Rethinking Technology & Creativity in the 21st Century: Crayons are the Future

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The past few decades have seen a tremendous burst of creativity and innovation fueled by digital technologies. From Google to Facebook, from cloud computing to tablet devices, new technologies have had an immense impact on the how we live, work and communicate. These new tools, devices, and applications, when combined with the economic and social pressures of globalization, are ushering in whole new world. Given this relationship between creativity and technology it is not surprising that educators (particularly those who are technically inclined) have argued that teaching and learning in this emerging world needs to emphasize these twin issues—technology and creativity. Thus it is important for us as educators to explore the relationship between technology and creativity, particularly in educational contexts.

This relationship is noteworthy because both technology and creativity in education are complex topics, which have confounded many legitimate attempts to find useful approaches to integrating them into educational settings. Despite these complexities we do believe that developing a better understanding of the connection between them is important. In this paper we identify some concerns (or misunderstandings) about how these two issues are typically framed and described. From there, we will offer a two-part framework – that of TPACK and "trans-disciplinary creativity" arguing that these two parts make up a larger whole, which provides a useful way to think about creativity and technology for teaching and learning. We begin by describing a few myths about technology and creativity.

Myth 1: The technology tools we have today should drive how we conceptualize teaching and learning in the 21st century.

Digital technologies have increasingly become a part of the way we work and play. From smart phones to internet technologies, from YouTube videos to multiplayer games like World of Warcraft, technology is center stage in our lives and interactions (Mishra, Koehler, and Henriksen, 2011). Most discussions of educational technologies and 21st century learning tend to focus on the newest and coolest tools around. For instance, Web 2.0 is often mentioned – as are other social media such as Twitter Facebook, wikis and blogs (Yardi and boyd, 2010). There is a fundamental problem with seeing these new technology tools as driving educational practice. This involves the assumption that the technologies we have today (early in the second decade of the 21st century) should determine what and how we should be teaching our students. But a century is a long time. Imagine if education in the 20th century were based on tools and technologies that emerged early in that century. A quick Google search (or two) later we have Table 1, a list of key innovations that occurred between 1901 and 1912 (to parallel the first dozen years of the 21st century).

There are many examples in this table that we could point to, but we will draw attention to the year 1903—which saw the invention of the *crayon*. The crayon is a wonderful educational tool—of value from elementary school onward. However, to think of the crayon (or any of the other tools mentioned in the list) as being of foundational significance to 20th century education is clearly naïve. Heavy emphasis on the tools and technologies of the early 21st century (twitter and wikis as being two examples) as the basis of education in *this* century is just as misguided. Do we really think that technological innovation is going to stop as of 2012? Do we really believe that our approaches to teaching with technology revolve around what we think of as new or cool today?

Technology changes rapidly, and it is not surprising that its integration in

Table 1: Technological innovation in the first 12 years of the 20th century

Year	Technological innovation
1901	Radio, vacuum cleaner
1902	Air conditioner, neon light, teddy bear
1903	Crayons, first flight, tungsten for bulbs
1904	Teabags, vacuum diode
1905	Theory of relativity
1906	Cornflakes, sonar, triode
1907	Synthetic plastic (bakelite), color photo, helicopter
1908	Cellophane, geiger counter
1909	Instant coffee
1910	Talking motion picture
1911	Electrical ignition system for cars
1912	Motorized movie cameras, life savers candy, tank

education still finds disappointing levels of penetration and success (Frank, Zhao & Boreman, 2004; Gulbahar, 2007; Keengwe, Onchwari & Wachira, 2008). To be used productively, teachers must understand the different ways that technology can represent content, and recognize how this synchs (or doesn't synch) with possible teaching approaches. The technical details of the digital world shift continuously, which is part of the problem. Technology over time has always been a moving target, which we cannot hope to hit if we view it as narrowly as that which is just "digital" or "modern".

We argue that technology has been conceived of too narrowly, as being just things that are digital, modern or computer-centric. The field of education has been "chrono-centric" in its view of technology (chrono-centric being the view that one's own era or time in history is the most important or the only one that matters). Thereby a major struggle in teaching with technology is that it is envisioned as a set of new gadgets, fads, devices or features. But whether it's a stone-age tool, a Guttenberg printing press, the simple crayon, or a high-tech digital simulation, any form of technology is a tool for living, working, teaching and learning. Each of these technologies has affordances and constraints, framed within broader educational goals. In the field of education, we must eschew the chrono-centric way of thinking about technologies, and focus on what's important and useful about any technology in the interaction with disciplinary content. Just teaching teachers about Web 2.0 or specific software packages is too short-sighted, because those websites and software packages perpetually change (Mishra and Koehler, 2006). Instead the focus should be on *what* it is that we want our students to learn and *how* that learning is to happen.

This is where the TPACK framework comes into play. TPACK suggests that expert teachers have a specialized brand of knowledge i.e. a blend of Technological, Pedagogical, and Content knowledge. Thus, it is the interaction between knowing a technology, knowing about pedagogy, and understanding a subject matter that makes for effective teaching with technology (Mishra and Koehler, 2008). TPACK shatters this myth of technology as being "chrono-centric", and asks only that we focus on "what can your technology do for your content and how best to do it?" The TPACK framework emphasizes the importance of teacher creativity in repurposing technology tools for make them fit pedagogical and disciplinary-learning goals (The TPACK framework has received a significant level of attention in the recent past, so we will not dwell on it. Interested readers can go to TPACK.org to learn more about the framework and its impact on scholarship and practice).

This brings us to the second issue we wish to discuss—that of creativity. There are many myths associated with creativity but in this context we will focus on one.

Myth 2: Creativity can be taught in a content neutral manner

If technology has advanced to the forefront of 21st century learning discussions, then creativity has been its partner in crime. Creative thought processes are considered increasingly necessary as criteria for accomplishment in the progressively complex and interdependent 21st century (Robinson, 2003). Globalization has brought a dramatic increase in knowledge and technology, as well as demographic and social changes in our world (Florida, 2002). This has led to diverse knowledge bases and complicated issues that demand creative thinkers and innovative problem solvers. Daniel Pink (2005) argues that the skills that were important in the information age (the so called "left-brain" capabilities) are necessary but not sufficient for the current emerging world. He suggests that "the 'right brain' qualities of inventiveness, empathy, joyfulness, and meaning—increasingly will determine who flourishes and who flounders" (p. 3) in the future. In trying to respond to these creative demands, organizations such as the Partnership for 21st Century Skills have aimed resources at infusing creative thinking into education for the 21st century.

Yet for all its importance, creativity is a concept that has generally been considered "ill-structured", a "fuzzy zone" that is not well defined and hard for many people to grasp (Spiro, et al, 1995). The role of creativity in education has rarely been clear, and it varies greatly depending on schools and programs. We argue that this lack of structure and generalizability of creativity in education is partly due to the fact that many have tried to make the concept too generalized, providing only broad, generic definitions that lack context or disciplinary differences. In this broad and fuzzy-state, creative approaches are difficult to integrate. In order for creative endeavors to mean something in education, they must be grounded in disciplinary knowledge (Mishra, Koehler and Henriksen, 2011). And yet, while these disciplinary differences exist and are important to creative work, there *are* commonalities of critical thinking between disciplines. This creates a tension between the importance of disciplines, and the need to transfer ideas between them, for creative thinking. As Rotherham and Willingham (2010) argue, "devising a 21st century skills curriculum requires more than paying lip service to content knowledge. Outlining the skills in detail and merely urging that content be taught, too, is a recipe for failure. We must plan to teach skills in the context of particular content knowledge and to treat both as equally important."

Consider the fact that creativity in science or mathematics is essential, as surely as it is in art or music; and creative thinking skills between varying disciplines certainly have similarities (Caper, 1996; Root-Bernstein, 1996; 1999). For example, consider the thinking skill of identifying/creating patterns: scientists look for, and construct, patterns, as do artists. But creativity in the sciences looks quite different from artistic creativity (and perhaps feels different in process). This is because of differences in disciplinary knowledge, techniques, processes and norms, influence creative outcomes in unique ways. So, what we need is a new framework for creative thinking. We need a conception of creativity that upholds disciplinary knowledge and differences, but also uses certain thinking skills that look across disciplinary boundaries for creative solutions and outcomes.

Having identified these two myths, we now offer an approach and solution to the issue of teaching for creativity using technology. As described, the problem with creativity has been too broad a focus (on generic skills divorced from disciplinary knowledge), while the problem with technology in education has been a too narrow a focus (on today's tools). We argue that these two problems have a single solution. To this end we offer a realistic, flexible structure for working both within and across disciplinary contexts, and the role that technology can play in making it happen. If we truly believe in the value of disciplinary learning (of deep content knowledge) as being essential for creativity, we need to think of technology use as being deeply integrated with content. What we need for technology in education is also what we need for creativity in education: a new framework for thinking creatively both *within*, and *across* the disciplines—an "(in)disciplined" framework, as it were. We offer a broad draft of such an approach below.

Reconnecting technology and creativity through (in)disciplined learning

At the core of our approach is an understanding that even as we value disciplinary learning, there are cognitive-creative skills that cut-across disciplinary boundaries. It stems from scholarship that demonstrates how creative scientists and artists generally use a key set of thinking tools work *with* disciplinary knowledge. As Root-Bernstein (1999) notes:

> … at the level of the creative process, scientists, artists, mathematicians, composers, writers, and sculptors use… what we call "tools for thinking," including emotional feelings, visual images, bodily sensations, reproducible patterns, and analogies. And all imaginative (and effective) thinkers learn to translate ideas generated by these (pg. 11).

It is from here that we derive the notion of *(in)disciplined* creative work, (a) meaning that creative work always happens *in* a discipline or context; while understanding that (b) at the same time, it is *indisciplined*, cutting across the boundaries of discipline to emphasize divergent thinking and creativity.

This is the first in a series of columns, which will follow-up on the ways in which trans-disciplinary creativity, alongside TPACK, can address creativity and technology for learning. Taken together, these two frameworks are enjoined into an inclusive, practical and flexible structure for teaching creatively and effectively with technology. While the coming columns will delve into this topic in detail, we will wrap up here with an in(disciplined) example that draws upon both TPACK and trans-disciplinary creativity - using the Kinect for teaching math. The Kinect is a motion sensing input device developed by Microsoft for use with the Xbox 360 video game console or a Windows computer. Using a webcam-style sensor, users can control and interact with the console through gestures and spoken commands.

Embodying mathematics

> While math is ultimately grounded in number, modern mathematics is such a complicated creature that understanding its organic workings requires much more than the ability to count. There is a great and growing body of linguistic and visual metaphors that constitute a healthy understanding of modern math, … mastery of these concepts often involves creativity more readily expected of a poet than of a scientist (Bahls, 2009, p. 77).

Mathematics has often been seen as problem solving by manipulating abstract symbol systems. More recently, however, math educators and cognitive scientists have emphasized the embodied nature of mathematical thinking. These researchers have argued that sensory-motor action is the foundation of mathematical thinking. For instance Lakoff and Nunez (2000) have suggested that abstract mathematical concepts are grounded (through thinking in metaphor) to sensory-motor experiences based on perception and action in the physical environment. According to this view, mathematical concepts are actually multi-modal, "rich spatial–dynamic simulations engaging different senses and different blends of these senses -- upon which "ride" mathematical reasoning, procedures, and vocabulary" (Abrahamson, 2006; Fuson & Abrahamson, 2005). Evidence for this view comes from studies of expert mathematical thinking, historical analysis of mathematical discovery (Wilensky, 1997; Root-Bernstein & Root-Bernstein, 1999) as well as studying the kinds of gestures made by teachers and learners as they explore mathematical ideas (Alibali & Nathan, 2011).

This view of mathematics say much about how we should teach and learn mathematics. Clearly, traditional curricula where students do rote solutions to arithmetic problems (Schoenfeld, 1985) does not help them engage in deep and embodied mathematical reasoning. As Abrahamson (2006) argues, students should rather be engaged in deep multi-modal learning that connects perception and action to deeper abstract ideas.

This embodied vision of mathematics is put into play in a research project conducted by Robin Angotti and her team at the University of Washington-Bothell. Dr. Angotti's team has created a custom Kinect app to help teach students functions (such as distance, acceleration, velocity etc.) by letting them plot these equations on a graph in real time using their bodies rather than merely graphing it with pencil and paper. Students move towards and away from the Kinect sensor, and their movement maps onto the screen. Essentially the software allows the user to graph using their position in relation to the camera. Moving closer makes the graph increase and stepping away from it results in the line sinking. The group has also developed a series of lesson plans for how this software can be used in the classroom.

Clearly the use of the software and the Kinect brings a new physical dimension to the learning of mathematics—aligning it with current scholarly work in the area of mathematical knowledge and development (as briefly described above). For instance students in a fifth grade classroom were able to understand concepts such as rate of change without any prior instruction about that concept. As Dr. Angotti said, "[The students realized that] if a line was steep, then the rate of change was high and that means they would have to move faster… All of a sudden, they were talking about rate of change—and these are fifth graders; they don't know rate of change yet." (Ureta, 2012)

This is a great example of how technology can powerfully change how and what we teach. The work by Dr. Angotti and her team shows TPACK in action—bringing together Technology, Pedagogy and Content in an original, innovative manner. More importantly, it allows students to view mathematics as few students have been able to do before—as abstraction embodied in physicality. This is an example of (in)disciplined learning at its very best. It is firmly grounded in the discipline of mathematics (students are grappling with serious mathematics ideas) and yet, in a very unique and physically embodied manner. The kinds of understanding that emerge from this truly take advantage of 21st century technologies for deep (in)disciplined learning. This is learning that breaks disciplinary boundaries to cross-pollinate ideas, and thus helps students become creative divergent thinkers!

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