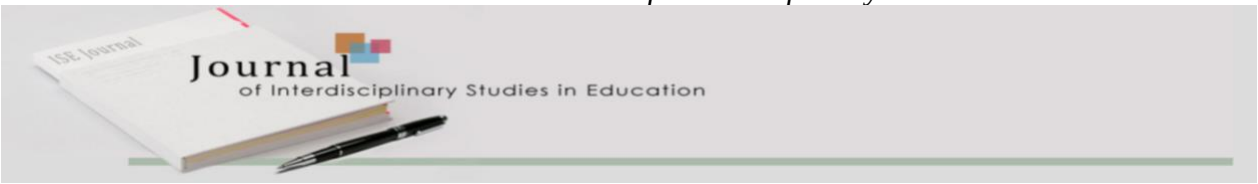
ISSN 2166-2681 |Volume 6, Number 1 | (2017)



Creating the Transdisciplinary Individual: Guiding Principles Rooted in Studio Pedagogy

Melita M. Morales

Abstract

It is widely recognized that the great challenges of the 21st Century cannot be understood or addressed through one discipline operating in a silo of research. Solutions to grand scale problems require varied expertise and multiple disciplinary methodologies to generate plausible solution strategies. The individuals involved in transdisciplinary research projects must be capable of employing scientific methods and traditional research skills, as well as engaging additional methods of inquiry such as those used in an art or design studio. In this paper, I first look at literature on transdisciplinarity and note the pattern of importance placed on the transdisciplinary individual. Secondly, I argue that studio pedagogy is integral to fostering the growth of the transdisciplinary individual capable of multi-modal inquiry practices.

Keywords: transdisciplinarity, transdisciplinary individual, studio pedagogy, arts integration, collaborative research, multi-modal inquiry

It is widely recognized that the great challenges of the 21st Century cannot be understood or adequately addressed through one discipline that operates in a silo of research (Jahn et al., 2012; Krellenberg & Barth, 2014; Malina, 2006; Scholz & Steiner, 2015; Sigel et al., 2014; Stokols, 2014; Wall & Shankar, 2008; Vogel et al., 2014). Addressing these great 21st Century challenges, also commonly referred to as wicked problems, will require varied expertise to uncover the interlocked societal and scientific systems at play. Generating successful solution strategies for such issues as global climate change, access to clean water, healthcare and nuclear energy demand shared disciplinary research methodologies and values that intersect political, economic, and environmental policy. Researchers in fields from medicine to ecology uphold the belief that teams engaging in transdisciplinary research involving multiple stakeholders can produce more innovative and effective results (Bernstein, 2015; Klein, 2013; Loevinsohn et al., 2015; Sousa & Pilecki, 2013). Moreover, the mindset of the

individuals involved in the collaborative practice, and their capacity to be flexible within the group and think creatively, has been found to be essential to the productivity of these teams (Jacobs & Nienaber, 2011; Stokols, 2014). The individuals, referred to as transdisciplinary practitioners, will be required to engage in multiple modes of inquiry, employing not only scientific methods and traditional research skills, but also additional methods of inquiry and understandings such as those used in the an art or design studio.

In this paper, I first look at the current literature on transdisciplinarity and note the pattern of importance placed on the transdisciplinary individual (Augsburg, 2014; Bernstein, 2015; Stokols, 2014). Secondly, I argue that studio pedagogy, and the practice of studio inquiry, has the potential to foster the growth of the transdisciplinary practitioner. Here, art and design study are merged and referred to as studio inquiry to highlight parallel pedagogical, environmental and research practices. Quality studio experiences, introduced in elementary school and continued into higher education, are uniquely situated to strengthen and encourage individuals to become capable transdisciplinary practitioners, providing young people the opportunity to practice the necessary components of transdisciplinary work and develop the skills and attitudes to function as a part of collaborative teams with integrated, diverse expertise (Montuori, 2012).

Transdisciplinary Collaborations

A Call for Transdisciplinary Practice

The earth is confronted with challenges that extend beyond local geographic boundaries and encompass regional and global dependencies and interactions (Loevinsohn et al., 2015). Emerging challenges such as climate change, water scarcity, and social inequality necessitate new and alternative research approaches (Costa, 2010; Jacobs & Nienaber, 2011). Taking into account global forms of knowing and accessing knowledge have become essential to addressing the dynamic, multifaceted qualities of complex problems (Molz & Edwards, 2013). Additionally, human interactions in social and natural environments link science and society in inextricable ways. Technology has allowed for a greater dispersing of scientific knowledge, which in turn has engendered a society that is able to directly impact science politically and personally, shifting the directionality of science-society communication (Gibbons & Nowotny, 2001).

The use of the scientific method has and will continue to serve us well as a society, yet disciplinarity in science in the twentieth century has contributed to the creation and maintenance of ‘knowledge silos’ (Jacobs & Nienaber, 2011), in which practitioners with domain-specific expertise work in isolation from one another. Inadvertently upholding a positivist, Newtonian belief system, knowledge generation and validation continue to be based primarily on empiricism and physical evidence, with ‘hard’ science seen as more credible than the ‘soft’ science of the social science realm (Repko, 2008; Scholz & Steiner, 2015). A predominant 20th-century reaction to a problem is to break it into its parts, which are then separately analyzed. Reducing a problem into its parts can come at the cost of losing the connections between the parts,

the unique functions that make the problem what it is (Capra, 1996 & 2008; Gibbons & Nowotny, 2001; Jacobs & Nienaber, 2011). Disciplinary expertise has generated extensive amounts of data and information, and we are now charged with the overwhelming task of how to make use of the knowledge produced in ways that are meaningful and applicable (Molz & Edwards, 2013).

The call for transdisciplinary research practices is a result of recognizing the interwoven processes and impacts of the major problems facing our world today and the resulting human response (Krellenberg & Barth, 2014). As humans interact with their environment, they become participants and driving agents in the science of the problems and the solutions (Malina, 2006; Repko, 2008; Sigel et al., 2014; Sullivan, 2010). Single disciplinary practices such as organic chemistry, experimental psychology, or ecology often leave out this critical interaction when designing solutions. Science sub-disciplines, with distinct research methodologies are not able to fully unravel the problems faced (Scholz and Steiner, 2015; Wall & Shankar, 2008), and greater insight can surface through understanding the web of relationships in complex, dynamic systems (Laidlaw, 1998; Malina, 2006). Highly technical language, disciplinary beliefs and values, and fragmentation in the discipline of science have led to ontological frictions that make collaborative practices difficult and often non-existent in many universities (Gómez-Gómez & Hochberg, 2014). Complexity thinking is integral to achieving integrated strategies and approaches for solution finding. With the vast amount of unknowns that exist in our world, research that involves diverse methodologies and knowledge structures is critical to a full understanding of a problem as well as the challenges of effective solution implementation (Malina, 2006; Repko, 2008; Sullivan, 2010).

Differing Models of Integrated Research Practice

There is a substantial body of work on the topic of interdisciplinary collaborations, which converge around definitions of different types of collaborative efforts (Gibbons & Nowotny, 2001; Marshall, 2014; Wall & Shankar, 2008; Wiek, 2007; Vogel et al., 2014). These definitions are marked by the extent to which integration of knowledge and research methodologies occur and for what purpose. *Disciplinary* (or unidisciplinary) research operates in the realm of its established practices, beliefs, and values, outside of any collaborative efforts. Research is communicated to colleagues and is validated through consensus in a specialized sphere of expertise (Stokols, 2014). Moving toward an integrated approach, *multidisciplinarity* exists in collaborations where practitioners are sharing expertise but continue to work from their own discipline-specific perspective. The research methodologies run parallel or sequentially to each other with a goal of combining results to solve a shared problem (Wall & Shankar, 2008; Vogel et al., 2014). *Interdisciplinary* collaboration occurs when researchers from different disciplines work jointly to focus on a common problem. Final contributions remain anchored in their own discipline, despite some integration of perspectives. The combination is a layering of qualitative and quantitative methodologies that integrate experimentation, observation, interviews, etc. (Gibbons & Nowotny, 2001).

Transdisciplinarity, in contrast, prioritizes mixed methodologies that allow researchers and members of the broader community to share and integrate knowledge paradigms of their respective disciplines, lending greater insight around a complex challenge and generating knowledge that is usable for real-world problems (Vogel et al., 2014). Transdisciplinarity has at its core the integration of multiple perspectives and disciplinary expertise, intentionally sharing research methodologies and beliefs to produce research that does not adhere to one thinking reality (Wall & Shankar, 2008). It connotes a practice or domain that rises above disciplines and dissolves their boundaries to create a new social and cognitive space (Marshall, 2014). In transdisciplinary teams, the collaborating practitioners grow in their understanding of the complexity of a problem, as well as learn alternative research methodologies the other practitioners.

Addressing wicked problems with a transdisciplinary lens requires the input of experts from varying science domains. Jacobs and Nienaber (2011) provide illustration of this concept with the example of a project to address water resources in the South African Development Community (SADC), in which transdisciplinary work is essential for effective progress in regional development. They note that water, energy, and food scarcity in many countries is often addressed in silos versus through an integrated approach. The traditional mono-disciplinary approach fails to recognize interconnected systems such as power generation relying on water input, potable water relying on transportation and purification through power input, and food security depending on the accessibility to potable water (Jacobs & Nienaber, 2011, p. 667). In this example, it was necessary for experts in the field of hydrology, sedimentology, chemistry, biology and geomorphology to all share deep disciplinary expertise to local and regional efforts to impact grand scale ecosystems.

Markers of Transdisciplinary Collaborations

Transdisciplinary collaborations work to address problems with a goal of either an applied or theoretical outcome (Augsburg, 2014). In one collaboration, the goal of the transdisciplinary research is to produce scientific outcomes of new theories, research methodologies, and knowledge that transcends any one discipline and seeks to better explain and understand the world (Klein, 2008; Nicolescu, 1999; Vogel et al., 2014). In another effort, the goal of the transdisciplinary collaboration is applied, problem-orientated action research that emphasizes the development of systems, protocols, equipment or products (Gómez-Gómez & Hochberg, 2014; Jacobs & Nienaber, 2011; Klein, 2008). While transdisciplinarity may look different based on the set goal of the collaboration, it generally can be characterized by four common elements:

1) Transdisciplinarity involves society in the research process (Gibbons & Nowotny, 2001). There is a communication and exchange of information between multiple disciplines, stakeholders, and actors associated with the problem, valuing both ‘hard’ and ‘soft’ science (Gómez-Gómez & Hochberg, 2014). Further, the complexity and interconnectedness of the problem is considered critical to the transdisciplinary understanding and it is not reduced to an exploration of its parts (Jacobs & Nienaber, 2011).

2) Problems are formulated at the beginning through dialog with a large number of actors and stakeholders who bring varied skills and expertise. The scope of a problem is not externally imposed on the research by a PI, but identified jointly by the transdisciplinary team, even when a PI is designated for securing grants or disseminating research communications.
3) Transdisciplinary research is carried out through the context of application and iteration. Problems are recognized as being situational, existing within the specific context surrounding the problem and the response must be tested within that context or deliberate variants (Jacobs & Nienaber, 2011).
4) The group maintains accountability and quality measures. Rigorous approaches from science and social sciences are integrated and the research team determines the validity of knowledge generation (Gibbons & Nowotny, 2001; Klein, 2008).

Transdisciplinary teams have the potential to address issues of global scale in new ways that prioritize the involvement of varied expertise and voice through multiple stakeholders who define the scope of the problem and put people at the center of solution finding. Transdisciplinary teams carry out their research through the context of application and iteration and together define measures of success and accountability. In order for such research to be possible, the individuals chosen for such work become a key factor in the positive functioning and overall capacity of the team.

The Transdisciplinary Individual

The focus on transdisciplinary teams has come from an acknowledged potential that these teams can generate greater insight than one reality alone (Nicolescu, 1999). Yet not all teams deemed "transdisciplinary" have demonstrated equal success. Research that investigates the Science of Team Science is emerging rapidly and includes analysis of what makes transdisciplinary projects successful and what makes them fail (Stokols, 2014). Jacobs and Nienaber (2011) suggest that the study of individuals involved in a collaborative project is "critically important" (p. 667). In an attempt to create stronger transdisciplinary teams, greater focus is being paid to the skills and traits of the individuals who participate in such collaborative undertakings (Nicolescu, 1999; Stokols, 2014; Augsburg, 2014). The following section highlights the pattern of traits described in emerging literature on the transdisciplinary individual.

Flexible in their Disciplinary Perspective

Collaborators in transdisciplinary projects are often asked to go outside of the methodologies in which they have been formally trained, or that are institutionally accepted, to engage in work that exists beyond disciplinarity as framed by the university. This requires elasticity, momentarily abandoning their own positionality to engage in a reality different from their own (Augsburg, 2014; Nicolescu, 1999). Stokols (2014) defines the 'transdisciplinary intellectual orientation' of the individual, emphasizing that the intrapersonal qualities that allow members of a team to communicate effectively with other team members are crucial to a successful collaborative outcome. The

transdisciplinary values he lists include, "…*open-mindedness, tolerance, and respect* toward other points of view; an *inclusive rather than exclusionary stance* toward perspectives that are unfamiliar or different from one's own (p. 63)." Driven by the need to solve problems, they will seek out alternative disciplinary perspectives based on an internal incentive for another's point of view and an understanding of the complexity of an issue (Augsburg, 2014). The ability to acknowledge one's individual perspective, as one of many possible perspectives, is a foundational trait of individuals who are capable of positive contribution to a transdisciplinary team.

Cognizant of Networks of Relationships

To contribute to the success of a transdisciplinary team, individuals must be able to build relationships and networks among the diverse participants within their team and de-compartamentalize information, what Nicolescu considers establishing bridges. True integrationists are system thinkers. They believe that the world cannot be understood by simply looking at the individual parts of a problem, reducing the frame of reference to something so small and isolated that the external factors and relationships become abstracted and insignificant (Bernstein, 2015). While deeply knowledgeable about their own discipline, transdisciplinary individuals are required to acknowledge the complexity of an issue, and to think broadly and holistically about the interconnected factors (Augsburg, 2014; Jacobs & Nienaber, 2011). Only when seen in full complexity can the emergence of a whole understanding of a problem be possible (Bernstein, 2015).

Recognizes Multiple Knowledge Realities

Transdisciplinary individuals acknowledge that understanding and make room for understanding the capacity to which local environments shape values and knowledge (Nicolescu, 1999). They also accept that knowledge can emerge in many ways, documented by experts and citizens in formal written traditions or embodied in people's memories and experiences (Jacobs & Nienaber, 2011), and that the definition and analysis of a problem constitute disputed ground (Klein, 2008). By acknowledging multiple levels of reality in which information is translated or communicated, such as music, stories or studies, the transdisciplinary researcher respects and utilizes realities in conjunction with each other to more fully know a problem (Bernstein, 2015).

Co-develops Direction of Research

Through meaningful dialogue, collaborative teams determine the direction and focus for the project jointly, and at different points along the way. It is invaluable for transdisciplinary team members to relate as equals, foregoing any hierarchical research processes to effectively become 'co-producers of hybrid knowledge' (Augsburg, 2014). Driven by a social consciousness that prioritizes problem solving to benefit future generations (Jacobs & Nienaber, 2011), they will have to establish and distribute research practices and tasks in ways that break down normative privileging of scientific ways of knowing (Gómez-Gómez & Hochberg, 2014; Wiek, 2007; Vanasupa et al., 2012).

Embeds Self in Research

Finally, transdisciplinary individuals become aware of and integrate their own worldview and natural curiosities into their work process (Augsburg, 2014). This includes a disciplined self-reflection in which the individual's own biases and cultural practices are recognized as the researcher documents their actions and reflects on them before and after. Montuori (2010) emphasizes this factor, noting "A fundamental assumption here is that in order to understand the world we must understand ourselves, and in order to understand ourselves we must understand the world" (p. 6). From a place of reflection and personal motivation, the individual also explores their own worldview in relationship to those in the collaborating group. Self-reflexivity, or the in-the-moment shift in behavior based on prior reflections, moves the research away from the objective requirements of traditional empirical research (Montuori, 2012). Nicolescu (1999) describes this as a permanent questioning of one's self as well as the world around them, placing the individual within the work versus as an objective bystander.

If transdisciplinary work has the potential to generate innovative responses to the world's most pressing problems, it is paramount to identify the individual personality traits and skills, necessary for reaching beyond a reductionist understanding of the world, to a complex view of interconnectedness. Preliminary research on transdisciplinary individuals indicates common traits that include flexibility in disciplinary perspective, a cognizance of networks of relationships, a capacity to recognize multiple knowledge realities, an openness to co-develop the direction of research, and a willingness to embed themself in the research. Jacobs and Nienaber (2011) pose that "the transdisciplinary team is only as strong as the individual team member's capacity to understand and internalize the complex-transdisciplinary logic" (p. 672). By so identifying the successful traits of a transdisciplinary individual, it is possible to begin to investigate the environment that is necessary to nurture the growth of such individuals, providing an initial point of origin for successful collaborative ventures in the future.

Studio Pedagogy and Arts Based Research

The inquiry happening in quality studio-based classrooms and professional arts based research environments has the potential to nurture the skills and traits necessary for the creation of the transdisciplinary individual. To make this argument I clarify the elements of studio environments that consistently provide a rich context for artists to conduct their research. I refer to studio inquiry as the type of learning and research that is rooted in the practices found in the physical space, the activities, and the epistemological beliefs that make up the pedagogy of arts education (Brandt et al., 2013; Hadjiyanni, 2008; Hetland et al., 2013). This pedagogy positions students as producers of knowledge within a practice community and provides an environment that closely aligns with the earlier mentioned markers of collaborative transdisciplinary projects. I also address how the elements of a studio research environment nurture the skills which emerging literature points to as essential for the transdisciplinary mindset. As with all pedagogical models, the quality of the studio experience is inextricably linked to the faculty facilitating the class, or practitioner, and their capacity to adhere to studio best practices. I refer to the

artist that is either in an educational art environment or a practicing artist who has internalized the studio inquiry process as a means of arts-based research.

Individual is Embedded in Research

Making in the studio is seeing and thinking in ways shaped by the cultural contexts that filter what we see and partially governed by the biology of how we see, placing the work in the context of the experienced personal environment (Sullivan, 2014). External input is organized into fundamental forms and then further to synthesis, interpretation, and meaningful thought formation (Solso, 1994). This input is categorized and interpreted through networks wired in the unique physiology of each person's brain, the cognitive functioning of which is deeply personal and filtered based on cultural influences, experiential memories, and stored emotion. Information is stored through personal associative links that contain individually relevant details filtered from the environment (Dietrich, 2004; Matthewson, 1999; Weisberg, 2006). The variation in one's brain physiology and psychology offer different circuitry and symbol systems to access and store information about the world, making the interpretations of information highly subjective and personalized. Research in a studio setting is seen as the construction of a version of the world through personal symbols. It is "is viewed first and foremost as an activity of the mind, an activity that involves the use of and transformation of various kinds of symbols and systems of symbols" (Gardner, 1990, pg. 9; see also Efland, 2002). Through the process undertaken in the studio, artists come to know and discover meaning about themselves and the world, meaning that could not otherwise be revealed (Al-Yahyai, 2014; Marshall & D'Adamo 2011; Niedderer & Roworth-Stokes, 2007; Sullivan, 2010).

Multiple Knowledge Realities are Recognized

Marshall emphasizes that making imaginative projection remixes information and makes it meaningful through reconstruction (Marshall, 2006; Sullivan, 2010). Visual arts have the capacity to contribute expertise in the formation of imagery, metaphor, and thematic discovery, finding significance and meaning in an ocean of data (Matthewson, 2005; Sullivan, 2014). To know through the arts, as Shaun McNiff (2008) points out, "can take us even closer to experiences than verbatim descriptions and the tedious and formalistic literalism that pervades case study literature (p. 28)." The link between studio practice and thinking/perceiving, what Schön (1985) would call *knowing-in-action,* is essential to rigorous studio practice. Process, materials or behavioral ideas drive an investigation to reveal tacit knowledge (Dunnigan, 2013). Gill refers to active versus passive prediction, in which inferential new leaps and insight in hypothesis formation are emergent and molded by interpretation (Gill, 1986). The studio-based researcher is trained to see that knowledge can be revealed through a tactile knowledge reality, different from deductive forms of reasoning.

Complexity is Valued

A focus on networks of relationships is an essential pedagogical part of a studio experience. As artists explore their problem research conducted through books, journal articles, media, interviews, and/or physical investigations into materials or techniques, they build an understanding of the given constraints, background knowledge, and prior attempts at resolution (Bovill, Gardner & Wiedemann, 1997; Brocato, 2009; Lackney, 1999). The research can also involve social, cultural, religious, political, environmental, technological and economic parameters that impact the resolution of the project (Hadiyanni, 2008). Rather than verifying hypotheses through purely quantitative or quantitative methods, the focus of studio research is to discover new connections and reveal the significance of relationships (McNiff, 2013; Sullivan, 2014). In this exploration, the artist, unbound by specific disciplines, utilizes knowledge in multiple fields to expose factors that might affect the issue, cutting across a single disciplinary understanding to define of the problem. As they work, the artist chooses what the next right step will be in their work in response to recognizing influences, connections, and networks of information (Niedderer & Roworth-Stokes, 2007).

Group Maintains Accountability and Quality as Research is Co-developed and Carried out in Context

Studio practice stands in contrast to academic arenas with defined end goals and set methods for investigation. In the pursuit of an answer, experiential learning drives understanding, and the work produced is seen as one point in an iterative cycle. Throughout the process of addressing a problem, artists utilize critiques (crits), a key pedagogical activity that frames studio inquiry in which a solution concept is submitted at various stages of development. Crits can take on many different styles and facilitate reflection and feedback on progress from multiple voices. They are essential to the art studio and are often the piece that introduces or reinforces reflection and reflexivity (Brandt et al., 2013; Brocato, 2009; Hetland et al., 2013; Kirby, Keefe & Laidlaw, 2004; Lackney, 1999; Sharma, 2013). Coherence and meaning are generated during critiques when knowledge is offered that is new, or that adds to or alters understanding of a topic (Sullivan, 2010; Marshall and D'Adamo, 2011).

Through critique, a community of artists establishes what is relevant and innovative and together co-define the epistemology, forming a common understanding of what is believed and valued (Brandt et al., 2013). Assessment of quality of studio research is "based upon factors such as usefulness to others and professions, creation of new knowledge, and the extent to which the work is cited and stimulates ensuing studies (NcNiff, 2013, p. 113)." Studio-based research submits to the same verification process of accountability for rigor, reliability and validity within the professional and vocational expectations of the art world (Niedderer & Roworth-Stokes, 2007; Sullivan, 2010).

In the pursuit of answering a research question, the artist remains in dialogue with their work in a reflection-in-action (Marshall, 2010; Schön, 1985; Siegesmund, 2013). Multiple alternative solutions to the problem prompt are generated as concepts and ideas

are developed and phenomena is expressed and interpreted in new ways (O'Farrell & Meban, 2003). Recording these observations, descriptions and analysis of the work is important for making the internal learning process explicit. It guides the understanding of the artist/designer and others about how the individual (or group in a collaborative project) came to resolve the prompt (Brandt et al., 2013). Documentation communicates the expertise developed throughout the process, both in formative stages and the summative stage (Marshall, 2010; Mathews, 2010).

The call for transdisciplinary efforts to address issues in the world today relies heavily on educating for a different model of understanding (Jacobs & Nienaber, 2011). The studio environment offer individuals the opportunity to come to knowledge and see patterns in a different way. It provides an ongoing practice to recognize the cultural and personal experiences that shape how we construct an understanding of the world. The recognition and identification of that positionality allows for divergent solution possibilities as the project is in development. Through bringing multiple solutions to the problem, the initial problem posed is developed collaboratively. The studio pedagogy tool of critique creates a shared valuing and accountability to others working on a similar problem, as meanings and knowledge in relationship to the problem is defined as a group. By stepping away from and returning to their work, artists solidify iteration as part of the process, using documentation to reflect and then make choices about the next step in addressing the problem. These are practices that mirror the elements of transdisciplinary collaboration are have great potential to nurture the development of a transdisciplinary individual.

Conclusion

Problems can no longer be understood in isolation, and insight will surface through recognizing relationships in complex, dynamic systems as characterize the natural and social world (Kirby, Keefe and Laidlaw, 2004; Malina, 2006). With the vast amount of unknowns that exist in our world, it is important to explore using diverse methodologies (Malina, 2006; Sullivan, 2010). A transdisciplinary approach to addressing real-world problems allows researchers to combine experiments conducted alone and with others with the goal of finding innovative ways to address global challenges, while involving multiple voices from science and society (Malina, 2006; McNiff, 2013).

The individual members of the transdisciplinary collaboration are critical to the success or failure of the project, specifically in their capacity to think in multi-modal ways, sharing methodologies and belief systems. Augsburg (2014) points out, "more research is needed on the subjective and embodied experiences of transdisciplinary participants; that is, how they become transdisciplinary individuals" (pg. 233; also see Stokols, 2014). They must be flexible in their thinking, demonstrate awareness of complexity, able to build networks of information, understand the relative nature of their own perspective, and capable of integrating their own curiosities and passion into the work.

Traditionally, schools teach convergent thinking, asking students to distill material by piecing together facts and data to arrive at a single answer. This type of information gathering and condensing is easily assessable through standardized tests, but does not move students to higher levels of transferable critical thinking. The nature of art practice is to ask questions not yet asked, and find answers that have meaning and relevance based on our personal interpretations of the world. In the studio, researchers reveal multiple ways of knowing, co-develop knowledge, reveal relationships in context, and are motivated through individual passions and questioning.

While disciplinarity has allowed for the cultivation of specialized expertise, addressing the world's biggest problems now requires a different educational experience. Studio-based educational models facilitate the strengthening of both divergent and convergent thinking to explore a topic, increasing opportunity for creative insight (Malina, 2006). There is much to gain by further research that investigates effective interdisciplinary experiences rooted in studio pedagogy on cultivating the attitudes and skills critical for transdisciplinary practitioners.

References

Al-Yahyai, F. K. (2014). Practice-based research as an approach for seeing, re-seeing and creating artworks. *International Journal of Education Through Art 10, (3),* 287–302.

Augsburg, T. (2014). Becoming transdisciplinary: The emergence of the transdisciplinary individual. *World Futures: The Journal of New Paradigm Research, 70 (3-4),* 233-247.

Bernstein, J. H. (2015). Transdisciplinarity: A review of its origins, development, and current issues. *Journal of Research Practice, 11*(1), Article R1. Retrieved from http://jrp.icaap.org/index.php/jrp/article/view/510/412

Bovill, C., Gardner, A., & Wiedemann. (1997). Intention, form, and execution: A comprehensive studio curriculum. *Journal of Architectural Education, 51(2),* 84.

Brandt, C., Cennamo, K., Douglas, S., Vernon, M., McGrath, M., & Reimer, Y. (2013). A theoretical framework for the studio as a learning environment. *International Journal of Technology and Design Education, 23 (2),* 329-348.

Brocato, K. (2009). Studio based learning. *Theory Into Practice, 48,* 138-146.

Capra, F. (2008). *The science of Leonardo: Inside the mind of the great genius of the Renaissance*. New York, New York: Random House.

Capra, F. (1996). *The web of life: A new scientific understanding of the world.* New York, New York: Anchor Books.

Costa, R. (2010). *The watchman's rattle: A new way to understand complexity, collapse and correction*. New York, NY: Vanguard. 288 pp.

Dietrich, A. (2004). The cognitive neuroscience of creativity. *Psychonomic Bulletin & Review, 11(6),* 1011-1026.

Dunnigan, J. (2013). Thingking. *The Art of Critical Making*. R. Somerson and M. L. Hermano (eds.). New Jersey: Wiley.

Efland, A. (2002). *Art and cognition: Integrating the visual arts in the curriculum*. New York: Teachers College Press.

Gardner, H. (1990). *Art education and human development.* Los Angeles, California: The J. Paul Getty Trust.

Gibbins, & Nowotny, H. (2001). The potential of transdisciplinarity. *Transdisciplinarity: Joint Problem Solving among Science, Technology, and Society. An Effective Way for Managing Complexity.* J. Thompson Klein, W. Grossenbacher-Mansuy, R. Häberli, A. Bill, R. W. Scholz, M. Welti (Hg.). Basel / Boston / Berlin: Birkhäuser Verlag 2001. 67-80

Gill, S. P. (1986). The paradox of prediction. S. R. Graubard, editor. *Art & Science.* Cambridge: MA, American Academy of Arts and Society.

Gómez-Gómez, J. M., Hochberg, D., (2014). Aiming for transdisciplinary science: Reflections and guidelines. *Interdisciplinary Science Reviews, 39(2),* 130-142.

Jacobs, I. M. & Nienaber, S.(2011). Waters without borders: Transboundary water governance and the role of the 'transdisciplinary individual' in Southern Africa *Water SA,* 37(5), 665-678.

Jahn, T., Bergmann, M., Keil, F. (2012). Transdisciplinarity: Between mainstreaming and marginalization. *Ecological Economic, 79,* 1-10.

Hadjiyanni, T. (2008). Beyond concepts - A studio pedagogy for preparing tomorrow's designers. *International Journal of Architectural Research, 2(2),* 41-48.

Hetland, L., Winner, E., Veenema, S. & Sheridan, K. M. (2013). S*tudio thinking 2: the real benefits of visual arts education*. New York, New York: Teachers College Press.

Klein, J. T. (2013). The transdisciplinary moment(um). *Integral Review, 9(2),* 181-199.

Klein, J. T. (2008). Evaluation of Interdisciplinary and transdisciplinary research: A literature review. *American Journal of Preventative Medicine, 35(2S),* S116-S123.

Krellenberg, K., & Barth, K. (2014). Inter- and transdisciplinary research for planning climate change adaptation responses: The example of Santiago de Chile. *Interdisciplinary Science Reviews, 39(4),* 160-175.

Kirby, R, Keefe D. F., & Laidlaw, D. H. (2004). Painting and visualization. C. Johnson and C. Hansen, (eds.). *Visualization handbook.* Cambridge, MA: Academic Press.

Lackney, J. (1999). *A history of the studio-based learning model*. Retrieved on 10.13.14 from http://edi.msstate.edu/work/pdf/history_studio_based_learning.pdf.

Laidlaw, D. (1998). Art and visualization: Oil and water? Panelists: davidkremers, V. Interrante, F. Frankel, T. Banchoff. *Proceedings of the conference on visualization.* 507-509

Loevinsohn, M., Mehta, L, Cuming, K., Nichol, A., Cumming, O. & Ensink, J. H. J. (2015). The cost of a knowledge silo: A systematic re-review of water, sanitation and hygiene interventions. *Health Policy and Planning, 30,* 660–674.

Malina, R. (2006). Welcoming uncertainty: The strong case for coupling the contemporary arts to science and technology. Jill Scott (Ed.). *Artists-In-Labs: Processes of Inquiry*. Vienna: Springer Vienna Architecture.

Marshall, C. (2010). A research design for studio-based research in art. *Teaching Artist Journal, 8(2),* 77-87.

Marshall, J. (2006). Substantive art integration = exemplary art education. A*rt Education, 59(6*), 17-24.

Marshall, J. (2014). Transdisciplinarity and art integration: Toward a new understanding of art-based learning across the curriculum. *Studies in Art Education, 55(2),* 104-127.

Marshall, J. & D'Adamo, K. (2011). Art practice as research in the classroom. *Art Education, 64(5),* 12-18.
Mathews, J. M. (2010). Using a studio-based pedagogy to engage students in the design of mobile-based media. *English Teaching: Practice and Critique,* 9(1), accessed on 10/12/14: http://edlinked.soe.waikato.ac.nz/research/files/etpc/files/2010v9n1art1.pdf
Matthewson, J. H. (2005) The visual core of science: definition and applications for education. *International Journal of Science Education, 27(5),* 529-548.
Matthewson, J. H. (1999) Visual-spatial thinking: An aspect of science overlooked by educators. *Journal for Learning in the Arts, 9(1),* 33-54.
McNiff, S. (2013). *Art as research: opportunities and challenges*. Chicago, IL: Intellect Press.
McNiff, S. (2013). Introduction: A critical focus on art-based research. *Journal of Applied Arts & Health, 4,(1),* 5–12.
McNiff, S. (2008). Art-based research. J. G. Knowles and A. L. Colein (eds.). *Handbook of the Arts in Qualitative Research*. California: Sage Publications.
Miller, A. (2014). *Colliding worlds: How cutting-edge science is redefining contemporary art.* New York, New York: W. W. Norton & Company.
Molz, M., & Edwards, M. (2013). Research across boundaries: Introduction to the first part of the special issue. *Integral Review, 9 (2),* 1-11.
Montuori, A. (2010). Research and the research degree: Transdisciplinarity and creative inquiry. In M. Maldonato & R. Pietrobon (Eds.), *Research on scientific research: A Transdisciplinary Study*. Brighton & Portland: Sussex Academic Press
Montuori, A. (2012). Creative inquiry: Confronting the challenges of scholarship in the 21st century. *Futures, 44,* 64-70.
Nicolescu, B. (1999, April). *The transdisciplinary evolution of learning.* Talk at the American Educational Research Association (AERA), Annual Meeting, Montréal. Round-Table "Overcoming the Underdevelopment of Learning: A Transdisciplinary View".
Niedderer, K. & Roworth-Stokes, S. (2007). *The role and use of creative practice in research and its contribution to knowledge.* From International Association of Design Research Conference. Hong Kong: Hong Kong Polytechnic University. Nov. 12-15, 2007. Retrieved 10.8.15 from http://niedderer.org/IASDR07SRS.pdf
O'Farrell, L. & Meban, M. (2003). *Arts education and instrumental outcomes: An introduction to research, methods and indicators.* Queen's University, Canada: commissioned by UNESCO with Faculty of Education, 1-52.
Pariser, D. (2009). Arts-based research: Trojan horses and shibboleths. The liabilities of a hybrid research approach. *Canadian Review of Art Education: Research and Issues*, *36*, 1-18.
Repko, A. (2008). *Interdisciplinary research: process and theory.* Thousand Oaks, California. Sage Publications, Inc.
Scholz, R. W., & Steiner, G. (2015). *Sustainable Science, 10,* 521-526.
Schön, D. (1985). *The design studio and exploration of its traditions and potentials*. London: RIBA Publications Limited.
Sharma, P. (2013). Acting into the unknown. *The Art of Critical Making*. R. Somerson and M. L. Hermano (eds.). New Jersey: Wiley.

Siegesmund, R. (2013). Art Education and a Democratic Citizenry. *International Journal of Art & Design Education*. *32(3),* 300-308.

Sigel, K., Hagemann, N., Leidel, M., Niemann, S., & Weigelt, C. (2014). Insights regarding transdisciplinarity and Knowledge transfer gained from two case studies on integrated water resources management in Ukraine and Mongolia. *Interdisciplinary Science Reviews, 33(4), 342-359.*

Solso, R. (1994). *Cognition and the visual arts.* Massachusetts: The MIT Press.

Sousa, D. & Pilecki, T. (2013). *STEM to STEAM: Using brain-compatible strategies to integrate the arts*. California: Corwin, A Sage Company.

Stokols, D. (2014). Training the next generation of transdisciplinarians. In O'Rourke, M.O., Crowley, S., Eigenbrode, S.D., & Wulfhorst, J.D. (Eds). E*nhancing communication & collaboration in interdisciplinary research*. Los Angeles, CA: Sage Publications.

Sullivan, G. (2014). The art of research. *Studies in Art Education: A Journal of Issues and Research*, 55(4), 270-286.

Sullivan, G. (2010). *Art Practice as research: Inquiry in the visual arts, (2nd ed)*. Sage Publications, Los Angeles.

Vanasupa, L., McCormick, K. E., Stefanco, C. J., Herter, R. J., & McDonald, M. (2012). Challenges in Transdisciplinary, Integrated Projects: Reflections on the case of faculty members' failure to collaborate. *Innovative Higher Ed, 37(3),* 171-184.

Vogel, A. L., Stipelman B. A., Hall, K. L., Nebeling L., Stokols D., & Spruijt-Metz, D. (2014). Pioneering the transdisciplinary team science approach: Lessons learned from National Cancer Institute grantees. *Journal of Transdisciplinary Medical Epidemiology, 2(2),* 1027.

Wall, S. & Shankar, I. (2008). Adventures in transdisciplinary learning. *Studies in Higher Education, 33(5),* 551-565.

Walker, A., & Leary, H. (2009). A problem based learning meta analysis: Differences across problem types, implementation types, disciplines, and assessment levels. *Interdisciplinary Journal of Problem-Based Learning, 3(1),* 12-43.

Weisberg, R. (2006). *Creativity: Understanding innovation in problem solving, science, invention and the arts*. Hoboken, New Jersey: John Wiley & Sons Inc.

Wiek, A. (2007). Challenges of transdisciplinary research as interactive knowledge generation - Experiences from transdisciplinary case study research. *GAIA, 16(1),* 52 - 57.

About the Author

Melita Morales, Rhode Island School of Design, RI. A current doctoral student at Boston College, working with the Rhode Island School of Design Edna Lawrence Nature Lab on practices and pedagogy of art + science collaborations, particularly related to the STEAM dialogue.

Supported in part by National Science Foundation grant #1004057

to Rhode Island Experimental Program to Stimulate Competitive Research (EPSCoR)

Acknowledgements

Note: The draft versions of this paper were reviewed by: Neal Overstrom, Director, Rhode Island School of Design Nature Lab, Jennifer Bissonnette, Biological Programs Director, Rhode Island School of Design Nature Lab, and Julia Marshall, Faculty, San Francisco State University. Each made valuable suggestions and offered helpful insight, but the final version is the product and responsibility of the author.