resonate throughout the interdisciplinary studies literature: complexity is at the heart of interdisciplinarity, and an epistemology of complexity is predicated on non-reductionist methodologies. William Newell (2001) first introduced complexity theory as an explanation and justification for interdisciplinary studies. Drawing on the theory of complexity as an explanatory framework for change and adaptation as developed in the natural sciences, Complexity implies a systems perspective in which "a complex system is composed of components actively connected through predominantly nonlinear [self-organized] relationships." (Newell 2001, 9). Newell posits that interdisciplinarity is necessitated by complexity and complexity provides a rationale for interdisciplinarity (2001).

Newell's work was met with much fanfare, and indeed, much dissent. Respondents argued that Newell's use of complexity was too generic (Mckey 2001), and that complexity in interdisciplinary studies was best used as a heuristic device (Klein 2001). Although Newell's original work continues to be widely cited, the meat of the theoretical framework has been largely excised, and the term "complexity" when utilized within this discourse typically refers to a generic understanding of something slightly beyond complicated. Indeed, the defining features of complexity, such as non-linearity and self-organization, are often completely absent. Complexity theory purports to explain chaos, adaptation and change in various realms of natural science, and it heralded a paradigm shift in the epistemology of science (Suteanu 2005; Morin 2007; Capra 2014). Paradigm shifts take time, however, and resistance to the challenges of the status quo have led to the adoption of "restricted complexity" in which, rather than pursue the new dimensions of knowledge promised by complexity, complexity is decomplexified (Morin 2007, 10).

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Newell's definition fully embraced the challenges of complexity. It does challenge the academic status quo, a large part of which is underwritten by an epistemological belief in the capacity of knowing objective truths about the world. Complexity theory suggests, as will be discussed in greater detail, that the world is comprised of complex systems that are fundamentally unpredictable, and so working together increases capacity to understand real-world problems and deal effectively with issues in the increasingly complex world. Eschewing Newell's assertions undermines the power and promise of interdisciplinarity and misses an opportunity to be among the leaders re-shaping the academic landscape in step with the shifting tides of culture, the economy, and the environment.

It may be the case that alternative theories are better suited to explain and justify interdisciplinarity; however, to the extent that complexity theory remains the dominant structural metaphor for interdisciplinarity throughout the interdisciplinary studies literature, it seems reasonable to take a closer look at the theory and flesh out (or re-flesh out) the implications for teaching and learning within and interdisciplinary studies context.

This paper revisits complexity theory to identify its key features and the epistemological implications thereof. As the foundation of interdisciplinary studies, a complexity theory renaissance is essential to effective teaching, learning and research in this growing academic arena.

## From Objects to Relationships-The Epistemology of Complexity

There is no consensus on the definition of complexity, however, there is sufficient consistency in the identification key elements thereof to compose a general picture. Complexity theory is a theory of development, adaptation and change that examines the regularities in systems that at times seem chaotic and even random. Complex systems are ubiquitous throughout the living world: organisms, ecosystems, weather systems, social systems. Complex systems are multi-faceted and multi-layered, such that they may have different appearances from different perspectives; in turn, these different perspectives often reveal different sets of relationships (Newell 2001, 2). Complex systems are multi-layered: trees and forests, people and societies, ants and ant colonies. The list is quite literally endless. Not surprisingly, then, complexity refers to a new science "that recognizes that there are fundamental principles governing our world— such as emergence and organization— that appear in various guises across all of the nooks and crannies of science" (Miller 2015, Kindle Locations 206-208).

Complexity theory compels a perspective that sees a world comprised of a series of interactional relationships among various entities at various levels of organization (Johnson 2009; Mitchell 2009; Capra and Luisi 2014; Holland 2014), thus its ontological orientation compels its epistemology. In other words, complexity compels a view of the world in which there are no static or inert objects, only relationships. This implies a view in which everything is dynamic, in motion, changing, and interactive. How one 'knows' about such things is thus rather different from a worldview in which the world is understood as being composed of discrete, individual, static object, as is the worldview of traditional mechanistic science. Whether it is the assortment of biological systems that orchestrate the human body or the transactions between consumers,

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businesses and regulators that animate the economy, the point is that these entities are relationships in process and cannot be reduced to basic or fundamental units.

The primary epistemological imperative of complexity theory, therefore, is a shift of focus from objects to relationships. Western epistemology has employed various strategies of reductionism such as logical positivism, dualisms, and commitments to absolute truth to capture and subdue complexity into linear, understandable, and ultimately manageable forms of knowledge, says Welch IV (2009). As one scholar points out, however, in the complexity view of the world "reductionism fails because even if you know everything possible about the individual pieces that compose a system, you know very little about how those pieces interact with one another when they form the system as a whole. Detailed knowledge of a piece of glass does not help you see, and appreciate, the image that emerges from a stained-glass window" (Miller 2015, Kindle Locations 204-206). The obvious utility of reductionism notwithstanding, its ability to deal with increasing complexity is limited and its methodologies limiting.

The shift of focus from objects to relationships is a key principle in this new science, and it has several important implications for Interdisciplinary Studies. That reductionist ideology is imprinted on our academic institutions via the disciplinary structure is well-established:

> Science as currently practiced— with psychology separate from economics, physics separate from biology, and on and on— has been remarkably productive. The creative destruction of scientific ideas, with its inherent quest to define the frontier by publicly disclosing, evaluating, and correcting ideas, has provided us with an engine of insight. The cost, however, is that individual fields have become increasingly separated from one another intellectually. Taking an exact look at a small piece of the world has become the academic norm and has almost fully displaced taking what my Santa Fe Institute colleague Murray Gell-Mann calls 'a crude look at the whole.' That may seem a minor problem, but we see its importance when we look at the true places we wish to explore. Take any global-scale, societal challenge, such as financial collapse, climate change, terrorism, epidemics, revolution, or social change: not one neatly aligns with any particular academic field. (Miller 2015, Kindle Locations 216-222)

Disciplines are tools of a reductionist epistemology, and so simply combining the tools of reductionism, regardless of how seamlessly they are integrated, amounts to another level of reductionism. Simply combining different forms of reductionism maintains reductionism, even if in a new form. Thus, interdisciplinarity, as grounded in complexity theory, as is often claimed by IDS scholars and implied by the limits of reductionism, has to be more than merely combining (integrating or whatever agitative verb one wishes to use) the established areas of study. This is not to suggest a destruction of all disciplinary structures, as some IDS scholars accuse dissenters from their perspective; rather, complexity theory compels a different way of working with them. There is a new way of doing knowledge (though the novelty of this approach is highly debatable).

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Indeed, we are beginning to see a re-structuring of academic institutions around key issues, problems, and ideas, as in the case of the re-structuring plans at the University of Central Florida.[1] For academia to remain relevant and maximize its benefits in society, it must be responsive to the changing needs of its students, faculty, and broader communities (ideally, it would adapt a lot quicker than it historically has). And to do this, it really must strive to cultivate insights more fruitfully from *between* the disciplines–hence interdisciplinarity. From an interdisciplinarian's perspective, the changing face of the university to this end is a good thing, but it is not quite sufficient without a broader more pervasive shift in how knowledge is done not just organized.

To know about complex systems, one cannot break them down, as this destroys the very system one is trying to study. In other words, one cannot approach the study of complex systems through a process of domination, dissection, and control such has been the methodological ideals of traditional scientific approaches. Complex systems exist through a continual exchange of information within the system and between the system and its environment(s). These are often referred to as feedback loops. Furthermore, people, researchers, knowers, are also complex systems, and so knowing about complex systems is best understood as a process of engagement: participation, or a creative exchange of information between the system and ourselves. With reductionist methodologies, the objective is often to subdue the object of inquiry, but a complexity perspective suggests that knowing in this context requires interaction or engagement. To engage as an active participant rather than an objective observer is a challenge to the cognitive status quo of Western epistemology (Welch IV 2009), yet it is revealing whole new dimensions of the universe.

There are two key interconnected takeaways: First, it is insufficient to teach interdisciplinary studies as merely a method of combining established areas of study. This is only a part of the picture, and arguably a rather small part as complexity compels a healthy skepticism of the disciplinary boundaries imposed from reductionist ideology (Post 2009; Forman 2012; Frodeman 2013; Crow 2015). Second, consistent with complexity theory, interdisciplinarity is best taught as process of engagement. In moving from objects to relationships the process of learning is transformed from that of an outside observer or consumer of information into a form of interactive engagement—a creative process. It is therefore the cognitive tools of engagement that are crucial to a fully realized complexity and hold the power and promise of a fully realized interdisciplinarity.

## Complexity and the Cognitive Toolkit for Interdisciplinary Studies

The concept of complexity, in the context of interdisciplinarity, provides both a means of "seeing" the living world—its organization and dynamics—and a helpful metaphor, as Klein (2001) suggests. Although scholars have already incorporated complexity theory into the humanities and social sciences in a variety of ways, Chettiparamb (2007, 7) suggests a framework of "generalized discourse" as a basis for more widely applicable use. Chettiparamb (2007, 7) notes that "systems can be material (e.g. the ecology), conceptual (e.g. theories) or semiotic (e.g.texts)." The concern here is thus not so much with the myriad of differences one might find in how complexity is

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[1] See article in UCF Today: https://today.ucf.edu/provosts-update-new-colleges-schools-will-chart-bold-future-ucf/.

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conceptualized, but rather, it is with particular key elements that various analysts have identified fairly consistently. These elements provide a common ground that allows for a window into potential benefits of the complexity lens.

Brent Davis (2004) defines complexity as: "the study of adaptive, self-organizing systems—or more colloquially, the study of living systems—or, more educationally, the study of learning systems" (211). The learning is not always conscious, is not always planned, and is often messy and chaotic. Insights that emerge from this context are unpredictable and often useless, yet one grasps for tools to render them intelligible. These tools typically come from established disciplines or a combination thereof. Some insights will stand, most will fall, yet there seems to be a tendency to yield to the urge to dive in again and again. Indeed, this is what interdisciplinarian tend to do (Woodill et. al. 2019). The following is a discussion of several key attributes at the heart of a complexivist orientation.

## Open (Open-mindedness and Empathy)

Complexity theory presents the organic world as constantly developing through the dynamic adaptive interaction of entities (which are themselves complex systems) with their environment through feedback loops (Miller 2016; N. Johnson 2009; Mitchell 2009). Referring to more literal understandings of complex systems, "unlike closed systems, which settle into a state of thermal equilibrium, open systems maintain themselves far from equilibrium in this "steady state" characterized by continual flow and change," (Capra and Luisi 2014, 86). Humans, for example, stay alive via a constant exchange of energy and information between the body and the environment. These entities change and are changed by their context.

Two points are important here: complexity is essentially a creative process thus engagement is also a creative process, and this process is facilitated by openness—an exchange of energy and information that implies impact or change. To "know" in the context of complexity is to engage, and to engage is to be open in various ways.

The concept of open-mindedness in education has a lengthy history explained by William Hare as one who is both willing and able to revise their own position (Hare 1993, 8). More contemporary understandings of open-mindedness include the action of taking seriously alternative perspectives such that open-mindedness is actualized not merely potential (Riggs 2015). This being said, how perspectives are acquired within frameworks of understanding and embodied in our experiences of the world can make open-mindedness quite a challenge (Wilson and Foglia 2017; Johnson 2017). Openness, it seems, is more fruitfully facilitated through embodied engagement (Johnson 2017).

That traditional education has squashed creativity and open-mindedness has been much lamented by education scholars, most famously argued in the Ted Talk by Sir Ken Robinson (2006).[2] The disciplinary nature of traditional education has been to prune, refine, and purify knowledge while policing the boundaries of disciplinary silos (Montuori 2012). Yet, the products of open and

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[2] This Ted Talk is listed as the most viewed talk of all time:
https://www.ted.com/talks/ken_robinson_says_schools_kill_creativity?referrer=playlist-the_most_popular_talks_of_all.

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creative engagement are often visible in artistic disciplines of music and theatre and even the humanities, although these areas often still suffer the stigma of lacking rigor, utility, and prestige. Interdisciplinary Studies has been showing that mixed methodology approaches that incorporate openness and engagement are at the forefront of innovation and the demand for such practitioners is increasing steadily (Schwab 2017; Schwab, Davis, and Nadella 2018; Repko, Newell, and Szostak 2011).

Open-mindedness is typically cited as an epistemic virtue, but it is predicated on empathy. Antithetical to certainty and judgement, empathy requires an often conscious attempt to inquire into the context in which behavior and action takes place (Ludvik 2016). It removes the barriers to inquiry by starting from the premise that despite the apparent morality or seemingly irrational aspects of action and behavior, there is a contributing context. It is an intentional look towards the context to survey the myriad of variables at play in any complex system, be it social or otherwise. It is an attitude that starts with an ignorance-based worldview—an assumption that regardless of what one knows, it is not all that there is to know (Montuori 2012). Humility, in other words.

There are some well-established ways of fostering open-mindedness and empathy. On a program level, flexible programs that are adaptable to the individual students or that are based around a particular topic rather than a discipline are some viable examples  (Montuori 2012), but these programs will be problematic for those students that might need development in the cognitive tools necessary for self-directed creative openness. Pedagogical tools, such as in the areas of mindfulness , play, improvisation, art, music and experience and storytelling can help in this area (Ludvik 2016). Relationship-building among those with a diversity of experiences is one way of developing empathetic capacity, and so finding ways to facilitate such relationships within the learning environment will undoubtedly contribute to cultivating these attributes.

## Intellectually Courageous (Tolerance of Ambiguity/Uncertainty and Taking Risks)

Western thought has often been marked by a compulsion for linearity, but complexity theory has prompted an acknowledgement of the non-linear structure of the living world as a composite of complex systems. Within the purview of science and reason, Welch (2009, 40) writes that traditional epistemology "constitutes an attempt to simplify complexity into linear structures." This is to say that the nature of complex systems—contrary to the demands of logical positivism that underwrites traditional epistemological orientations—precludes precise determination of initial conditions, which confounds the task of identifying cause and effect. This is perhaps the largest challenge to the traditional scientific paradigm (Suteanu 2005). Minute changes can have gigantic effects and vice versa, and so prediction and control in the traditional sense must be relinquished in exchange for and uncertainty and ambiguity. Intellectual courage is thus a fundamental feature of creative engagement.

Traditional educational approaches to knowledge have centered on how one knows for sure, and throughout the development of standard scientific practices, debates raged as whether or not certainty was found in inductive or deductive methodologies. What was not up for debate, however, was that objective knowledge existed independent of one's perception and this objective knowledge was indeed accessible (Woodill 2014). Disciplines have developed methods and explanatory frameworks for bringing forth a world of rigorous and reliable knowledge that is

delivered to learners in a context that rewards truth and accuracy and penalizes alternatives. Furthermore, the right/wrong ideology permeates a host of cultural realms in which uncertainty is denigrated in its equation with vulnerability, weakness, danger, and even sin (Gilson 2011). Yet, complexity compels knowledge through interaction and engagement, engagement through openness, and openness through skill in navigating ambiguity and uncertainty.

In many ways, where IDS programs facilitate the recuperation of an academic trajectory seemingly gone awry, it does provide an academic context amenable to the profits of failure, but extending this concept to the classroom more extensively is problematic when buttressed against the demands for reports and analysis that focus goals and objectives contrived in the pedagogical tools of traditional academia. Institutional academic structures are deeply rooted in reductionist ideology, though this is undoubtedly changing. Program innovation and faculty can do much to provide accommodating space, as UCF notes in its "Collective Impact Strategic Plan".[3] Pedagogical tools such as virtual reality and simulation, role-playing, service-learning, internships, entrepreneurship opportunities and iterative authoring exercises provide safer spaces for trial and error experiences that can foster students' capacities with ambiguity and uncertainty as they develop intellectual and academic courage to step out into the unknown. The challenge for educators in this framework is to develop assessment tools that do not re-capitulate the trauma of catastrophic failure characteristic of the traditional disciplinary approach.

## Collaborative (Attunement)

The mechanistic metaphor that has come to symbolize science, though it offers considerable utility, has also yielded an understanding of the world as essentially constructed through external manipulation and force; by contrast, complexity theory demonstrates the creative powers of self-organization. Some genes self- organize into skin cells and others into muscle cells. Birds form flocks and people form societies through interaction and correspondence with each other and the environment. Self-organization is a process-based relationship that opens to the emergence of unpredictable and uncertain novelty. It is the creative power of the collective that drives innovation at scale. Learning from a complexity viewpoint means interaction/engagement, engagement requires openness, intellectual courage, and collaboration.

Complexity of systems implies that it is not possible to know everything there is to know about a system, thus collaboration provides some important resources. It is a way of gaining others' insights into the system thus broadening knowledge. Each person involved in the collaborative project becomes a type of cognitive augmentation for another. Furthermore, given the inherent unpredictability of complex systems, and given that everyone is impacted by these systems, it becomes increasingly important to develop effective ways to respond to unexpected events in a coordinated fashion. Collaboration increases the capacity to rise to this challenge.

Collaboration is nothing new or specific to interdisciplinarity; however, there is an argument to be made that interdisciplinarity has a higher demand for it. Collaboration can be understood loosely as a process of co-creation between an entity and the host of resources one encounters within its environment, and this is an important understanding of collaboration in terms of engaging

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[3] See: https://www.ucf.edu/wp-content/uploads/2012/08/UCF-Strategic-Plan-BOT-FINAL-052616-Web.pdf.

complexity. It is the basis of what Alfonso Montouri calls "Creative Inquiry" (2012). In this framework, an appreciation for the richness provided by diversity is paramount. More practically, for the purpose of curriculum development, self-organization implies collaboration with other learners in a context that allows for a great deal of autonomy. Complexity is a product of self-organization, a concept that will be discussed further in the next section, but crucial to self-organization is a great degree of autonomy. This means a relinquishing of the hierarchical gate-keeping ethos of disciplinary ideology, and this poses a great challenge for evaluation and assessment within traditional modes.

The cognitive tools of collaboration overlap with the discussion in previous sections. What is significant here, however, is the willingness to participate in shared experiences. Education as a collective accomplishment rather than an individual achievement challenges the individualistic meritocracy typically asserted as the basis of learning. Communication, open dialogue, listening, compromise, and finding common ground, are all important aspects of collaborative interactions, but what seems to prove difficult is the notion of relinquishing power and control of the situation in favor of adopting the power of influence. Cooperation rather than domination.

The winners and losers framework permeates Western culture, and there is something to be said for the power of competition, but complexity theory inspires another approach. The concept of the butterfly effect is well known beyond the confines of complexity theory, but it is deeply rooted in the systems thinking perspective. The idea is that given the unpredictability of complexity one cannot know the impact of one's action, and thus small actions can have dramatic impacts or no visible impact at all. The win/lose framework is not applicable here, at least not in any conventional sense; rather, what seems more relevant is the adoption of appropriate epistemic values as guiding principles of a collaborative (read: complexity) epistemology. These epistemic values include prioritizing conservation, cooperation, quality and partnership overs expansion, competition, quantity, and domination (Capra and Luisi 2014, 13). Complexity is often represented by the web metaphor, and in this framework, in which individuals are portrayed as deeply connected, empowering others can be seen as a form self-empowerment, thus "a social network, people are empowered by being connected to the network. Power as empowerment means facilitating this connectedness" (Capra and Luisi 2014, 14). Collaboration might be best understood as the art influence, or "gentle action," (Peat 2016, Kindle Location 2324).

The pedagogical tools for cultivating these values need to be more fully developed for implementation into the interdisciplinary studies context, but there are sources that seem viable. Frank Barrett (2012), for example, draws on jazz pedagogy, a quintessential forum of collaboration, to propose lessons for organizations to develop their collaborative capacity. James Welch IV (2007) utilizes a similar framework as explanation for the development of interdisciplinary skills. The basic premise is a shared set of relatively simple rules (common ground), basic facility in the genre (individual experience), and repetitive engagement in communities of practice (development through iterative feedback loops: attunement).

What all knowledge practitioners share is the human experience and one's own interpretations of it. It seems that experiences that challenge comfort zones such as trying new things and learning new skills provide a platform for developing the types of tools necessary for collaborative skills

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(Ludvik 2016). Opportunities for planning and creating events, documents, artifacts, and open discussions, storytelling and sharing resources would be constructive in this vein.

Curious (Critical and Creative Thinking)

Complex systems are nested arrays of relationships, or webs of interaction that develop through the process of self-organization. Webs, which may be seen as comprising individual systems or individual entities, cohere into larger systems: they self-organize into complex adaptive systems, generally conceptualized as networks (Barabási and Pósfai 2016; Capra and Luisi 2014). For example, cells interact to form an organ, organs interact to form a body, bodies (at this level now understood as people) interact to form communities, and so on. Complexity theory posits that a multitude of intricate web-like systems constitutes the fabric of the living world.

A complexity framework acknowledges that the observer's perspective conditions the observations (Chettiparamb 2007). For instance, clouds that may resemble a jumble of shape-shifting wildlife to a lay person's gaze, may instead appear as a complex system to the environmental scientist interested in the various elements of their constitution and their role in the atmospheric system. The cognitive investments of the observer, as Welch IV (2007) suggests, are significant. In contrast to the dictates of traditional Western epistemology, complexity theory conceives of the observer as the fulcrum of the research process.

Flourishing is most abundant at the edge of chaos where resources are rich and rules are simple. "The edge of chaos is where new ideas and innovative genotypes are forever nibbling away at the edges of the status quo, and where even the most entrenched old    guard will eventually be overthrown" (Waldrop 1992, 12). Such conditions encourage dancing with chaos and cultivating complexity rather than merely imposing dualistic habits of thought that advocate "control over chaos, the reconciliation of its inherent disorder with a more static underlying order" (42). Simeon Dreyfuss (2011) argues that interdisciplinary work requires several important skills on the part of the interdisciplinarian. These skills include being able to think relationally, which he describes as "holding in relationship different ways of knowing" (67). The more one wanders in a topic the greater the resources that are encountered and the greater the potential to "discover" something new and cultivate the art of "smart luck," (Woodill et. al. 2019, 116). Research is thus, as Montouri (2013) points out, a creative process in and of itself.

Critical thinking and creative thinking, in this construction, are seemingly interchangeable, but both are compelled by the necessity of broad exploration. Part of this exploration must include self-reflection and an investigation into one's own intellectual orientation and constitution as it is part of the knowledge matrix in which the learner is embedded. Another way of thinking of this is to suggest that critical/creative thinking is a form of self-reflection to the extent that knowledge in this framework emerges from engagement and experience.

To develop this capacity, it is necessary to provide opportunities to engage in non-binary thinking that understands contradictions and paradox as essential structuring elements of the world and experience rather than pathologies or 'incorrect' rationale or reasoning. Some of this is accomplished in the exploring of ideas from multi-disciplinary lenses, but the perspectives to be included must be much broader: stakeholders, collective and individual impact analysis, local and

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global analysis, expert and 'folk' knowledge, experience, beliefs, culture, tradition, are just a few potentially rich perspectives. Engagement of these perspectives can occur through interview, research, reflection, and action/interaction.

## Emotionally Intelligent

The epistemology of complexity requires interaction/engagement, and all the aspects of engagement discussed thus far are underwritten by emotional intelligence. The World Economic Forum lists emotional intelligence as one of the most in-demand skills of the contemporary workforce.[4] Though somewhat of a buzz word in popular business literature, the central role of emotions in cognition has spurred a re-thinking of the historical denigration of emotion to the category of wimpy, hysterical, and irrational as scholars of emotion assert that emotions are a crucial element of embodied cognition that is central to reasoning, communicating, and collaborating (Damasio 2018).

It is typical to see the concept of emotional intelligence conflated with the concept of emotional suppression or control, but this is not an accurate rendering of the concept. Brene Brown's (2015) now infamous work on vulnerability demonstrates the creative power of stepping into the unknown. In the framework of complexity, knowing means engaging, and engaging requires openness. Thus, the primary knowledge activity in a complexity framework is to avail oneself to surrounding possibilities, but this is not possible if one clings to certainty of their own beliefs and perspectives. Exploration is not possible if one is certain about their own perspective, thus the first thing an interdisciplinarian must learn to do is to embrace doubt, uncertainty, or an ignorance-based worldview. This is no-doubt unsettling for many accustomed to a culture that equates doubt with weakness and uncertainty with danger (Gilson 2011). Emotional intelligence, then, is the capacity to step into the uncertainty, feel the fear, and keep walking, so to speak. It is about the capacity to embrace and harness vulnerability, to connect to others through the common ground of a shared human experience.

There are pedagogical tools to improve emotional intelligence: mindfulness or similar practices develop the awareness 'muscle' that allows the insertion of space between thoughts and actions thus reducing tendencies toward uncritical reaction (Ludvik 2016). Learning new skills or getting out of one's comfort zones create mini emotional crises in relatively safe contexts. Each time one navigates these experiences can be an opportunity to handle emotional upheaval in productive ways (Brown 2015). Building relationships with others from different backgrounds and perspectives can alleviate our natural fear of 'outsiders' and broaden our emotional capacity for connection. Creating opportunities for these in the interdisciplinary classroom can lay the foundation for cultivating the competencies necessary for engaging complexity and fostering the full power and promise of interdisciplinarity.

## Conclusion

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[4] See: https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution/.

Uncertainty, vulnerability, ambiguity, openness, risk-taking, and repeated failure are not epistemic values of traditional education, yet they are the crucial epistemic values of creativity and innovation. They are crucial epistemic values of complexity, and to the extent that complexity is at the heart of interdisciplinarity, they are crucial epistemic values of interdisciplinarity.

Certainly, a great deal of these pedagogical tools are already imbedded into the curricula across the academy, but the argument here is that the attributes discussed form the intentional foundation of an interdisciplinary studies curriculum that embraces the messiness of complexity such as introduced by Newell (2001) rather than seeks to smooth it out into and representation of complexity are merely complicated. The hope is that this theoretical framework provides a starting point for the intentional development of classes that cultivate these cognitive tools in the bid to truly transform the academy into an adaptive, innovative, and relevant institution capable of engaging and positively influencing the increasingly complex world.

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