Rethinking Technology & Creativity in the 21st Century: On Being *In*-Disciplined

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> *"Dostoyevsky gave me more than any thinker, more than Gauss."*
>
> ~ Albert Einstein

Ludwig Boltzmann (1844–1906) was one of the greatest scientists of his time. His work on statistical mechanics and the kinetic theory of gases helps explain and predict how the properties of atoms (such as charge and mass) determine the physical properties of gases (such as viscosity, diffusion and temperature). Ludwig Boltzmann was also an accomplished musician. Boltzmann, however, did not see these two interests (in science and music) as being independent of each other. In contrast, he often described a synchronicity between mathematics and music, seeing both as being involved in the creative act of identifying and manipulating underlying rhythms and patterns to create new ones. Moreover, Boltzmann perceived this process as being deeply personal, in how an individual's creative voice was deeply connected to the final product. This of course is in sharp contrast to the prevailing view of science as being a coolly dispassionate methodology, disconnected from the personality of the scientist. Boltzmann's viewpoint can be seen in how he described the experience of reading physicist James Clerk Maxwell's work on the dynamical theory of gases. Note the manner in which Boltzmann connects his reading of mathematics to the experience of hearing a musical composition:

> The variations of the velocities are, at first, developed majestically: then from one side enter the equations of state: and from the other side, the equations of motion in a central field. Ever higher soars the chaos of formulae. Suddenly we hear, as from kettle drums, the four beats "Put N = 5." The evil spirit V (relative velocity of molecules) vanishes: and, even as in music a hitherto dominating figure in the bass is suddenly silenced, that which had seemed insuperable has been overcome as if by a stroke of magic…One result after another follows in quick succession till at last, as the unexpected climax, we arrive at the conditions for thermal equilibrium together with the expressions for the transport coefficients. The curtain then falls! (Boltzmann quoted in Root-Bernstein, 1989, p. 334)

Boltzmann's experience of Maxwell's mathematics has a breathtaking, compulsive, dramatic quality to it, with a clear feeling of musical affect in his descriptions of the equations and formulae. This is not merely analogy, but rather was an explanation of what Boltzmann experienced in the connection between music and mathematical physics. And he is not alone, great thinkers in the areas of math and science often relate their efforts to music or the arts, highlighting the aural and visual experiences of their work, much more than the logical or formulaic.

William Lipscomb, a Nobel Prize laureate in Chemistry, wrote about the artistic and aesthetic aspects of scientific idea generation, which he described as "a focusing of intellect and emotions which was surely an aesthetic response." Going on to describe his experience, he wrote that though the process of testing the ideas followed the stringent rules of science, the initial process of coming up with predictions and alternatives had an artistic flavor. As he wrote, "Was it science? Our later tests showed it was. But the process that I used and the responses I felt were more like those of an artist." (Lipscomb quoted in Root-Bernstein & Root-Bernstein, 1999, p. 4). It is not that the analytic and the logical are not important – but rather that they don't tell the whole story.

These examples are significant not just because they represent insights on creative thinking from certain great thinkers, but because they represent a *pattern* of insights from *most all* great thinkers (Root-Bernstein, 2003). Most creative people do not view their work as confined to their discipline, but rather are inspired and elevated by connections within and between other disciplines (Lehrer, 2012). From science to art, from music to mathematics or literature, people who work creatively within their own discipline do so in ways that cut across disciplines (Catterall, 2002).

We argue that examples such as these (and there are countless more that we could list here) have significant implications for how we approach teaching and learning. If we ignore these boundary-breaking ways of thinking – these personal, aesthetic connections to knowledge – we deny our students approaches that have worked for great thinkers, and prevent them from experiencing the true richness of thinking and learning (Pink, 2005).

These unbounded ways of thinking stand in contrast to how our education system is structured today. Robinson (2003) has noted that schools are structured to maintain rigid disciplinary boundaries, and subject matter is confined to distinct classes and allotted time-periods. This is not how critical and creative thinking skills develop, and it's not how truly extraordinary thinkers operate (Root-Bernstein, 2003). This mismatch between what we need and what we are doing is a problem, because we can never achieve desired outcomes (flexible, creative thinkers and learners) without using appropriate means (a flexible, creative framework in teaching and curriculum).

Within and Without Discipline

There is an increased interest in the teaching of creativity in schools today (Florida, 2002; Williams, 2002). It's generally agreed that creative thinkers and learners are needed in our society and into the future (Partnership for 21st Century Learning, 2004; Freedman, 2007). Yet most discussions of creativity tend to focus on generic, content-free skills and techniques (Freedman, 2003). This is problematic, since, it is clear from historical and biographical studies that innovative scientists are both deeply enmeshed in their fields of study, even while being open to other disciplinary ways of working and thinking (Root-Bernstein, 2003). Though we are in agreement with these calls for a greater emphasis on creativity, we are critical of how these approaches are being conceptualized and implemented.

Creativity requires deep knowledge of the discipline that creative work emerges within. In a previous article (Mishra & the Deep-Play Research Group, 2012) we noted that creative thinking also spans disciplines. Certain creative thinking skills (such as observation or pattern recognition/creation) are as common to creative scientists and mathematicians as they are to artists or musicians (Hudson, 1967; Caper, 1996). Such skills reveal continuity in creative work across varied domains; yet clearly creativity is not the same across disciplines. The products and processes of creative work vary quite a bit between areas like physics and musical composition, or biology and painting (Eisner, 1998; Starko, 2005). *So we're left with a contradiction, in which creativity both requires deep disciplinary knowledge and also the ability to break disciplinary boundaries and transfer ideas across other subject matters.*

It is to confront this apparent paradox that we introduce the notion of *in-disciplined* learning, i.e. creativity happens *in* a discipline or context; while understanding that at the same time, it is "*indisciplined*" (cutting across disciplinary limits to emphasize divergent thinking and imagination). This view of creativity is analogous to how physicists describe light as having a dual-nature, being both a wave and a particle, behaving like either or both at different times and different contexts (Smoot, 1994). We suggest that creativity has a similar "dual-nature," in that it is both deeply embedded within each discipline and at the same time cuts across disciplinary boundaries.

A Trans-disciplinary Approach: Creative-Cognitive Skills

While the notion of *in*-disciplined thinking expresses the way that creativity works, we are left with the question of how to approach this as a mindset. How do we stay within a discipline and still cut across the disciplines? To manage this paradox, we need a framework for creative thinking that is broad enough to be used across varying disciplines, yet flexible enough to work within each discipline. "Trans-disciplinary thinking" offers just such a set of meta-level thinking skills, which respects the importance of disciplinary knowledge while allowing for novel connections between them (Root-Bernstein, 1996; 1999; 2003; Mishra, Koehler and Henriksen, 2011; Henriksen, 2011). This is an open yet guiding structure that involves a range of specific cognitive skills including: perceiving, patterning, abstracting, embodied thinking, modeling, play, and synthesis. These skills allow people to transfer information creatively from one domain to another, solving problems or developing unique insights by seeing things in a new way. This is particularly relevant in the context of educational technology, because technology also allows people develop these skills in powerful and creative ways.

Echoes of trans-disciplinary thinking are already resonating in areas of STEM (science, technology, engineering, and math) education. Increasingly, educators and researchers have begun to note the need for an infusion of creativity in traditional "analytic" curriculum like STEM disciplines (White, 2010). One response has been to suggest an artistic component within the traditional STEM curriculum. There has recently been much discussion of "STEAM" (Science, Technology, Engineering, Arts, & Mathematics) as a new paradigm.

This STEAM paradigm is an interesting and potentially useful approach, as it begins to chip away at rigid notions of science and mathematics, and considers the value of traveling between disciplines. But trans-disciplinary thinking can take us even farther, with a complete, flexible and useful structure of skills for thinking in any discipline. The new ways of experiencing and creating that it provides for are potentially even more powerful in the context of technology, and all that technology allows for and opens up to us.

The Three T's (technology, trans-disciplinary thinking, and teaching)

In other publications, we have described examples of how trans-disciplinary thinking can allow teaching with technology to happen in interesting and compelling ways (Mishra, Koehler and Henriksen, 2011; Mishra & the Deep-Play Research Group, 2012). In this paper we provide on example of how the trans-disciplinary skill of "perceiving" (or finely-tuned observation) can be used in a Master's level course focusing on design and technology. We contextualize this by considering the parallel ideas of *déjà vu* and *véjà du.*

If déjà vu is the process by which something strange becomes abruptly and surprisingly familiar, then véjà du is the very opposite. It is the seeing of a familiar situation with "fresh eyes," as if you have never seen it before. So if déjà vu is about making the strange look familiar, véjà du is all about making the familiar look strange! We argue that all learning is about either *déjà vu* or *véjà du.* In the sciences, for example, the "strange" idea that time actually slows down when something approaches the speed of light emerges through the application of straightforward equations, based on the fact that the speed of light is the ultimate speed limit (déjà vu). A flipside example might be the idea that something as "familiar" as a rainbow is also the strange interplay of waves of light with droplets of rain (véjà du).

In our courses, students learn to "see" their world differently by using digital cameras to create videos that reveal something – an object, an idea, an incident, etc – in a dramatically new light. The goal is to familiarize the strange, or reveal the weird qualities of the familiar. For example, by taking a digital picture of an object at extended intervals (e.g. hourly, daily, weekly, depending on the rate of change in the depicted object) and editing these images together using design software, the object or scene can be brought to life in unexpected ways. Conversely, slowing a scene down can bring out qualities that are usually outside of our awareness (the slow-motion view of a rain drop hitting the surface of a glass of puddle of water is an example). Other ways to go about this assignment are capturing the organic features of non-living things, or drawing out stable patterns from moving scenes (as when a busy traffic intersection at night turns into a stream of bright lines when shown in quick motion).

The kinds of cameras or software that students use vary a bit; and the kinds of videos created, or approaches to the assignment vary a lot. But at the heart of this is the notion that it's important to be able to see things in a completely new and different way. The trans-disciplinary skill of "perceiving" (just one in the range of trans-disciplinary skills) is highlighted here, because this skill focuses on observation or attention to incredibly fine detail. In order to see something, really *see* it, in a revolutionary way, one has to observe it more painstakingly then any casual observer ever would. Most renowned scientists and artists have commented on the ways that their abilities and creative insights transformed when they made the jump from "looking" to "seeing" (Root-Bernstein & Root-Bernstein, 1999). Csikzentmihalyi (1990) calls this the perception-recognition distinction. So it is important that students get these opportunities too, at all grade levels and subject matters; and technology, with all its unique affordances, give us new ways of doing this. For instance, in our example, students learn the design/technology content of the lesson in a way that also engages their "perceiving" skills. Innovative scientists and talented artists alike require this thinking ability, and weaving it into the content of a technology-rich lesson is a way to engage deep and multi-modal learning experiences.

In Conclusion

In recent years creativity has become a trait of intense interest in fields such as education and psychology (Plucker, Beghetto, and Dow, 2004). Although our educational policy has veered toward rigid, standardized approaches, there remains a broad consensus that creativity is essential, and we need to find ways to infuse it in classrooms and students' thought processes (Williams, 2002; Freedman, 2003). But even with this recognition of need, most researchers, psychologists, educators and policy makers still talk about creativity in very generic and fuzzy terms. Researchers have suggested that this problem of vagueness is due to the abstract and complex nature of creativity, and the fact that there is not one consistent definition of "what creativity is" in teaching or educational research (Marksberry, 1963; Sternberg, 1999; Baker, Rudd and Pomeroy, 2001; Friedel & Rudd, 2005). We would argue that the problem has also been due to the lack of a workable framework – thinking skills that are broad enough to cover a range of disciplines and flexible enough to be used differently in different disciplines – such as trans-disciplinary thinking.

We need to break away from the current approaches to incorporating creativity in the classroom (which are often too generic, and do not take the notion of content or disciplines into account). Education today requires a more action-oriented view, where we consider creativity and thinking in ways that great creative minds actually do. Our notion of being *in*-disciplined suggests that it is important to work within a discipline, and also be able to learn and gather ideas by crossing over into others.

We began with a quote from Einstein where he noted how Dostoyevsky had influenced his thinking than Gauss. Consider that fact – a great literary figure had more influence on Einstein's work and thinking than a great mathematician did (Schlain, 1993). It is this form of trans-disciplinary thinking that we need to provide to our students. To do that we need a framework of skills, one that can be used for lessons and learning experiences that are rich in creativity and technology. That is where being "in-disciplined", and using "trans-disciplinary" thinking, comes out to play.

References

Baker, M., Rudd, R., & Pomeroy, C. (2001). Relationships between critical and creative thinking. *Journal of Southern Agricultural Education, 51(1), 173-188.*

Caper, R. (1996). Play, Experimentation And Creativity. *International Journal of Psycho-Analysis. 77*, 859-869.

Catterall, J. S. (2002). The arts and the transfer of learning. In R. J. Deasy (Ed.), *Critical Links: Learning in the arts and student academic and social development*. Washington, DC: Arts Education Partnership.

Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience.* New York: Harper and Row.

Eisner, E.W. (1998). *The kind of schools we need: Personal Essays.* Portsmouth, NH: Heinemann.

Florida, R. (2002). *The rise of the creative class and how it's transforming work, leisure, community and everyday life.* New York: Basic Books.

Freedman, K. (2003). Teaching visual culture: Curriculum, aesthetics and the social life of art. New York: Teachers College Press.

Freedman, K. (2007). Artmaking/troublemaking: creativity, policy, and leadership in art education. Studies *in Art Education: A Journal of Issues and Research*, 48(2), 204-217.

Friedel, C. & Rudd, R. (2005). Creative thinking and learning styles in undergraduate agriculture students. *National AAAE Reserach Conference*, (pp. 199-211).

Henriksen, D. (2011) *We Teach Who we are: Creativity and Trans Disciplinary Thinking in the Practices of Accomplished Teachers*. (Doctoral Dissertation). Michigan State University. Retrieved from ProQuest Dissertations and Theses. (3489807).

Hudson, L. (1967). *Contrary Imaginations: a psychological study of the English schoolboy.* Harmondsworth: Penguin.

Lehrer, J. (2012). *Imagine: How creativity works*. Boston, MA: Houghton Mifflin Harcourt.

Mishra, P., Koehler, M.J., & Henriksen, D. (2011). The seven trans-disciplinary habits of mind: Extending the tpack framework towards 21st century learning. *Educational Technology, 11*(2), 22-28.

Mishra & the Deep-Play Research Group. (2012). Crayons are the future: Rethinking Technology & Creativity in the 21st Century. *Tech Trends 56*(5).

Partnership for 21st Century Skills. (2004). Skills Framework. From: http://www.21stcenturyskills.org.

Pink, D.H. (2005). *A whole new mind*. New York, NY: Riverhead Books.

Plucker, J.A., Beghetto, R.A., & Dow, G.T. (2004). Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educational Psychologist, 39* (2), 83-96.

Robinson, K. (2003). Mind the gap: The creative conundrum. *Critical Quarterly, 43*(1), 41-45.

Root-Bernstein, R.S. (1989). *Discovering: Inventing and Solving Problems at the Frontiers of Science*, Cambridge, MA: Harvard University Press.

Root-Bernstein, R.S. (1996). The sciences and arts share a common creative aesthetic. In: A. I. Tauber (Ed.), *The elusive synthesis: Aesthetics and science* (pp. 49–82). Netherlands: Kluwer.

Root-Bernstein, R.S, & Root-Bernstein, M. (1999). *Sparks of genius: The thirteen thinking tools of the world's most creative people*, New York: Houghton Mifflin.

Root-Bernstein, R.S. (2003). The art of innovation: Polymaths and the universality of the creative process. In L. Shavanina (Ed.), *International handbook of innovation*, (pp. 267-278), Amsterdam: Elsevier

Schlain, L. (1993). *Art & Physics: Parallel Visions in Time, Space and Light. New York: NY. William Morrow & Company.*

Smoot, G. (1994). Wrinkles in Time. New York: NY. William Morrow & Company.

Starko, A. (2005). *Creativity in the classroom: Schools of curious delight* (third ed.). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Sternberg, R. (1999). *Handbook of creativity.* (R. Sternberg, Ed.) New York: Cambridge University Press. 137

White, H. (2010). STEAM not STEM – Whitepaper [White Paper]. *STEAM not STEM*. Retrieved from, http://www.steam-notstem.com/articles/whitepaper/

Williams, S. D. (2002). Self-esteem and the self-censorship of creative ideas. *Personnel Review, 31*(4): 495-503.

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